Effect of the motion correction technique on image quality at 320-detector CT coronary angiography in patients with atrial fibrillation

Poster No.: C-0091
Congress: ECR 2016
Type: Scientific Exhibit
Authors: F. Tatsugami, T. Higaki, M. Iida, C. Fujioka, M. Kiguchi, K. Awai; Hiroshima/JP
Keywords: Technology assessment, CT-Angiography, Cardiac, Image verification, Artifacts
DOI: 10.1594/ecr2016/C-0091

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Aims and objectives

Coronary computed tomography angiography (CTA) is a robust noninvasive imaging modality that can yield an accurate diagnosis and exclude coronary artery disease (CAD) with a high degree of diagnostic accuracy. On 320-detector CT scanners it is possible to cover the entire heart in a single rotation; one-heartbeat acquisition can be performed in patients with a slow and regular heartbeat. However, as the temporal resolution of this type of CT scanner is not high enough it may not yield images free of motion artifact, especially in patients with higher and irregular heartbeats. In patients with heart rates above 65 beats per minute (bpm) or irregular heartbeats, 2 to 4-heartbeat scan acquisition is performed with 2 to 4-segment reconstruction for improved temporal resolution.

A new adaptive motion correction (AMC) technique that suppresses blurring of the coronary arteries has been developed by Toshiba Medical Systems Corp. on a 320-detector CT scanner. It estimates the degree of motion at each segment of these arteries and accurately corrects the location using prospective ECG-gated data. AMC is expected to reduce motion artifacts of the coronary arteries in patients with higher or irregular heartbeats.

There are few reports on the use of a motion correction technique for coronary CTA performed on other CT systems (SnapShot Freeze; GE Healthcare). To our knowledge, the effect of AMC on the image quality of coronary CTA scans obtained on a 320-detector scanner in patients with atrial fibrillation (AF) has not been evaluated. Therefore, we compared coronary CTA images reconstructed with and without AMC in patients with AF, and evaluated whether AMC improved these images.

Methods and materials

**Adaptive Motion Correction (AMC):**

AMC is a new technique that can suppress blurring of the coronary arteries by using redundant imaging data (padding) obtained with prospective ECG-gating. In this process, a volume image of a cardiac phase of interest, the target phase, is acquired by half-scan reconstruction. To obtain cardiac motion during the padding scan range, two reference phases that correspond to the two end time points of the padding scan range are determined and half-scan reconstruction of the two reference phases is performed. Using information from the two reference phases, AMC estimates coronary artery motion by the artery tree-tracking and matching approach and then determines its actual location in the target phase. If voxels with motion shift from the actual location are present, AMC...
corrects the shift. As it estimates entire cardiac motion by using a non-rigid imaging registration technique, motion compensation can be achieved in the coronary artery as well as the myocardium or valve.

**Patients**

Institutional review board approval was obtained for this retrospective study; informed consent was waived. We enrolled 37 patients who had persistent AF and underwent coronary CTA between December 2014 and March 2015. The exclusion criteria were renal insufficiency (estimated glomerular filtration rate < 30 mL/min/1.73m²), allergy to contrast agents, history of bypass grafting, and potentially pregnant women. Patients with AF and heart rates below 64 bpm (n=9) underwent one-heartbeat CT acquisition; they were excluded from this study as were patients with pacemakers (n=2) and severe coronary artery calcification (n=1) to avoid the influence of beam-hardening artifacts. Consequently, 25 patients (17 men, 8 women; median age 65 years; range 34-84 years) were enrolled; 22 were scheduled for catheter ablation, 2 for mitral valve surgery and one patient for the surgical management of left atrial myxoma.

**CT scanning**

All CT scans were performed on a 320-detector CT scanner (Aquilion ONE Vision, Toshiba Medical Systems Corp., Tokyo, Japan). Patients with a resting heart rate exceeding 65 bpm received 20-40 mg of metoprolol (Selokeen; AstraZeneca, Zoetermeer, Netherlands) perorally 60 min before the CT studies. In all patients we used a nitroglycerin spray (Myocor; Astellas Pharma, Tokyo, Japan) 5 min before the examination to dilate the coronary arteries.

