Adaptive Iterative Dose Reduction using Three Dimensional Processing (AIDR 3D): Capability for Radiation Dose Reduction for Chest CT Examination in Various Pulmonary Disease Patients

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Purpose

• To determine the utility of AIDR 3D for image noise reduction and assessment of radiological findings obtained with reduced- and low-dose chest CTs in patients with various pulmonary diseases.

Methods and Materials

1. Subjects

• 37 consecutive pathologically diagnosed lung cancer patients with various pulmonary diseases (17 males <mean age, 65 years; age range, 53-78 years> and 20 females <mean age, 66 years; age range, 35-84 years>) underwent chest MDCT examination at three different tube current (25mAs, 50mAs and 150mAs).

2. CT Examination

• CT scanner: Aquilion 16 and 64 (Toshiba Medical Systems, Ohtawara, Japan)
• Scan parameters: ü16 or 64°0.5 mm collimation, Beam pitch 0.85-1.5, 300-350 mm field of view, 512°512 matrix, 120kV, 0.5 sec/rotation, 25mAs, 50mAs and 150 mAs, 1 mm reconstruction section thickness.
• The following data sets were reconstructed for each patient as follows: 1) standard-dose CT (150mAs) without AIDR 3D, 2) reduced-dose CT (50mAs) without and with AIDR 3D, and 3) low-dose CT (25mAs) without and with AIDR3D
• All data set were reconstructed for lung window setting by using a high-frequency reconstruction algorithm (FC51, Toshiba) and mediastinal window setting by using a standard reconstruction algorithm (FC13, Toshiba).

3. Image Analysis

• As quantitative assessment of image noise, images at the level of the lung apices, aortic arch, carina, left atrium, and lung bases were used for quantitative analysis of image quality. Circular ROIs were placed on the lung window and mediastinal window settings at the tracheal lumen, bilateral lung parenchyma, aortic arch or descending aorta or heart as the mediastinal structure, as well as at the bilateral soft-tissue structures within the chest wall. All ROIs were then copied to another CT image series, and image noise at each ROI was determined as the standard deviation of the CT value within the ROI.
• As qualitative assessment of image quality, image noise reduction capability of each CT series with that of standard-dose CT was assessed by using
a 5-point visual scoring system (1, non-diagnostic; 2, poor; 3, acceptable; 4, good; 5, excellent). To compare the capability of each CT protocol with that of standard-dose CT, a 5-point visual scoring system (1, absent; 2, probably absent; 3, equivocal; 4, probably present; 5, present) was used to determine the presence of emphysema, ground glass opacity, reticular opacity, interlobular septal thickening, bronchiectasis, honeycomb pattern and nodules at the lung window setting and aneurysm, calcification at coronary artery, pericardial or pleural effusion, pleural thickening, pleural calcification, and lymph adenopathy at the mediastinal window setting.

4. Statistical Analysis

- To determine the utility of AIDR 3D, image noises of all series at both window settings were compared by using Fisher’s protected least significant difference (PLSD) test for quantitative and qualitative assessment.
- Weighted kappa statistical analyses were performed to determine the appropriateness for routine clinical practice of reduced- and low-dose CT without and with AIDR 3D as compared with that of standard-dose CT.
- Inter-method agreement was considered as slight for $\kappa < 0.21$, fair for $\kappa = 0.21 - 0.40$, moderate for $\kappa = 0.41 - 0.60$, substantial for $\kappa = 0.61 - 0.80$, and almost perfect for $\kappa = 0.81 - 1.00$.
- A p value less than 0.05 was considered significant for statistical analyses.

Results

- Results of comparison of quantitative and qualitative assessments of image quality among standard-, reduced- and low-dose CTs are shown in Table 1 as Fig. 1. Image noise and image quality score of reduced- and low-dose CT without AIDR 3D was significantly lower than those of standard-dose CT, and those of reduced- and low-dose CTs with AIDR 3D (p<0.05). In addition, low-dose CT without AIDR 3D produced significantly poorer image quality than did reduced-dose CT without AIDR 3D (p<0.05).
- Results of kappa analyses for agreement between standard-dose CT and others on lung window setting are shown in Table 2 as Fig. 2. All agreements of reduced- and low-dose CTs with AIDR 3D were substantial or almost perfect ($\kappa > 0.73$), although agreements of those CTs without AIDR 3D were moderate, substantial or almost perfect ($\kappa > 0.55$).
- Results of kappa analyses for agreement between standard-dose CT and others on mediastinal window setting are shown in Table 3 as Fig. 3. All agreements of reduced- and low-dose CTs with and without AIDR 3D were almost perfect ($\kappa > 0.87$).
- Representative case is shown in Fig. 4.
### Adaptive Iterative Dose Reduction (AIDR) 3D
*Quantitative and Qualitative Image Quality Assessment*

