Purpose

Introduction:

Recently, the adaptive iterative dose reduction technique has been developed as a new reconstruction algorithm to improve image noise, and has already been shown to reduce the radiation dose in clinical practice [1-4]. Adaptive iterative dose reconstruction (AIDR) developed for CT by Toshiba Corporation Medical Systems, is a modified iterative reconstruction technique in which the original high noise image undergoes a number of reconstructions that reduce image noise until the resultant image displays the desired noise level. This technique is expected to reduce the radiation dose for a similar noise level compared with the current reconstruction method, filtered back projection (FBP).

Purpose:

The purpose of this study was to evaluate the effect of AIDR regarding image noise and image quality in comparison to FBP in 320-detector row CT coronary angiography (CTCA).

Methods and Materials

Patients#

Fifty patients (36 men, 14 women; mean age 68.2 ± 9.4 years; range 40-88 years) referred to CTCA for clinical indications were enrolled in this study. Patients who had previous allergic reaction to iodinated contrast material, elevated serum creatinine level (> 1.5 mg/dl), or who were potentially pregnant were excluded.

CT scanning#

CT scanning was performed using a 320-detector-row scanner (Aquilion ONE, Toshiba Corporation Medical Systems). Patients with a prescan heart rate of 65 beats per minute (bpm) or higher were given 20-60 mg of metoprolol orally 1 hour before scanning. Tube voltage and tube current were adapted to individual body mass index (BMI) according to the protocol shown in Table 1 on page 4. Other scanning parameters were a collimation of 320×0.5 mm, a rotation time of 0.35 seconds and z-coverage value of 140-160 mm in which the entire heart was scanned in a single rotation.

All the patients received 0.7 ml/kg of nonionic contrast material (Iomeprol, Iomeron 350 mgl/ml) injected at a fixed duration of 10 seconds, followed by 20 ml of saline solution.
injected at the same flow rate as the contrast material. After the single density level in the ascending aorta reached 150 Hounsfield units (HU), contrast-enhanced CT scan was performed. All the examinations were performed with a dose modulation for a visualization of the myocardial or valve motion throughout the cardiac cycle.

**Image Reconstruction:**

For evaluation of the coronary arteries, data was reconstructed at 75% of the R-R interval with a slice thickness of 0.5 mm and a reconstruction interval of 0.25 mm, using a medium soft tissue kernel (FC13). The raw data were reconstructed with a standard FBP and subsequently AIDR. The reconstructed image data was transferred to a computer workstation for post processing.

**Quantitative Analysis#**

Calculation of the CNR in the proximal right (RCA) and left main (LMA) coronary arteries comprised the following steps. First, attenuation was measured in a region of interest (ROI) in the proximal RCA and the LMA. Vessel contrast was calculated as the difference in mean attenuation between the contrast-enhanced vessel lumen and the adjacent perivascular tissue. Second, image noise was determined as the standard deviation (SD) of the attenuation value in an ROI placed in the ascending aorta. Third, the CNR was calculated as the ratio of vessel contrast over noise.

**Qualitative Analysis#**

Coronary arteries were classified according to the guidelines of the American Heart Association (15 segments). Overall image quality was assessed on a 5-point rating score for each coronary artery segment: 5 = excellent (absence of motion artifacts or noise-related blurring, and excellent vessel opacification); 4 = good (minor motion artifacts or noise-related blurring, and good vessel opacification); 3 = acceptable (some motion artifacts or noise-related blurring, and fair vessel opacification); 2 = suboptimal (marked motion artifact or noise-related blurring, and poor vessel opacification), 1 = nondiagnostic. Images with a score of 3 or higher were considered diagnostic.

**Statistical Analyses#**

Differences in image quality parameters between the two scanning protocol groups were compared using the Mann-Whitney U test. Pearson correlation analysis was performed to compare BMI with image noise. A $P$ value of $< 0.05$ was considered to indicate a statistical significance.
**Table 1.** Body mass index (BMI)-adapted scanning protocol.

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>Voltage (kV)</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20</td>
<td>100</td>
<td>400</td>
</tr>
<tr>
<td>20 - 22.4</td>
<td>100</td>
<td>450</td>
</tr>
<tr>
<td>22.5 – 24.9</td>
<td>100</td>
<td>500</td>
</tr>
<tr>
<td>25 - 27.4</td>
<td>120</td>
<td>550</td>
</tr>
<tr>
<td>&gt; 27.5</td>
<td>120</td>
<td>580</td>
</tr>
</tbody>
</table>

**Table 1:** Body mass index (BMI)-adapted scanning protocol.
Results

All the examinations were performed within a single heartbeat with ECG-gating; the mean heart rate during acquisition of CT scans was 53.1±6.7 bpm (range 37-65 bpm). The mean BMI of the study population was 23.9±2.8 (range, 18.0-30.1).

