Chest CT with Ultra-High Resolution Collimator for Sub-millimeter Fat Plane Detection: A Phantom Study

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Purpose

Lung cancer is the most important malignancy in Japan, with a mortality rate of about 55.7 deaths per 100,000 inhabitants, making it the leading cause of cancer-related death (reference 1). Improvement of the detection of the fat plane by chest CT and chest MRI is directly related to the accuracy of preoperative diagnoses of the T factor in lung cancer of the chest wall and mediastinal invasion (references 2-4). The accuracy of chest MRI is higher than that of chest CT for the detection of the fat plane (reference 5), but the duration of the breath-holding required in chest MRI is longer than that in chest CT, and the directional accuracy of chest MRI is dependent on the stability of the susceptibility of the fat. Average life span and life expectancy have grown, and the incidence of lung cancer diagnosed in elderly patients is rising (reference 6). The breath-holding time for chest CT is shorter than that for chest MRI; therefore, improvement of the fat plane detection is required.

An ultra-high resolution collimator (UHR) improves the spatial resolution in the XY-plane of CT; however, the UHR increases the image noise dramatically; therefore, the UHR is clinically used for high-contrast objects such as the inner ear. Noise reduction image reconstruction technology has been developed in recent years; therefore, the technology might make possible the use of UHR for non-high contrast objects such as the fat plane with the administration of a routine radiation dose to the chest. The purpose of this study is to assess the potential improvement of fat detection by chest CT with UHR in a phantom study.
Methods and Materials

**Phantom Scanning and Image Reconstruction:**

A phantom (ODA Type - 3D Digital Image Assessment Phantom; Kyoto Kagaku, Kyoto, Japan) consists of 0.4, 0.5, 0.7, 1.0, 1.5 and 2.0-mm diameter holes; salad oil was inserted into the holes to simulate fat. The phantom was scanned six times with and without UHR by a 256-slice multidetector CT at the phantom's direction in the X-Y and the Z planes (Fig. 1). The scanning parameters with UHR included a rotation time of 1500 milliseconds; 20×0.625 mm collimation; tube voltage, 120 kV; 1000 mAs; small focal spot; and pitch, 0.14. Those without UHR included a rotation time of 1500 milliseconds; 16×0.625 mm collimation; tube voltage, 120 kV; 1000 mAs; small focal spot; and pitch, 0.20. The scanned data were reconstructed by filtered-back projection with the following reconstruction parameters: slice thickness, 0.67 mm; standard (B) reconstruction kernel; display field of view, 150 mm. The multi-planner reformat was reconstructed by the workstation with a slice thickness of 3.0 mm.

**Measurement of fat detectability:**

The improvement of fat detection was assessed by full width at half maximum (FWHM) and a contrast vale of the profile (reference 7), which was obtained by a numerical slit (1 x 20 pixels) on multi-planner reformat images. We assumed that the fat was visible when the fat's FWHM was measurable. The contrast value was the Hounsfield unit (HU) between the peaks and valleys of the profile curve in the holes.

**Statistics**

The comparisons of the contrast values with UHR and without UHR were performed by use of the two-tailed paired t-test assuming equal variance for the X-Y plane and assuming unequal variance for the Z plane. The statistical analyses were performed with commercially available software (JMP, version 9.0, SAS Institute, Cary, NC, USA). Data are expressed as means ± SD. For all statistical analyses, a p-value of less than 0.05 was considered to indicate significance.
Fig. 1: Illustrations demonstrate the position of the phantom (a) in the X-Y plane and (b) in the Z plane. The pictures show the position of the phantom (a) in the X-Y plane and (b) in the Z plane.
Results

The contrast values are listed in Table 1. In the X-Y plane, the contrast values with UHR were significantly higher than those without UHR over 1.0 mm. The FWHMs are shown in Fig. 2. The minimum detected diameters of the holes were 0.7 mm with UHR and 1.0 mm without UHR in the X-Y plane, and 0.7 mm both with and without UHR in the Z plane. The phantom images are shown in Fig. 3.
Fig. 1: Illustrations demonstrate the position of the phantom (a) in the X-Y plane and (b) in the Z plane. The pictures show the position of the phantom (a) in the X-Y plane and (b) in the Z plane.

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Fig. 2: FWHM with UHR and without UHR in the X-Y plane and in the Z plane. FWHM = full width at half maximum.

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Fig. 3: Phantom images with UHR and without UHR in the X-Y plane and in the Z plane. Red frames demonstrate that the images were evaluated as visible by measurement of the FWHMs of the profiles. UHR = Ultra-high resolution collimator.
<table>
<thead>
<tr>
<th>Hole’s diameter (mm)</th>
<th>X-Y plane</th>
<th></th>
<th>Z plane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contrast value (HU)</td>
<td>P</td>
<td>Contrast value (HU)</td>
</tr>
<tr>
<td>With UHR</td>
<td>Without UHR</td>
<td></td>
<td>With UHR</td>
</tr>
<tr>
<td>2.0</td>
<td>72.0 ± 2.9</td>
<td>65.91 ± 0.5</td>
<td>0.0030</td>
</tr>
<tr>
<td>1.5</td>
<td>49.9 ± 1.2</td>
<td>44.6 ± 0.3</td>
<td>0.0001</td>
</tr>
<tr>
<td>1.0</td>
<td>26.4 ± 1.6</td>
<td>20.1 ± 0.5</td>
<td>0.0001</td>
</tr>
<tr>
<td>0.7</td>
<td>13.8 ± 2.4</td>
<td>11.6 ± 0.7</td>
<td>0.0952</td>
</tr>
<tr>
<td>0.5</td>
<td>7.1 ± 0.8</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>0.4</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Fig. 4:** The contrast values with UHR and those without UHR in the X-Y plane and in the Z plane. The differences between the contrast values with UHR and those without UHR were assessed using the two-tailed paired t-test assuming equal variance for the X-Y plane and assuming unequal variance for the Z plane. A p-value of less than 0.05 was considered to indicate significance.

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Conclusion

The contrast values in the X-Y plane for holes over 1.0 mm in diameter with UHR were significantly higher than those without UHR because of the improvement of the spatial resolution in the X-Y plane by UHR. This improvement might be the cause of the improvement of the reliability of the detection of over 1.0-mm-thickness fat plane clinically. The contrast values in the X-Y plane of 0.7-mm diameter holes with UHR were higher than those without UHR, although the differences were not significant. In addition, the FWHMs in the X-Y plane were measurable only with UHR. Consequently, the improvement of the spatial resolution by UHR enables the detection of a sub-millimeter fat plane in the X-Y plane.

The contrast values in the Z plane for holes over 1.0 mm in diameter with UHR showed no significant difference compared with those without UHR; however, the contrast values in the Z plane of 0.7-mm diameter holes with UHR were significantly higher than those without UHR. The contrast improvement was confirmed because the improvement of the spatial resolution in the X-Y plane only influenced small objects in the Z plane with the effective slice thickness. Consequently, the improvement of the spatial resolution by UHR improved the image quality of a sub-millimeter fat plane in the Z plane.

We concluded that the chest CT with UHR improved fat plane detection in both the X-Y plane and the Z plane. The potential improvement of the spatial resolution by UHR enables the detection of sub-millimeter fat planes in the future with noiseless reconstruction technology.
1. Cancer Statistics in Japan 2011: Center for Cancer Control and Information Services, National Cancer Center, Japan.
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