The contrast material volume was adapted to the body weight. Using a dual shot injector (Nemoto Kyorindo, Tokyo, Japan) and a 20-gauge intravenous injection catheter (Termo, Tokyo, Japan) inserted into an antecubital vein, we delivered 300 mgI/kg of nonionic contrast material (Iomeprol, Iomeron 350 mgI/mL; Eisai, Tokyo, Japan) at a fixed duration of 14 seconds to all patients. This was followed by 30 mL of a 0.9% saline solution injected at the same flow rate as the contrast material. The scan delay was determined with an automatic bolus tracking system (Real Prep technique; Toshiba). A region of interest (ROI) was placed in the ascending aorta; triggering was at a threshold of 150 Hounsfield units (HU).

The scan parameters were collimation, 320×0.5 mm; rotation time, 0.275 seconds; tube voltage, 100 kV; tube current, 680-750 mA. The field of view (FOV) was adjusted to exactly cover the heart (range 120-180 mm). As all patients required functional
assessment, CT studies were with ECG-gated dose modulation. The window for the full tube current was limited to 35-85% of the R-R interval. Outside the window of full radiation the tube current was reduced by 80%. In patients with HR > 70 bpm, 2 to 4 heartbeats were used for CT data acquisition (HR < 80 bpm 2-heartbeat acquisition, HR > 80 bpm 3- or 4-heartbeat acquisition).

To evaluate the effect of the AMC technique on coronary CTA we used one of the acquired cardiac cycles with the highest heart rate. The reconstruction phase with minimum artifacts was identified on the CT console by cardiac-phase search software (Phase Navi) and then the AMC technique was applied (Fig. 1). Axial images were reconstructed with a slice thickness of 0.5 mm, a reconstruction interval of 0.25 mm, and the "mild" setting of iterative reconstruction (adaptive iterative dose reduction 3D: AIDR 3D, Toshiba Medical Systems). All reconstructed images with and without AMC were transferred to a computer workstation (Virtual Place ver. 3.3; Aze, Tokyo, Japan) for post-processing.

**Fig. 1:** Outline for selecting the cardiac phase and reconstructed images.

**References:** Diagnostic Radiology, Hiroshima University - Hiroshima/JP
The CT dose index ($\text{CTDI}_{\text{vol}}$) and dose-length product (DLP) provided by the CT scanner were recorded for each patient. The effective radiation dose was calculated as the product of the DLP multiplied by a conversion coefficient for the chest ($k = 0.017 \text{ mSv/mGycm}$).

**Quantitative analysis**

One board-certified radiologist with 9 years of experience in cardiac radiology used a workstation to measure the image noise of the perivascular coronary artery tissue in the ROI. All measurements were at the level of the center of the left ventricle on axial images reconstructed with and without AMC. The ROIs were drawn around the right- and left anterior descending- and the left circumflex coronary arteries (RCA, LAD, LCX) (Fig. 2). The ROIs were as large as possible; inclusion of coronary vessels, heart muscles, and the pericardium was carefully avoided.

**Fig. 2:** ROI measurements in the perivascular tissue of the (a) right, (b) left anterior descending, and (c) left circumflex coronary arteries.

**References:** Diagnostic Radiology, Hiroshima University - Hiroshima/JP
**Qualitative analysis**

Coronary arteries were classified into 15 segments based on the guidelines of the American Heart Association. All vessels with at least a 1.5 mm diameter were subjected to coronary artery analysis. For evaluation of the image quality we used axial image data. Two board-certified radiologists (with 9 and 12 years of experience in cardiac radiology, respectively) who were blinded to clinical information and the reconstruction method assessed the reconstructed axial images on the workstation. If their data analysis disagreed, the final decision was reached by consensus. The overall image quality of each coronary artery segment was rated on a 4-point score where 4=good (no motion artifacts or noise-related blurring); 3=moderate (minor/some motion artifacts or noise-related blurring), 2=limited diagnostic value (marked motion artifact or noise-related blurring), and 1=uninterpretable (Fig. 3). Images with a score of 3 or 4 were considered diagnostic.

