Radiation dose, image quality, and diagnostic acceptability of 128-slice dual-source computed tomographic coronary angiography with prospective electrocardiogram-gated high-pitch spiral mode.

Poster No.: C-0826  
Congress: ECR 2012  
Type: Scientific Exhibit  
Keywords: Imaging sequences, Diagnostic procedure, Acceptance testing, CT-Angiography, Radioprotection / Radiation dose, Radiation physics, Cardiac, Arteriosclerosis  
DOI: 10.1594/ecr2012/C-0826

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Purpose

The higher temporal resolution of a 128-section dual-source computed tomography (DSCT) enables the use of CT coronary angiography (CTCA) in prospective electrocardiogram (ECG)-gated high-pitch spiral (HPS) mode.

The aim of this study was to compare the radiation dose, image quality, and diagnostic acceptability of CTCA performed in three different acquisition modes, including prospective ECG-gated HPS mode.
Methods and Materials

128-section DSCT scanner

A 128-section DSCT SOMATOM Definition Flash (Siemens Healthcare, Erlangen, Germany) was used.

Acquisition modes

CTCA can be performed using 128-section DSCT in the following three acquisition modes: 1) prospective ECG-gated HPS, 2) prospective ECG-gated step-and-shoot (SAS), and 3) retrospective ECG-gated low-pitch spiral (LPS) modes (Fig. 1 on page 6).

During acquisition in the HPS mode, the entire cardiac volume can be scanned within a fraction of one cardiac R-R cycle. The entire period of data acquisition is approximately 260 ms long and placed in diastole. The temporal resolution of each image is 75 ms.

In the SAS mode, CT data are only acquired over a fraction of the R-R interval by performing multiple non-spiral acquisitions.

In the LPS mode, CT data are acquired throughout the cardiac cycle, and the data required for the reconstruction phase is chosen retrospectively.

Patients

The data from 138 patients who underwent CTCA with a 128-slice DSCT scanner to diagnose coronary artery disease were retrospectively included in this study. The collection and review of the data were approved by our institutional review board.

The acquisition mode used for each patient was determined by his/her age, anatomical size, and heart rate prior to acquisition after consultation with the cardiologist, radiologist, and radiographer. As a result, 17 patients were examined using HPS mode (defined as group A), 88 were examined using SAS mode (group B), and 33 were examined using LPS mode (group C). The characteristics of the patients in the three groups are shown in Table 1. The patients with heart rates higher than approximately 80 beats per minute (bpm) just before acquisition received an intravenous beta-blocker (Inderal, AstraZeneca, Osaka, Japan) before examination.

Table 1: Comparison of patient characteristics among the three groups.

<table>
<thead>
<tr>
<th>Acquisition mode</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>HPS (N = 17)</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Number of male</td>
<td>8</td>
</tr>
<tr>
<td>Number of female</td>
<td>9</td>
</tr>
<tr>
<td>Age (y)</td>
<td>57 ± 21</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>156.0 ± 6.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>52.8 ± 6.2</td>
</tr>
<tr>
<td>Body mass index</td>
<td>21.0 ± 2.0</td>
</tr>
</tbody>
</table>

*Kruskal-Wallis Test

**Acquisition methods**

All CT data were acquired during end-expiratory breath holding. A volume of contrast agent (Iopamiron 370; Bayer Pharma, Osaka, Japan) equivalent to body weight (kg) × 0.5 + 20 ml was injected with a power injector (Auto Enhance A-300; Nemoto Kyorindo, Tokyo, Japan) at an injection time of 12 s, followed by a saline solution flush at an injection time of 5 s.

Prior to acquisition, the following test bolus protocol was used: the contrast agent was injected at an injection time of 2.5 s, followed by a saline solution flush at an injection time of 5 s, and the time to peak enhancement in the aorta at the left main tract level was measured using a series of images obtained from the test bolus protocol.

Image acquisition was started with a delay corresponding to the time to peak enhancement plus 6 s (in HPS mode) or 4 s (in SAS and LPS modes).

The acquisition parameters used in the three acquisition modes are shown in Table 2.

**Table 2: Acquisition parameters in the three acquisition modes.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HPS</th>
<th>SAS</th>
<th>LPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collimation (mm)</td>
<td>128×0.6</td>
<td>128×0.6</td>
<td>128×0.6</td>
</tr>
<tr>
<td>kV</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Pitch factor</td>
<td>3.4:1</td>
<td>N/A</td>
<td>0.17:1</td>
</tr>
<tr>
<td>Rotation time (s)</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>Padding window (%)</td>
<td>N/A</td>
<td>35-85 or 55-85</td>
<td>N/A</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------</td>
<td>----------------</td>
<td>-------</td>
</tr>
<tr>
<td>Slice thickness (mm)</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Kernel</td>
<td>B36f</td>
<td>B36f</td>
<td>B36f</td>
</tr>
</tbody>
</table>

*Data analysis*

The average heart rate during acquisition, radiation dose (the volume CT dose index \(\text{CTDl}_{\text{vol}}\) and dose length product \(\text{DLP}\) were displayed on the CT console and the effective dose \(\text{ED}\) was estimated from the DLP), and image noise in the ascending aorta, pulmonary vein, and descending aorta were recorded (Fig. 2 on page 6).

Furthermore, the diagnostic acceptability was graded using a four-point scale (1, unacceptable; 2, suboptimal; 3, acceptable; 4, fully acceptable) by two radiologists with 10 and 15 years of experience. Discrepancies in the score between the radiologists were resolved by consensus after the independent readings.
Images for this section:

Prospective ECG-gated high-pitch spiral mode

Prospective ECG-gated non-spiral mode

Retrospective ECG-gated spiral mode

Fig. 1: Three acquisition modes used in CT coronary angiography.

