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Assessment of volume reduction effect after lung lobectomy for cancer

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ABSTRACT

Background: Lung lobectomy results in an unexpected improvement of the remaining lung function in some patients with moderate-to-severe emphysema. Because the lung function is the main limiting factor for therapeutic decision making in patients with lung cancer, it may be advantageous to identify patients who may benefit from the volume reduction effect, particularly those with a poor functional reserve.

Methods: We measured the regional distribution of the emphysematous lung and normal lung using quantitative computed tomography in 84 patients undergoing lung lobectomy for cancer between January 2010 and December 2012. The volume reduction effect was diagnosed using a combination of radiologic and spirometric parameters.

Results: Eight patients (10%) were favorably affected by the volume reduction effect. The forced expiratory volume in one second increased postoperatively in these eight patients, whereas the forced vital capacity was unchanged, thus resulting in an improvement of the airflow obstruction postoperatively. This improvement was not due to a compensatory expansion of the remaining lung but was associated with a relative decrease in the forced end-expiratory lung volume. According to a multivariate analysis, airflow obstruction and the forced end-expiratory lung volume were independent predictors of the volume reduction effect.

Conclusions: A combined assessment using spirometry and quantitative computed tomography helped to characterize the respiratory dynamics underlying the volume reduction effect, thus leading to the identification of novel predictors of a volume reduction effect after lobectomy for cancer. Verification of our results by a large-scale prospective study may help to extend the indications for lobectomy in patients with oncologically resectable lung cancer who have a marginal pulmonary function.

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1. Introduction

Although lung lobectomy generally leads to a permanent loss in the pulmonary function, lobectomy sometimes results in an unexpected improvement of the remaining lung function in some patients with moderate-to-severe emphysema [1]. Relief of the airflow obstruction, an improved respiratory muscle function, the elimination of dead space ventilation in ventilated, but unperfused areas, and improved cardiovascular hemodynamics may all contribute to this unexpected improvement [2–4], which is called the volume reduction effect. Because the lung function is the most important limiting factor for therapeutic decision making in patients with oncologically resectable lung cancer [5], it may be advantageous to identify patients who may be favorably influenced by the volume reduction effect, particularly in patients with a poor functional reserve. However, according to the pertinent literature, the only potential predictor of the volume reduction effect after lung lobectomy is an "impaired FEV_1/FVC" [6]. Nevertheless, there was an important methodological flaw in the previous reports. When predicting the postoperative pulmonary function, the previous studies did not consider how much of functioning lung tissue was resected and how much functioning lung tissue remained, or how much of the emphysematous lung tissue was resected and how much of the emphysematous lung tissue remained, which may be indispensable factors for discussing the volume reduction effect. The additional difficulty of evaluating the volume reduction effect may be that the remaining lungs expand to some degree, so that the remaining lungs match the thoracic cavity, which is also accompanied by some proportionate gain in the remaining lung function, the so-called compensatory lung response [7]. Therefore, a comprehensive assessment of the pulmonary ventilatory capacity and regional lung structures is needed to solve these issues.

Quantitative computed tomography (CT) can be used to quantify the density and volume of the target lung portions, which enables the normal functioning lung areas to be distinguished from emphysematous lung areas, separately in the resected lung lobe and the remaining lung regions. The aim of the present study was to characterize the patients who were favorably influenced by a volume reduction effect after lobectomy for cancer using quantitative CT, and furthermore, to identify the predictors of the volume reduction effect.

2. Patients and methods

2.1. Patients

We retrospectively reviewed our prospective database of patients who underwent pulmonary lobectomy for primary lung cancer between January 2010 and December 2012. Patients who underwent resection of two lobes or more or who underwent right middle lobectomy were excluded. Because this study evaluated the preoperative and 6-mo postoperative CT and spirometry data, patients without these data were excluded. Finally, 84 cases were included in this study. This study was approved by our institutional review board. The patient data obtained before surgery included the age, sex, height, smoking habits, spirometric variables, surgical procedures, and quantitative CT-derived parameters, as described later. The smoking data included the pack-years smoked (smoking index: average number of packs of cigarettes smoked per day multiplied by the number of years the individual smoked).

There were 43 males and 41 females, with a mean age of 71.3 ± 9.1 y. A total of 50 patients underwent hemilateral upper lobectomy and 34 patients underwent hemilateral lower lobectomy (Table 1).

2.2. Operation

Operability was determined based on the existing guidelines for pulmonary resection [5]. The operation was basically performed via two ports and one window (2–8 cm), without rib spreading. During lobectomy, we used an endoscopic stapler (Ethicon, Cincinnati, OH) to divide fused fissures and to excise the bronchus. We did not perform pleural tenting to obliterate the residual pleural space after an upper lobectomy.

2.3. Pulmonary function tests

The preoperative spirometric variables were obtained within 1-mo preoperatively and included the forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). The percent predicted FEV_1 is expressed as the percentage of the predicted value for age, gender, and height. Postoperative spirometric variables were also obtained 6-mo postoperatively.

2.4. CT scanning

Helical CT scans were obtained using 64-detector (Somatom Definition or Sensation 64; Siemens, Munich) row CT scanners. With the patient in the supine position, we obtained 2-mm high resolution CT images of the entire lungs during a deep inspiratory breath hold. We used a 512 × 512 matrix, a 2-mm collimation, and a scan time of 1.0 s, at 120–130 kVp and 220–230 mA. This was a routine practice, and thus, patients were not exposed to any additional radiation for the purpose of measuring the radiologic parameters in this study.

2.5. Image interpretation and data analysis

Three-dimensional volume rendering lung images were created using a commercially available, user-friendly imaging software program (Virtual Place Raijin; AZE, Tokyo, Japan). Threshold limits of −600 to −1024 HU were applied to segment the entire lungs and to exclude soft tissues surrounding the lungs and the large vessels, atelectasis, fibrosis, and tumors within the lung. The volume of a lung that was segmented by a certain threshold limit can be readily obtained with the imaging software program. We called the volume of the entire lung (−600 to −1024 HU) the total lung volume (TLV). The entire lung was divided into two areas, low-attenuation areas (LAAs), representing emphysematous lung tissue (<−910 HU), and normal-attenuation areas (−600 to −910 HU),