<table>
<thead>
<tr>
<th>CT protocol</th>
<th>Image Noise (Mean ± SD)</th>
<th>Image Quality Score (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard-Dose CT</td>
<td>31.4±12.6</td>
<td>4.9 ± 0.3</td>
</tr>
<tr>
<td>Reduced-Dose CT without AIDR 3D</td>
<td>48.4±17.8* , ** , ***</td>
<td>4.3 ± 0.5* , ** , ***</td>
</tr>
<tr>
<td>Reduced-Dose CT with AIDR 3D</td>
<td>30.1±10.1</td>
<td>4.8 ± 0.4</td>
</tr>
<tr>
<td>Low-Dose CT without AIDR 3D</td>
<td>66.7±26.9* , ** , *** , ****</td>
<td>3.4 ± 0.7* , ** , *** , ****</td>
</tr>
<tr>
<td>Low-Dose CT with AIDR 3D</td>
<td>32.1±7.5</td>
<td>4.7 ± 0.5</td>
</tr>
</tbody>
</table>

- Lung window setting
- Mediastinal window setting

SD: Standard deviation  
*, **: Significant difference with standard-dose CT (p<0.05)  
***: Significant difference with reduced-dose CT without AIDR 3D (p<0.05)  
****: Significant difference with low-dose CT with AIDR 3D (p<0.05)  
*****: Significant difference with reduced-dose CT with AIDR 3D (p<0.05).

**Fig. 1:** Table 1. Comparison of Quantitative and Qualitative Assessment of Imaging Quality among all methods.
## Table 2. Intermethod Agreements on Lung Window Setting.

<table>
<thead>
<tr>
<th>Radiological findings (Kappa values)</th>
<th>Emphysema</th>
<th>GGO</th>
<th>Reticular opacity</th>
<th>Interlobular septal thickening</th>
<th>Bronchiectasis</th>
<th>Honeycomb</th>
<th>Nodules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced-Dose CT without AIDR 3D</td>
<td>0.92</td>
<td>0.82</td>
<td>0.87</td>
<td>0.79</td>
<td>0.81</td>
<td>0.98</td>
<td>1.00</td>
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<tr>
<td>Reduced-Dose CT with AIDR 3D</td>
<td>0.96</td>
<td>0.88</td>
<td>0.93</td>
<td>0.82</td>
<td>0.92</td>
<td>0.98</td>
<td>1.00</td>
</tr>
<tr>
<td>Low-Dose CT without AIDR 3D</td>
<td>0.87</td>
<td>0.71</td>
<td>0.59</td>
<td>0.56</td>
<td>0.77</td>
<td>0.95</td>
<td>0.98</td>
</tr>
<tr>
<td>Low-Dose CT with AIDR 3D</td>
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<td>0.81</td>
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<td>0.78</td>
<td>0.81</td>
<td>0.98</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Fig. 3: Table 3. Intermethod Agreement on Mediastinal Window Setting

<table>
<thead>
<tr>
<th>Radiological findings (Kappa values)</th>
<th>Aortic aneurysm</th>
<th>Calcification at coronary artery</th>
<th>Pericardial or pleural effusion</th>
<th>Pleural thickening</th>
<th>Pleural calcification</th>
<th>Tumor</th>
<th>Lymphadenopathy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced-Dose CT without AIDR 3D</td>
<td>1.00</td>
<td>0.95</td>
<td>0.89</td>
<td>1.00</td>
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<td>1.00</td>
<td>1.00</td>
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</tbody>
</table>
**Fig. 4:** Fig. 4. Representative Case in Patient with Partly Solid Nodule
Conclusion

- AIDR 3D was found to be useful for assessment of image noise reduction and radiological findings on reduced- and low-dose CTs for patients with various pulmonary diseases.
- AIDR 3D could decreased almost 80 % radiation dose without any degradation of radiological findings assessment capability in routine clinical practice.

Personal Information

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References