Inspiratory and expiratory computed tomographic volumetry for lung volume reduction surgery

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Abstract

Three-dimensional (3D) computed tomographic (CT) volumetry has been introduced into the field of thoracic surgery, and a combination of inspiratory and expiratory 3D-CT volumetry provides useful data on regional pulmonary function as well as the volume of individual lung lobes. We report herein a case of a 62-year-old man with severe emphysema who had undergone lung volume reduction surgery (LVRS) to assess this technique as a tool for the evaluation of regional lung function and volume before and after LVRS. His postoperative pulmonary function was maintained in good condition despite a gradual slight decrease 2 years after LVRS. This trend was also confirmed by a combination of inspiratory and expiratory 3D-CT volumetry. We confirm that a combination of inspiratory and expiratory 3D-CT volumetry might be effective for the preoperative assessment of LVRS in order to determine the amount of lung tissue to be resected as well as for postoperative evaluation. This novel technique could, therefore, be used more widely to assess local lung function.

Keywords: Pulmonary function test • Three-dimensional computed tomographic volumetry • Lung volume reduction surgery

INTRODUCTION

Three-dimensional (3D) computed tomographic (CT) volumetry has been introduced into the field of thoracic surgery [1, 2]. In addition, a combination of inspiratory and expiratory 3D-CT volumetry provides useful data on regional pulmonary function as well as the volume of individual lung lobes [1]. It is often difficult to make a decision to perform lung volume reduction surgery (LVRS) for a patient with severe emphysema, but a combination of inspiratory and expiratory 3D-CT volumetry might provide helpful information on the indication for LVRS, the amount of lung tissue to be resected and the prediction of postoperative lung function. We report here a case of a 62-year-old man with severe emphysema who had undergone LVRS, in order that we could assess this technique as a tool for the evaluation of regional lung function and volume before and after LVRS.

CASE REPORT

A 62-year-old man with pulmonary emphysema was referred to our hospital for LVRS. According to pulmonary function tests, forced expiratory volume in 1 s (FEV₁) was 0.87 l (28% of predicted) and the FEV₁/forced vital capacity ratio was 32% (Table 1). Chest CT showed severe pulmonary emphysema with predominant lesions in both upper lobes. According to a

combination of inspiratory and expiratory 3D-CT volumetric data, both upper and lower lobes showed a decreased ratio of expiratory lung volume over inspiratory lung volume (E/I ratio; Fig. 1). In addition, in both lungs, the lower lobe volume was only about 40% of the corresponding right or left lung volume (Table 1). These findings clearly implied that emphysematous lungs in the upper lobes compressed relatively normal underlying lung tissue in the lower lobes, resulting in the decreased E/I ratio of both lower lobes in addition to the remaining less emphysematous upper lobes. We expected the patient's lung function to recover. He subsequently underwent bilateral LVRS for the targeted lesions in both the upper lobes through video-assisted thoracoscopic surgery. The postoperative course was uneventful, and the patient recovered very well after LVRS. His postoperative pulmonary function was maintained in good condition despite a gradual slight decrease 2 years after LVRS (Table 1). According to the 3D-CT volumetric data, after the LVRS, both remaining upper lobes and lower lobes showed an improvement of the E/I ratio (Table 1). These changes were also well confirmed visually (Fig. 1).

DISCUSSION

In 1995, Cooper *et al.* clarified the benefit of LVRS for a patient with severe emphysema [3], and it has been proved that LVRS is superior to medical treatment in selected patients with heterogeneous emphysema [4]. The benefit of LVRS has also been assessed by using spirometry, exercise capacity, quality of life, etc. In our

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Table 1: Perioperative characteristics, including pulmonary function