![Fig. 3: Reconstructed axial images of the right coronary artery show the image quality score. (a) Good image quality (score 4). (b) Moderate image quality (score 3). (c) Limited diagnostic value (score 2). (d) Uninterpretable (score 1).](image-url)
Statistical analyses

The image noise in perivascular coronary artery tissues on images reconstructed with and without AMC was compared with the paired t-test; the image quality score of the coronary arteries on the two image datasets with the Wilcoxon signed-rank test. Interobserver agreement in the qualitative evaluation was assessed with the Cohen kappa # coefficient where a # value of less than 0.20=poor-, 0.21-0.40=fair-, 0.41-0.60=moderate-, 0.61-0.80=substantial-, and 0.81-1.00=near-perfect agreement.

Differences were considered to be statistically significant at \( p < 0.05 \). We performed all statistical tests with Med-Calc software (version 11.3.7.0, MedCalc, Mariakerke, Belgium).

Images for this section:

Fig. 1: Outline for selecting the cardiac phase and reconstructed images.
Fig. 2: ROI measurements in the perivascular tissue of the (a) right, (b) left anterior descending, and (c) left circumflex coronary arteries.

© Diagnostic Radiology, Hiroshima University - Hiroshima/JP
Fig. 3: Reconstructed axial images of the right coronary artery show the image quality score. (a) Good image quality (score 4). (b) Moderate image quality (score 3). (c) Limited diagnostic value (score 2). (d) Uninterpretable (score 1).

© Diagnostic Radiology, Hiroshima University - Hiroshima/JP
Results

CT scans were acquired without complications in all 25 patients. The mean heart rate during the acquisition of CT images was 89.6±19.0 bpm (median, 86 bpm; range, 65-133 bpm); one (n=2), two (n=6), three (n=14) or four (n=3) heartbeats were scanned for CT data acquisition. The mean total dose of contrast material and the mean flow rate were 54.7±9.4 ml and 3.9±0.7 ml/sec, respectively. The mean CTDI\textsubscript{vol} and effective radiation dose were 96.8±31.3 mGy (range, 38.5-132.3 mGy) and 25.2±8.9 mSv (range, 7.9-36.0 mSv), respectively.

The mean image noise in the perivascular tissue of the RCA was significantly reduced by AMC; it was not significantly reduced in the LAD and LCX (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>RCA</th>
<th>LAD</th>
<th>LCX</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-AMC group</td>
<td>52.5 ± 12.2</td>
<td>40.9 ± 9.5</td>
<td>49.1 ± 19.4</td>
</tr>
<tr>
<td>AMC group</td>
<td>43.8 ± 9.2</td>
<td>39.8 ± 8.7</td>
<td>50.5 ± 21.6</td>
</tr>
<tr>
<td>p value</td>
<td>&lt; 0.001</td>
<td>0.44</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Table 1: Mean image noise (HU) in the perivascular tissue of coronary arteries on images reconstructed with and without adaptive motion correction (AMC).

References: Diagnostic Radiology, Hiroshima University - Hiroshima/JP
The results of our qualitative image quality assessment are shown in Tables 2 and 3. In both two-volume data sets a total of 248 coronary artery segments with at least a 1.5 mm vessel diameter were available for evaluation. Of these 248 segments, 31 segments (12.5%) were improved; however 12 segments (4.8%) were deteriorated by AMC. In the non-AMC group, the image quality was diagnostic for 197 of 248 segments (79.4%); the images of 214 segments (86.3%) were diagnostic in the AMC group. The mean overall image quality scores for images reconstructed with and without AMC were 3.17 and 3.06, respectively ($p < 0.001$). The score for the RCA, but not the LAD and LCX, was significantly improved by AMC (Table 3, Fig. 4). There was substantial interobserver agreement with respect to the overall image quality ($# = 0.64$). A representative case is shown in Fig. 5.

