MDCT assessment of the Adamkiewicz artery with model-based iterative reconstruction

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Purpose

Identification of the Adamkiewicz artery is important in planning surgical or endovascular treatment of aortic diseases[1-3]. In spite of the advancement of multi-detector row computed tomography (MDCT) technology, non-invasive detection of Adamkiewicz artery using MDCT is still challenging[4-8]. The purpose of this study was to investigate if model based iterative reconstruction (MBIR) can improve visualization of the Adamkiewicz artery on MDCT in comparison with adaptive statistical iterative reconstruction (ASIR) and filtered back projection (FBP).
Methods and Materials

Patient population

This study was approved by the ethics committee at our institution. Written informed consent for participation in the study was obtained from all patients before CT examination. From March to April 2011, a total of 20 consecutive patients (18 men and 2 women; age 74±6.8, range 54-82 years) undergoing CT angiography for aortic aneurysm or aortic dissection were prospectively enrolled in the study.

CT data acquisition and reconstruction

All CT examinations were performed using a 64-detector-row CT system (Discovery CT750HD, GE healthcare, Milwaukee, Wis). Data were acquired with a tube voltage of 120 kV, a 0.5-s gantry rotation speed, a collimation of 64×0.5 mm, and a beam pitch of 0.984. Automatic exposure control was used to determine a tube current (noise index 10.00). Iopamidol with an iodine concentration of 370 mgI/mL (Iopamiron; Bayer-Schering, Berlin, Germany) was administered at a rate of 5ml/s with a total volume of 100ml using a double-head power injector (Dual Shot-Type GX; Nemoto-kyorindo, Tokyo, Japan) via a 20-gauge intravenous catheter placed in an antecubital vein. Image acquisition timing was determined using a bolus tracking system. The CT attenuation value was monitored in a ROI set in the descending aorta at the T10 level on the scout CT image. The trigger threshold was set at 250 Hounsfield units (HU) for the aortic region of interest (ROI). Ten seconds after the trigger, CT data acquisition was started. Data were acquired during a single breath-hold in the head-to-foot direction. The CT examination extended from the level of the sternal end of the clavicle to the groin.

The helical data were reconstructed in the axial plane with a 0.625-mm section thickness at 0.3-mm intervals and field of view of 150mm using FBP with standard kernel, ASIR with standard kernel and a blending factor of 50%, and MBIR. Data were then transferred to a workstation (Advantage Workstation VS4, GE healthcare, Milwaukee, Wis). The multiplanar reformation (MPR) images, including axial images with 0.6-mm thickness, sagittal images with 0.3mm thickness, and coronal images with 0.3mm thickness, were reconstructed.

Quantitative image analysis

Quantitative measurements were performed by a radiologist (J.N.). The three image datasets, reconstructed with FBP, ASIR, and MBIR in each patient, were displayed side by side with a preset soft-tissue window (window width, 400 HU; window level, 80HU).
We obtained mean CT attenuation values (in Hounsfield units) for the aorta and spinal cord by manually placing circular regions of interest (ROIs) (20mm and 10mm in diameter, respectively) at the same position on axial images with 0.6mm thickness (Fig. 1). The attenuation of the aortic lumen was recorded as the mean of three ROIs placed at the level of diaphragm, and 3cm above and below of it. The attenuation of the spinal cord was also recorded as the mean of measurements of three ROIs. Vessels and prominent artifacts, if any, were carefully avoided. It was difficult to precisely measure the attenuation value of the Adamkiewicz artery because of its small diameter. Instead, the degree of enhancement of the anterior spinal artery was obtained by segmenting the anterior spinal artery for 3cm on a sagittal MPR image of 0.3 mm thickness. To ensure consistency, the segmentation was performed three times, and mean value was calculated. For all measurements, the size, shape, and position of the ROIs were kept constant among the three reconstruction algorithms by applying a copy.

The signal-to-noise ratio of the aorta and the contrast-to-noise of the anterior spinal artery relative to the spinal cord were obtained by using the following equation:

\[
\text{SNR} = \frac{\text{mean attenuation of aorta}}{\text{SD of aorta}} \\
\text{CNR} = \frac{\{\text{mean attenuation of anterior spinal artery} - \text{mean attenuation of spinal cord}\}}{\text{SD of spinal cord}}
\]

SD: standard deviation

**Qualitative image analysis**

CT images were visually evaluated according to the degree of visualization of the Adamkiewicz artery using a four-point scale developed by Utsunomiya et al[9]. A rating of 1 = poor, indicating that no information could be obtained because the Adamkiewicz artery was not visualized. A rating of 2 = fair, indicating that the characteristic hairpin-curve appearance of the union of the Adamkiewicz artery and the anterior spinal artery was demonstrated, but the continuity of the intercostal artery was not delineated, providing insufficient information because the branching level of the innate origin of the Adamkiewicz artery was indeterminate. A rating of 3 = good, indicating that the continuity between the posterior branch of the intercostal artery or lumbar artery and the Adamkiewicz artery was partially obscured at the intervertebral foramen because of the thinness of the artery and its proximity to bone, but the branching level could be identified, providing sufficient useful information. A rating of 4 = excellent, indicating that the full length of the arterial course, starting from the origin of the intercostal artery or lumbar artery and then its posterior branch, proceeding to the Adamkiewicz artery, and continuing as far as the anterior spinal artery, was clearly traceable, providing very useful information prior to surgery.
The evaluation was performed by two radiologists who had not been given any information about the patients. The final results of visual evaluation were based on consensus between the two radiologists who had 14 and 13 years of experience with CT, respectively. We used an Adamkiewicz artery visualization scale of 3 or 4 to indicate assessable and a scale of 1 or 2 to indicate non-assessable. The level and the side from which the Adamkiewicz artery originated were also evaluated.