**Qualitative Analysis (Table 2 on page 5):**

Image noise in the aorta was significantly lower in axial CT images reconstructed with AIDR than standard FBP (21.4±3.1 HU vs. 36.9±4.5 HU; \( p < 0.001 \)). No significant differences were observed between FBP and AIDR for the mean vessel contrast in the proximal coronary arteries. Consequently, CNRs in the proximal coronary arteries were significantly higher for AIDR than for FBP (\( p < 0.001 \)). Using AIDR, image noise reduced by 42.0±3.3% with an increase of CNR by 72.3±11.8% in proximal RCA and by 69.5±13% in LMA, when compared to FBP.

There were no significant correlations between BMI and image noise in axial CT images reconstructed with AIDR (\( r = -0.14, p = 0.35 \)), or between BMI and those reconstructed with FBP (\( r = -0.10, p = 0.51 \)) (Fig. 1 on page 6).

**Qualitative Analysis (Table 3 on page 7):**

In both two reconstruction methods, a total of 630 coronary artery segments with at least a 1.5 mm vessel diameter were available for evaluation. The rate of an overall diagnostic image quality in the FBP group was 92.9% of all segments (585/630), while 98.3% of segments (619/630) were diagnostic in the AIDR group. Among 630 segments, 45 (7.1%) were considered nondiagnostic in the FBP group, and 11 (1.7%) in the AIDR group. The mean image quality score was significantly improved by AIDR (3.75±0.38 in the FBP group and 4.24±0.38 in the AIDR group; \( p < 0.001 \)). A representative case is shown in Fig. 2 on page 8.

Images for this section:
Table 2. Quantitative image quality parameters.

<table>
<thead>
<tr>
<th></th>
<th>FBP</th>
<th>AIDR</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image noise (HU)</td>
<td>36.9±4.5</td>
<td>21.4±3.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vessel contrast of the RCA (HU)</td>
<td>555.7±87.2</td>
<td>553.2±88.3</td>
<td>0.83</td>
</tr>
<tr>
<td>Vessel contrast of the LMA (HU)</td>
<td>564.7±69.3</td>
<td>560.9±74.2</td>
<td>0.78</td>
</tr>
<tr>
<td>CNR in the RCA</td>
<td>15.2±2.4</td>
<td>26.1±4.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CNR in the LMA</td>
<td>15.7±2.1</td>
<td>26.5±3.8</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data are the mean ± standard deviation.
RCA, right coronary artery; LMA, left main artery.

Table 2: Quantitative image quality parameters.
**Fig. 1:** Plots of image noise (HU) versus body mass index (BMI) (kg/m²). No significant differences were observed between BMI and image noise in axial CT images reconstructed with FBP ($r = -0.10$, $p = 0.51$) (dotted line), and between BMI and those reconstructed with AIDR ($r = -0.14$, $p = 0.35$) (solid line). # = FBP group, # = AIDR group.
Table 3: Qualitative assessment of image quality.

<table>
<thead>
<tr>
<th></th>
<th>FBP</th>
<th>AIDR</th>
</tr>
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<tbody>
<tr>
<td>Image quality score</td>
<td>3.75 ± 0.38</td>
<td>4.24 ± 0.38</td>
</tr>
<tr>
<td>Total no. of coronary artery segments</td>
<td>630</td>
<td>630</td>
</tr>
<tr>
<td>Segments with diagnostic image quality</td>
<td>92.9% (585/630)</td>
<td>98.3% (619/630)</td>
</tr>
<tr>
<td>Nondiagnostic segments</td>
<td>7.1% (45/630)</td>
<td>1.7% (11/630)</td>
</tr>
</tbody>
</table>

Data are the mean ± standard deviation.
Fig. 2: Comparison of image noise and quality in a 63-year-old man with a BMI of 28.2 kg/m². A and B are curved-planar reconstruction images of the RCA and axial images of the proximal RCA (insets) reconstructed with FBP (A) and AIDR (B) algorithms: A) Image noise of 30.0 HU and vessel contrast in the proximal RCA of 464.6 HU. Image quality was rated as good. B) Image noise of 16.5 HU and vessel contrast in the proximal RCA of 461.9 HU. Image quality was rated as excellent.
Conclusion

1) Use of AIDR reduced image noise by 42%, with an improvement of CNR by approximately 70%, when compared to FBP. Qualitative assessment of image quality was also improved by AIDR, likely reflecting this significant decrease in image noise and improved CNR.

2) Since the resulting image noise in data sets reconstructed with AIDR as well as FBP was similar in all patients independent of BMI, the results of our study show that use of AIDR reduced image noise in a similar manner in all patients.

3) AIDR would have a potential for further radiation dose reduction in CTCA.

References


Personal Information