<table>
<thead>
<tr>
<th></th>
<th>non-AMC group</th>
<th>AMC group</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segments evaluated</td>
<td>248</td>
<td>248</td>
<td></td>
</tr>
<tr>
<td>Diagnostic</td>
<td>197 (79.4%)</td>
<td>214 (86.3%)</td>
<td>$&lt; 0.01$</td>
</tr>
<tr>
<td>Non-diagnostic</td>
<td>51 (20.6%)</td>
<td>34 (13.7%)</td>
<td>$&lt; 0.01$</td>
</tr>
</tbody>
</table>

**Table 2**: Qualitative assessment of the image quality.

**References**: Diagnostic Radiology, Hiroshima University - Hiroshima/JP
<table>
<thead>
<tr>
<th></th>
<th>RCA</th>
<th>LAD</th>
<th>LCX</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-AMC group</td>
<td>2.74</td>
<td>3.29</td>
<td>3.29</td>
<td>3.06</td>
</tr>
<tr>
<td>AMC group</td>
<td>3.01</td>
<td>3.26</td>
<td>3.32</td>
<td>3.17</td>
</tr>
<tr>
<td><em>p</em> value</td>
<td>&lt; 0.01</td>
<td>0.46</td>
<td>0.63</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

**Table 3:** Mean image quality score of coronary arteries on images reconstructed with and without adaptive motion correction (AMC).

**References:** Diagnostic Radiology, Hiroshima University - Hiroshima/JP
Fig. 4: Comparison of the mean image quality scores of the coronary arteries on scans reconstructed with and without adaptive motion correction (AMC).

References: Diagnostic Radiology, Hiroshima University - Hiroshima/JP
A 57-year-old man with atrial fibrillation and heart rate of 92 bpm.

Adaptive motion correction (AMC) eliminates motion artifacts of the right coronary artery.

**Fig. 5:** Axial images of the middle right coronary artery in a 57-year-old male with atrial fibrillation and a heart rate of 92 bpm. (a) The image was reconstructed without adaptive motion correction (AMC). The image quality was rated as of limited diagnostic value (score 2). (b) The image was reconstructed with AMC. The image quality was rated as good (score 4).

**References:** Diagnostic Radiology, Hiroshima University - Hiroshima/JP

The mean overall quality scores for images reconstructed with and without AMC in different heart rate groups are shown in Table 4. The image quality scores in patients with heart rate of 75-114 bpm tended to be improved by AMC; in patients with a heart rate up to 74- or above 115 bpm they were not.
<table>
<thead>
<tr>
<th></th>
<th>Up to 74 bpm</th>
<th>75 - 94 bpm</th>
<th>95 - 114 bpm</th>
<th>Above 115 bpm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 9)</td>
<td>(n = 8)</td>
<td>(n = 5)</td>
<td>(n = 3)</td>
</tr>
<tr>
<td>non-AMC group</td>
<td>3.09</td>
<td>3.01</td>
<td>2.84</td>
<td>3.18</td>
</tr>
<tr>
<td>AMC group</td>
<td>3.13</td>
<td>3.19</td>
<td>3.08</td>
<td>3.23</td>
</tr>
<tr>
<td>p value</td>
<td>0.46</td>
<td>0.06</td>
<td>&lt; 0.01</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**Table 4**: Mean overall image quality scores for images reconstructed with and without adaptive motion correction (AMC) in different heart rate groups.

**References**: Diagnostic Radiology, Hiroshima University - Hiroshima/JP

**Images for this section:**
<table>
<thead>
<tr>
<th></th>
<th>RCA</th>
<th>LAD</th>
<th>LCX</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-AMC group</td>
<td>52.5 ± 12.2</td>
<td>40.9 ± 9.5</td>
<td>49.1 ± 19.4</td>
</tr>
<tr>
<td>AMC group</td>
<td>43.8 ± 9.2</td>
<td>39.8 ± 8.7</td>
<td>50.5 ± 21.6</td>
</tr>
<tr>
<td>$p$ value</td>
<td>&lt; 0.001</td>
<td>0.44</td>
<td>0.37</td>
</tr>
</tbody>
</table>

**Table 1:** Mean image noise (HU) in the perivascula r tissue of coronary arteries on images reconstructed with and without adaptive motion correction (AMC).

© Diagnostic Radiology, Hiroshima University - Hiroshima/JP
### Table 2: Qualitative assessment of the image quality.

