The usefulness of a new iterative approximation reconstruction algorithm in low-dose CT screening for lung cancer

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Purpose

National Lung Screening Trial (NLST) reported a 20% reduction in lung cancer mortality in patients underwent chest CT compared to those screened with chest x-ray. Although CT is effective tools to detect lung cancer in early stage, the patient doses in CT examinations are higher than those in other X-ray diagnostic procedures. Thus, radiation doses in the lung cancer CT screening for healthy person should be kept as low as possible while maintaining high image quality.

Recently, a new reconstruction algorithm, Adaptive Iterative Dose Reduction 3D (AIDR 3D, Toshiba Medical Systems), based on a statistical iterative reconstruction technique has been commonly used as an alternative to traditional Filtered Back Projection (FBP) reconstruction algorithm. The AIDR 3D is an image reconstruction technique to effectively reduce noise and streak artifact in consideration of a various models including statistical noise model, scanner model and anatomical model. The iterative reconstruction algorithm has the potential to significantly reduce doses compared with FBP reconstruction algorithm.

Because AIDR3D improves the contrast noise ratio and mainly reduces artifact at the apex area, it can be useful technique for lung CT screening. However, no previous studies evaluated the image quality and radiation dose in lung CT screening with AIDR 3D.

A purpose of this study is to compare the detectability and radiation doses in lung CT screening using AIDR3D with those using FBP.
Methods and Materials

Lung Screening CT (LSCT) phantom (Kyoto Kagaku) (Fig. 1 on page 5) is used for the evaluation of an detectability and radiation doses in this study. The Phantom represents the chest of a standard Japanese adult male and is composed of tissue equivalent materials to the human body.

This phantom has the spherical nodules representing Ground Glass Opacity (GGO) at the position of lung apex, tracheal bifurcation, and base of lung in both lung fields, respectively. The CT value of the lung is designed to be -900 Hounsfield units (HU). The each area in right lung has five nodules of 4-12mm in diameter (in 2mm steps) and the contrast of nodules is 100HU against the background lung field. The each area in left lung has five nodules of 2-10mm in diameter (in 2mm steps) and the contrast of nodules is 270HU against the background lung field. The phantom also has a hole drilled along the central axis of the phantom for setting a pencil chamber into the phantom.

We evaluated the detectability and radiation doses using LSCT phantom for two protocols. One protocol is the standard protocol for lung CT screening used in a National Cancer Research Center for Cancer Prevention and Screening and the CT images were reconstructed with FBP algorithm. The other is the low dose protocol set to the smallest tube current and the CT images were reconstructed with AIDR 3D algorithm.

**Standard protocol**

Scan condition: tube voltage; 120kVp#tube current; 30mA#rotation time; 0.5s/rot#pitch factor; 0.69, slice thickness; 1mm×32, scan length; 300mm

Reconstruction condition: image reconstruction method; FBP algorithm, image slice thickness; 5mm, slice interval; 5mm, reconstruction function; mediastinal kernel (FC03)

**Low dose protocol**

Scan condition: tube voltage; 120kVp#tube current; 10mA#rotation time; 0.5s/rot#pitch factor; 0.69, slice thickness; 1mm×32, scan length; 300mm

Reconstruction condition: image reconstruction method; AIDR 3D (standard), image slice thickness; 5mm, slice interval; 5mm, reconstruction function; mediastinal kernel (FC03)

1. Dosimetry
We set a 30cm ionization chamber calibrated at a laboratory of the Japan Quality Assurance Organization into the LSCT phantom and measured the exposure doses for the two protocols. The doses were converted to the values of absorbed dose for air. We also recorded the values of CTDI and DLP displayed on a CT console.

2. Image and statistical analysis

We conducted the receiver operating characteristic curve (ROC) analysis using 240 LSCT phantom images in total obtained in the two protocols. These CT images included images of nodules at the position of lung apex, tracheal bifurcation, and base of lung in both lung fields and images of background near the nodules (Fig. 2 on page 5)

The images of the nodules of 6mm in diameter and 270HU in #CT values in right lung and the nodules of 4mm in diameter and 100HU in #CT values in left lung were used for ROC analysis.

Two doctors (radiologist, pulmonologist) and four radiological technologists assessed the presence or absence of the nodules and the confidence was rated on 1 to 5 scales.

We conducted ROC analysis using ROCKIT program, and evaluated a significance of the differences between the Area Under the Curves (AUC) derived from two protocols with Student’s t-test.
Fig. 1: Figure Caption (LSCT phantom) LSCT phantom represents the chest of a standard Japanese adult male and has the spherical nodules (#CT values: 100HU#270HU) at the position of lung apex, tracheal bifurcation, base of lung in both lung fields, respectively.

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Fig. 2: Sample image used for ROC analysis at the bifurcation of trachea. CT images of the site surrounded with squares were used for ROC analysis. The images included nodules of 4mm and 6mm, and background near the nodules

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Results

1. Dosimetry

The absorbed doses for air measured in the LSCT phantom was 2.38mGy for the standard protocol and 0.80mGy for the low dose protocol and the dose for the low dose protocol was approximately one-third of that for the standard protocol.

CTD\textsubscript{vol} and DLP displayed on a CT console was 1.7mGy and 55.3mGy\#cm for the standard protocol, respectively, and 0.6mGy, 18.4mGy\#cm for the low dose protocol.

CTD\textsubscript{vol} and DLP for the low dose protocol were also approximately one-third of that for the standard protocol.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>The absorbed doses in the LSCT phantom</th>
<th>CTD\textsubscript{vol} and DLP displayed on a CT console</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard protocol</td>
<td>2.38mGy</td>
<td>1.7mGy, 55.3mGy#cm</td>
</tr>
<tr>
<td>(15mAs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low dose protocol</td>
<td>0.80mGy</td>
<td>55.3mGy#cm, 18.4mGy#cm</td>
</tr>
<tr>
<td>(5mAs+AIDR3D)</td>
<td></td>
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</tr>
</tbody>
</table>

Table 1. Absorbed doses for air, CTD\textsubscript{vol} and DLP for two different protocols

2. Image and statistical analysis

Values of the AUC for the CT image obtained in the standard protocol was 0.9327 and for the low dose protocol was 0.9231.

The shapes of the ROC curve for two scan protocol were almost same and the p-value between the values of the AUC was 0.64. (Fig. 3 on page 8), This result showed no significant difference in the detectability of nodules between two protocols.
Fig. 3: The ROC curves for two scan protocol

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Conclusion

We compared detectability and radiation doses for the standard protocol used in lung cancer CT screening with those for the low dose protocol using the iterative reconstruction technique.

This study showed that radiation doses in the low dose protocol decreased by 65% compared with those in the standard protocol and that there were no significant differences in the detectability of GGO lesions between the two protocols. Thus, the low dose protocol with the AIDR3D algorithm should be used in lung cancer CT screening.
References


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