Parameter	Preoperative	Postoperative		
		3 months	6 months	24 months
Spirometry				
FVC (ml)	2760	3290	3870	3570
FVC (%)	78	94	112	94
FEV ₁ (ml)	870	1900	1900	1390
FEV ₁ % (%)	35	58	49	39
TLC (ml)	6370	6230	6490	6510
RV/TLC (%)	50	46	41	42
Arterial blood gas (room air)				
PaO ₂ (mmHg)	70.6	83.4	77.7	79.9
PaCO ₂ (mmHg)	38.2	38.5	39.9	42.7
3D-CT volumetry				
Inspiratory (expiratory)				
Right lung				
Upper + middle lobes (ml)	2108 (2005)	724 (603)	812 (612)	837 (752)
E/I ratio (%)	95.1	83.3	75.4	89.8
Lower lobe (ml)	1417 (1300)	1943 (1475)	2050 (1580)	2040 (1563)
E/I ratio (%)	91.7	75.9	77.1	76.6
Sum (ml)	3525 (3305)	2667 (2078)	2862 (2192)	2877 (2315)
E/I ratio (%)	93.8	77.9	76.6	80.5
Left lung				
Upper lobe (ml)	1753 (1652)	950 (812)	970 (801)	1083 (891)
E/I ratio (%)	94.2	85.5	82.6	82.3
Lower lobe (ml)	1231 (1102)	1497 (1084)	1538 (1132)	1423 (1126)
E/I ratio (%)	89.5	72.4	73.6	79.1
Sum (ml)	2984 (2754)	2447 (1896)	2508 (1993)	2506 (2017)
E/I ratio (%)	92.3	77.5	77.1	80.5

3D-CT: three-dimensional computed tomography; E/I ratio: expiratory 3D-CT volume divided by inspiratory 3D-CT volume; FEV₁: forced expiratory volume in 1 s; FVC: forced vital capacity; PaCO₂, arterial partial pressure of carbon dioxide; PaO₂, arterial partial pressure of oxygen; RV: residual volume; TLC: total lung capacity.

Figure 1: Three-dimensional computed tomographic volumetry before and 3 months after lung volume reduction surgery. The major fissure is shown between two arrowheads.

patient, we used inspiratory and expiratory 3D-CT volumetry to evaluate perioperative local anatomical change for 2 years after the LVRS. Our findings were clearly associated with the pulmonary

function test results. To our knowledge, this is the first report describing the perioperative assessment of LVRS using a combination of inspiratory and expiratory 3D-CT volumetry.

Furthermore, 3D-CT volumetry enabled us to estimate the volume of each lobe and gave us additional information about perioperative lung function. Specifically, in this patient, inspiratory and expiratory 3D-CT volumetry apparently visualized data showing that the preoperative lungs experienced marked air trapping and decreased lung elastic recoil. Although both lobes should be almost the same size in healthy subjects [2], in this patient both lower lobe volumes were approximately 70% of the corresponding upper lobe volumes. The finding of overinflated bilateral upper lobes with marked air trapping, assessed by inspiratory and expiratory 3D-CT volumetry, was considered to provide a good indication for LVRS. The excision of non-functional lung tissue is believed to improve lung function by relieving the compression of relatively normal underlying lung tissue and allowing lung elastic recoil, which permits outward forces to restore the collapsed bronchioles. Given that chest CT showed predominant bilateral upper lobe pulmonary emphysema, compressing the underlying normal lung tissue in both lower lobes, improvement of lung function was strongly expected to follow LVRS, which was clearly shown by a perioperative evaluation using a combination of inspiratory and expiratory 3D-CT volumetry. In terms of the amount of lung tissue to be resected, we resected as much emphysematous lung tissue in the upper lobes as possible in this patient; however, if the 3D-CT volumetric technique is more widely used, it will be possible in the near future to make an accurate prediction of the standard values of inspiratory and expiratory lung volumes in an individual patient. Then, it is very likely that it will be possible to assess preoperatively the amount of emphysematous lungs to be resected in each case. Furthermore, regular post-operative evaluation using a combination of inspiratory and expiratory 3D-CT volumetry provides useful information regarding not only the impact of LVRS but also the duration of its effect.

Although the use of CT with volume rendering was reported in perioperative assessment of LVRS [5], compared with a combination of inspiratory and expiratory 3D-CT volumetry it would

be too complex and time-consuming for thoracic surgeons to use this method in routine practice.

In conclusion, we confirm that a combination of inspiratory and expiratory 3D-CT volumetry was effective for the perioperative evaluation of LVRS, because it provided useful information on regional pulmonary function as well as local lung volume. We believe that this novel technique has the potential to be used widely to assess local lung function.

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Conflict of interest: none declared.

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