**Statistical analysis**

All data are reported as mean ± standard deviation. The quantitative evaluation results of the three different reconstructions were compared using the Mann-Whitney U test. The results of visual evaluation were compared using the Wilcoxon signed-rank test. Statistical analysis of these tests was performed with a statistical software package (SPSS, version 19.0; SPSS, Chicago, IL). A p-value <0.05 was considered statistically significant.
Fig. 1: ROI placements for measuring the CT attenuation values (mean and SD) of the aorta, the spinal cord, and the anterior spinal artery.

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Results

Quantitative image analysis

MBIR showed significantly improved SNR of the aorta (34.6±5.6) and CNR of the anterior spinal artery (3.97±1.98) in comparison with those by ASIR (p<0.001 and p=0.027) and FBP (p<0.001 and p=0.006) (Fig 2). While ASIR demonstrated increased SNR of the aorta compared with FBP (22.3±4.6 vs. 15.5±3.2, p<0.001 by Mann-Whitney U test), no difference was found for CNR of the anterior spinal artery (2.79±1.08 vs. 2.56±0.91, p=0.52).

Qualitative image analysis

The visualization score of the Adamkiewicz artery was significantly improved by using MBIR (2.80±1.00) in comparison with ASIR (2.15±1.14, p=0.009 by Wilcoxon signed ranks test) and FBP (2.05±1.10, p=0.004) (Table 1, 2). As a result, the level and the side from which the Adamkiewicz artery originated was identified in 80% (16/20) of the patients by using MBIR compared with 40% (8/20) and 30% (6/20) of the patients, respectively, by using ASIR and FBP. No significant difference was found between the scores by ASIR and FBP (p=0.16).

Representative cases

[Case 1]

Coronal MPR images (0.3mm thickness) of the Adamkiewicz artery and anterior spinal artery reconstructed using FBP, ASIR and MBIR in an 82-year-old man after endovascular aneurysm repair for the descending thoracic aortic aneurysm. Although identification of the Adamkiewicz artery is possible regardless of the reconstruction method, MBIR demonstrated the best visualization of the Adamkiewicz artery and anterior spinal artery due to the reduced noise (Fig. 3).

[Case 2]

Coronal maximum intensity projection images (3.8mm thickness) of the Adamkiewicz artery in an 74-year-old woman before endovascular aneurysm repair for an abdominal aortic aneurysm. Notice the improved contiguity of the Adamkiewicz artery from the intercostal artery on the MBIR image compared with FBP and ASIR (Fig. 4).

[Case 3]
Coronal MPR images (0.3mm thickness) of the Adamkiewicz artery reconstructed using FBP, ASIR and MBIR in an 77-year-old man with aortic arch aneurysm prior to surgical repair. MBIR was useful to determine the origin of the Adamkiewicz artery because visualization of the Adamkiewicz artery was suboptimal with FBP and ASIR especially at the intervertebral foramen (Fig. 5).
**Fig. 2:** Results of quantitative image analysis. MBIR showed significantly improved SNR of the aorta and CNR of the anterior spinal artery in comparison with those by ASIR and FBP.

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### Patients list

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<th>visualization score</th>
<th>Adamkiewicz artery's branching</th>
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*: Not identified

**Table 1:** 20 patients' age, sex, visualization score of three reconstruction methods, and the level and the side from which the Adamkiewicz artery originated.

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The visualization score

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<th>MBIR</th>
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<td>2.2 ± 1.1</td>
<td>2.8 ± 1.0</td>
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</table>

\[ p=\text{n.s} \quad p=0.009 \quad p=0.004 \]

Wilcoxon signed-rank test

**Table 2:** The visualization score of the Adamkiewicz artery.

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Fig. 3: [Case 1] 82-year-old man after endovascular aneurysm repair for the descending thoracic aortic aneurysm. Although identification of Adamkiewicz artery is possible regardless of the reconstruction method, MBIR demonstrated the best visualization of Adamkiewicz artery and anterior spinal artery due to the reduced noise.

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Fig. 4: [Case 2] 74-year-old woman before endovascular aneurysm repair for an abdominal aortic aneurysm. Notice the improved contiguity of Adamkiewicz artery from the intercostal artery on the MBIR image compared with FBP and ASIR.

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Fig. 5: [Case 3] 77-year-old man with aortic arch aneurysm prior to surgical repair. MBIR was useful to determine the level of Adamkiewicz artery origin because visualization of Adamkiewicz artery was suboptimal with FBP and ASIR especially at the intervertebral foramen.

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Conclusion

The new MBIR algorithm considerably improved the MDCT visualization of the Adamkiewicz artery when compared with ASIR and FBP. This reconstruction method may therefore be helpful in planning surgical or endovascular treatment of aortic diseases.
References


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