The effect of section thickness on MDCT lung densitometry

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Purpose

Three-dimensional volumetry of the lung, using multidetector-row computed tomography (MDCT), has been shown to be useful for the specific measurements required for assessment of emphysema. With recent advances in MDCT technology, thinner volumetric data can easily and more quickly be acquired and used for the evaluation of 3-dimensional (3D) lung volumes. Many reports have shown that 3D volumetry of entire lung and of emphysematous lung areas in patients with chronic obstructive pulmonary disease (COPD) is useful for the assessment of pulmonary function [1-4]. Additionally, 3D computer-aided volumetry (3D-CAV) has been developed recently, which is capable of automatically measuring the volume of the lung and of emphysematous lung areas.

The evolution of MDCT has enabled the reconstruction of submillimeter-thick sections of axial images. Although the section thickness used for the original volume data is correlated with image quality and the capability to detect the low attenuation areas (LAA) indicating emphysema, previous researchers have used different section thicknesses; it is unclear whether the results are comparable when the section slices are different.

In this study, we retrospectively investigated the effect of section thickness on measurements using 3D-CAV. We compared the correlation between the computed tomography (CT) indexes and the results of pulmonary function tests (PFTs).
Methods and Materials

Subjects:

A total of 60 patients (42 male, 18 female; mean age, 65± 14 years), including 33 with COPD, were referred for surgical resection of thoracic tumors between July and October, 2010. All patients underwent preoperative MDCT and PFTs. The patient characteristics are summarized in Table 1 on page 5. This study was approved by the institutional review board of Nagoya University Graduate School of Medicine.

CT Examination:

All preoperative CT imaging was acquired using a 64-row multi-detector row CT scanner (Aquilion 64; Toshiba Medical Systems Corp., Tokyo, Japan). Patients were scanned from the lung apex to the diaphragm during a breath-hold at deep inspiration, using the following parameters: x-ray tube voltage of 120 kVp; automatic tube-current at a maximum of 225 mAs; gantry rotation speed of 0.5 sec; and beam collimation of 64 x 0.5 mm. Three type thin-section CT data were reconstructed for each patient at 0.5-mm thickness with 0.5-mm intervals, at 1.0-mm thickness with 1.0-mm intervals, and at 2.0-mm thickness with 2.0-mm intervals using a standard spatial-frequency reconstruction algorithm (FC11). Iterative reconstruction algorithms were not available. No contrast medium was administered.

3D-CT Volume Measurement:

The Digital Imaging and Communications in Medicine (DICOM) data for 3D-CT evaluation were transferred to a 3D workstation (Synapse Vincent ver. 3.1; Fujifilm Medical Systems, Tokyo, Japan). The extent of emphysema was estimated using the threshold technique, quantifying the volume of voxels with an apparent x-ray attenuation value below -950 Hounsfield units (Fig. 1 on page 5) [5-6]. The 3D workstation automatically quantified total lung volume (TLV) and emphysematous lung volume (ELV) (Fig. 2 on page 6); normal lung volume (NLV) was calculated by subtracting ELV from TLV. The NLV calculated by 3D-CAV is one of the CT indexes which have been reported to correlate significantly with the value of PFTs in the previous articles [3-4].

Goddard's score (GS) is a semiquantitative visual score of emphysema proposed by Goddard et al [7]. The 3D workstation was able to calculate the GS automatically, without incurring interobserver differences. The GS was determined by the percent of emphysematous volume within the axial images selected from 3 levels: the top of the aortic arch, the level of the carina, and above the diaphragm (Fig. 3 on page 6). The score was estimated separately for the left and right lung, giving a total of 6 lung-
fields. Each field is graded as follows: 0 = no emphysema, 1 = less than 25%, 2 = 25-49%, 3 = 50-74%, 4 = more than 75%.

CT indexes, including the GS, were calculated for images of all 3 thicknesses (0.5 mm, 1.0 mm, and 2.0 mm).

**Pulmonary Function Tests:**

Pulmonary function was determined within 1 month of CT scanning (either before or after), using a flow-sensing spirometer (FUDAC-70; Fukuda Denshi Co. Ltd., Tokyo, Japan). Results of PFTs, including vital capacity (VC), forced expiratory volume in 1 second (FEV₁), and the single-breath diffusion capacity for carbon monoxide (DL₅₀), are summarized in Table 1 on page 5.

**Statistical Analysis:**

Correlations between CT indexes and the results of the PFTs were compared by using Pearson correlation coefficients (r) for each section thickness. The same correlations were also evaluated in COPD patients as a subgroup analysis. We interpreted the calculated r-value as follows: 0.4 to 0.7 indicated a moderate correlation and > 0.7 indicated a strong correlation.