<table>
<thead>
<tr>
<th></th>
<th>non-AMC group</th>
<th>AMC group</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segments evaluated</td>
<td>248</td>
<td>248</td>
<td></td>
</tr>
<tr>
<td>Diagnostic</td>
<td>197 (79.4%)</td>
<td>214 (86.3%)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Non-diagnostic</td>
<td>51 (20.6%)</td>
<td>34 (13.7%)</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

© Diagnostic Radiology, Hiroshima University - Hiroshima/JP
**Table 3**: Mean image quality score of coronary arteries on images reconstructed with and without adaptive motion correction (AMC).

© Diagnostic Radiology, Hiroshima University - Hiroshima/JP
Fig. 4: Comparison of the mean image quality scores of the coronary arteries on scans reconstructed with and without adaptive motion correction (AMC).

© Diagnostic Radiology, Hiroshima University - Hiroshima/JP
A 57-year-old man with atrial fibrillation and heart rate of 92 bpm.

Adaptive motion correction (AMC) eliminates motion artifacts of the right coronary artery.

Fig. 5: Axial images of the middle right coronary artery in a 57-year-old male with atrial fibrillation and a heart rate of 92 bpm. (a) The image was reconstructed without adaptive motion correction (AMC). The image quality was rated as of limited diagnostic value (score 2). (b) The image was reconstructed with AMC. The image quality was rated as good (score 4).

© Diagnostic Radiology, Hiroshima University - Hiroshima/JP
Table 4: Mean overall image quality scores for images reconstructed with and without adaptive motion correction (AMC) in different heart rate groups.

<table>
<thead>
<tr>
<th></th>
<th>Up to 74 bpm (n = 9)</th>
<th>75 - 94 bpm (n = 8)</th>
<th>95 - 114 bpm (n = 5)</th>
<th>Above 115 bpm (n = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-AMC group</td>
<td>3.09</td>
<td>3.01</td>
<td>2.84</td>
<td>3.18</td>
</tr>
<tr>
<td>AMC group</td>
<td>3.13</td>
<td>3.19</td>
<td>3.08</td>
<td>3.23</td>
</tr>
<tr>
<td>p value</td>
<td>0.46</td>
<td>0.06</td>
<td>&lt; 0.01</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Table 4: Mean overall image quality scores for images reconstructed with and without adaptive motion correction (AMC) in different heart rate groups.

© Diagnostic Radiology, Hiroshima University - Hiroshima/JP
Conclusion

AF, the most common type of arrhythmia, is often associated with structural heart disease. As patients with AF may present with symptoms that mimic CAD, the ability to detect its presence or absence is important for the treatment of patients with AF. However, high or irregular heartbeats may result in inappropriate data sampling and severe motion artifacts on coronary CTA images. AMC may eliminate motion artifacts and improve the image quality of coronary arteries in patients with AF and higher heart rates.

We found that the image quality of the RCA, but not the LAD and LCX, was significantly improved by AMC. In all cardiac phases, the motion velocity of the RCA is higher than of other segments. As motion shift of the RCA within the padding scan range is larger than of the LAD and LCX, AMC is more effective in the RCA than in any other segments.

AMC tended to improve the image quality scores in patients with a heart rate of 75-114 bpm, but not in patients with a heart rate up to 74 bpm or above 115 bpm. At a lower heart rate, the distance of coronary artery movement within the padding scan range might be small, rendering AMC less effective. On the other hand, at a higher heart rate, coronary artery movement might be larger and this may result in insufficient temporal resolution, even when AMC is applied.

In this study, 12 of 248 segments (4.8%) were deteriorated by AMC: the effect of AMC may also depend on the heart rate irregularity. Therefore, we recommend using the both images of coronary CTA reconstructed with and without AMC in clinical practice.

In conclusion, AMC eliminated motion artifacts and improved the image quality of the RCA, especially in patients with a heart rate of 75-114 bpm.

Personal information

Fuminari Tatsugami, MD
Department of Diagnostic Radiology, Hiroshima University
1-2-3 Kasumi, Minami-ku, Hiroshima 734-8551, Japan
References