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**Fig. 2:** Regions where image noise was measured.

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**Results**

\textit{Heart rate}

The average heart rates during acquisition were 59.1 ± 6.0, 68.1 ± 10.5, and 76.6 ± 21.6 bpm in groups A, B, and C, respectively.

\textit{Radiation Dose (Table 3)}

The CTDI$_{vol}$, DLP, and ED in group A were lower than those in group B, and those in group B were lower than those in group C. There were significant differences in these values among the three acquisition modes (p < 0.001, Kruskal-Wallis Test).

Table 3: Comparison of radiation doses among the three groups.

<table>
<thead>
<tr>
<th>Acquisition mode</th>
<th>HPS (N = 17)</th>
<th>SAS (N = 88)</th>
<th>LPS (N = 33)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTDI$_{vol}$ (mGy)</td>
<td>5.84 ± 0.56</td>
<td>45.14 ± 13.46</td>
<td>102.35 ± 19.36</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>DLP (mGy cm)</td>
<td>107 ± 12</td>
<td>633 ± 190</td>
<td>1534 ± 310</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>ED (mSv)</td>
<td>1.5 ± 0.2</td>
<td>8.9 ± 2.7</td>
<td>21.5 ± 4.3</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*Kruskal-Wallis Test

\textit{Image noise (Table 4)}

There were significant differences among the three groups in the image noise level in the ascending aorta (p < 0.001, Kruskal-Wallis Test), but there were no significant differences among the three groups in the image noise levels in the pulmonary vein and descending aorta.

Table 4: Comparison of image noise levels among the three groups.

<table>
<thead>
<tr>
<th>Acquisition mode</th>
<th>HPS (N = 17)</th>
<th>SAS (N = 88)</th>
<th>LPS (N = 33)</th>
<th>P value*</th>
</tr>
</thead>
</table>

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Ascending aorta (HU)  
14.86 ± 2.58  
15.65 ± 3.80  
12.55 ± 3.32  
< 0.001

Pulmonary vein (HU)  
18.82 ± 3.37  
18.24 ± 4.45  
16.69 ± 4.56  
0.128

Descending aorta (HU)  
17.46 ± 3.29  
17.55 ± 5.11  
15.46 ± 3.72  
0.105

*Kruskal-Wallis Test

Diagnostic acceptability (Table 5)

The average diagnostic acceptability was 3.2, 3.6, and 3.7 in groups A, B, and C, respectively, and the differences were significant (p < 0.01, Kruskal-Wallis Test).

Table 5: Comparison of diagnostic acceptability among the three groups: frequency distribution.

<table>
<thead>
<tr>
<th>Score</th>
<th>Acquisition mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HPS (N = 17)</td>
</tr>
<tr>
<td>4 (fully acceptable)</td>
<td>5</td>
</tr>
<tr>
<td>3 (acceptable)</td>
<td>11</td>
</tr>
<tr>
<td>2 (suboptimal)</td>
<td>1</td>
</tr>
<tr>
<td>1 (unacceptable)</td>
<td>0</td>
</tr>
</tbody>
</table>

Case 1 (80-year-old male, Fig. 3 on page 11)

In this case, the HPS acquisition mode was selected for CTCA. The average heart rate during acquisition was 53 bpm, CTDI<sub>vol</sub> was 6.80 mGy, DLP was 119 mGy cm, and estimated ED was 1.7 mSv. The diagnostic acceptability was graded as 4 (fully acceptable).

The CTCA images showed severe stenosis caused by soft plaque in the left anterior descending artery (90% of the diameter at segment 6 of the American Heart Association classification, and 75% of the diameter at segment 7 [Fig. 4 on page 11, Fig. 5 on page 12]).

Case 2 (55-year-old female, Fig. 6 on page 13)
In this case, the HPS acquisition mode was also selected for CTCA. The average heart rate during acquisition was 56 bpm, CTDI\textsubscript{vol} was 5.50 mGy, DLP was 95 mGy cm, and estimated ED was 1.3 mSv. The diagnostic acceptability was graded as 3 (acceptable).

The CTCA images showed mild stenosis that included a pin-point calcified lesion (less than 50% of the diameter at segment 6 [Fig. 7 on page 14]).

Case 3 (71-year-old female, Fig. 8 on page 15)

In this case, the HPS acquisition mode was also selected for CTCA. The average heart rate during acquisition was 65 bpm, CTDI\textsubscript{vol} was 6.78 mGy, DLP was 127 mGy cm, and estimated ED was 1.8 mSv. The diagnostic acceptability was graded as 2 (suboptimal).

In the CTCA images, the left circumflex artery was blurred. Apparently, there were some soft plaques at segment 11, but there was a high probability that these low-density areas were motion artifacts (Fig. 9 on page 16).
Images for this section:

**Fig. 3:** Images from CT coronary angiography in case 1: transverse images (movie).

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Fig. 4: Images from CT coronary angiography in case 1: severe stenosis caused by soft plaque at segments 6 and 7.

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**Fig. 5:** Images from CT coronary angiography in case 1: severe stenosis caused by soft plaque at segments 6 and 7.

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Fig. 6: Images from CT coronary angiography in case 2: transverse images (movie).

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**Fig. 7:** Images from CT coronary angiography in case 2: mild stenosis including a pinpoint calcified lesion at segment 6.

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Fig. 8: Images from CT coronary angiography in case 3: transverse images (movie).

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Fig. 9: Images from CT coronary angiography in case 3: low-density areas at segment 11.

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Conclusion

Although the radiation dose in HPS mode was low compared with that in the other modes, the diagnostic acceptability also was lower than that in the SAS and LPS modes. However, the images acquired in the HPS mode were almost at the level acceptable for diagnostic image interpretation.
References


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