Data are reported as the mean ± standard deviation unless otherwise specified.
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>mean±SD</th>
<th>range</th>
<th>mean±SD</th>
<th>range</th>
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<tr>
<td></td>
<td></td>
<td>All patients</td>
<td>COPD group</td>
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</tr>
<tr>
<td>Female</td>
<td>18</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLC (L)</td>
<td>5.17±1.17</td>
<td>(1.43–8.73)</td>
<td>5.43±1.17</td>
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<td>% VC</td>
<td>109.7±18.0</td>
<td>(70.5–155.5)</td>
<td>110.9±20.0</td>
<td>(77.7–155.5)</td>
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<tr>
<td>FEV₁ (%)</td>
<td>69.8±11.4</td>
<td>(34.74–98.71)</td>
<td>61.8±7.32</td>
<td>(34.74–69.24)</td>
</tr>
<tr>
<td>DLCO (%)</td>
<td>109.4±26.7</td>
<td>(30.6±181.2)</td>
<td>104.2±23.9</td>
<td>(30.6±162.1)</td>
</tr>
</tbody>
</table>

**Table 1:** Patient Characteristics

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**Fig. 1:** Quantitative measurement of emphysematous areas. (A) Coronal multiplanar reconstruction (MPR) view from 0.5 mm section CT. (B) Red areas show low attenuation areas (LAA) < -950 HU.

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**Fig. 2:** 3D-CT images of lung and bronchi from 63-year old man. Red areas show low attenuation areas (LAA) < -950HU. The section thicknesses of (A), (B), and (C) are 0.5 mm, 1.0 mm, and 2.0 mm, respectively. LAA% are 12.4%, 12.1%, and 11.5%, respectively.

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Fig. 3: Three selected levels for the evaluation of Goddard's score (GS). The GS was determined by the percent of emphysematous volume within the three axial images: from the top of the aortic arch, the level of the carina, and above the diaphragm. Red areas show low attenuation areas (LAA) < -950HU. The GS of this patient, calculated by 3D computer-aided volumetry (3D-CAV), is 6.

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Results

The estimated 3D-CT volumes by 3D-CAV:

The estimated 3D-CT volumes are summarized in Table 2 on page 9. Thinner section thickness led to higher ELV. This tendency was considered that the thinner thickness caused enhanced detectability of low attenuation area by reduction of partial volume effect.

Normal Lung Volume and Goddard's Score vs. PFTs:

At all section thicknesses, NLV was correlated with VC and FEV$_1$ (r = 0.75 and r = 0.49, respectively). The GS was not correlated with VC and FEV$_1$ (r = 0.11 to 0.13 and r = -0.04 to -0.09, respectively). NLV showed a slight correlation with DLco (r = 0.39 to 0.40), while the GS was not correlated with DLco (r = -0.31 to -0.35) (Table 3 on page 9).

Subgroup analysis: Normal Lung Volume and Goddard's Score vs. PFTs in patients with COPD:

At all section thicknesses, NLV was correlated moderately with VC, FEV$_1$, and DLco (r=0.68-0.69, r=0.63, and r=0.58-0.59 respectively). GS was not correlated with VC and FEV$_1$, but was correlated negatively with DLco (r=-0.38 to -0.48) (Table 4 on page 10).
### Table 2: Results of 3D-CT volumetry

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### Table 3: Correlation Coefficient between CT Indexes and Pulmonary Function

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<table>
<thead>
<tr>
<th>Section Thickness</th>
<th>vs. VC</th>
<th>vs. FEV₁</th>
<th>vs. DLₑₒ₂</th>
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<tr>
<td>NLV GS</td>
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<tr>
<td>1mm</td>
<td>0.75</td>
<td>0.14</td>
<td>0.49</td>
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</tbody>
</table>

### Table 4: Correlation Coefficient between CT Indexes and Pulmonary Function among COPD group

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<table>
<thead>
<tr>
<th>Section Thickness</th>
<th>vs. VC</th>
<th>vs. FEV₁</th>
<th>vs. DLₑₒ₂</th>
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<tbody>
<tr>
<td>NLV GS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1mm</td>
<td>0.69</td>
<td>-0.11</td>
<td>0.63</td>
</tr>
</tbody>
</table>
Conclusion

The section thickness used for the original MDCT volume data, ranging from 0.5 -2.0 mm, did not affect the quantitative diagnosis of pulmonary function by 3D-CAV. This finding enables us to compare the results of previous studies conducted at various section thicknesses, provided other CT parameters are the same [1, 8].

In addition, we found that the NLV was able to estimate pulmonary function more correctly than the GS. This means that the extent of emphysema should be estimated as a continuous value rather than a categorical score. Because of the well-known heterogeneous distribution of emphysema within the lung, it is logical that whole-lung densitometry should have reflected the extent of emphysema more accurately than the evaluation of 3 axial sections.

Interestingly, the GS showed a slight correlation with DLco, especially in patients with COPD. This result may suggest that both the normal lung volume and the distribution of normal parenchyma affect the value of DLco.
References

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