Image Quality and Absorbed Dose of Iterative Reconstruction in X-ray CT of Acute Ischemic Stroke

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Aims and objectives

In Japan, cerebrovascular disease is the fourth cause of death and the first cause of bedridden patients\(^1\). Recently, cerebral stroke has been under serious consideration due to the westernization of the diets and an increase in geriatric diseases. At present, cerebral stroke is still one of the most important diseases to control and prevent.

To establish a method for image-based diagnosis of cerebral stroke, the authors developed a phantom that could correctly evaluate disease detection by image-processing and that could visualize disease using X-ray CT imaging, while evaluating the imaging conditions\(^2\)-\(^7\). Visualization of acute cerebral infarction within 4.5 hours, after the development of cerebral infarction is essential because it is the time index used to judge whether thrombolytic therapy with use of rt-PA is applicable\(^8\). Traditionally, it has been difficult to visualize acute cerebral infarction from images produced by X-ray CT\(^9\). This study attempted to improve the contrast of acute cerebral infarction using Iterative Reconstruction in X-ray CT in order to achieve accurate visualization within the critical 4.5 hours period.

We have recently developed a phantom that simulates cerebral infarction and absorbed dose. We attempted to visualize acute-stage cerebral infarction by applying Adaptive Statistical Iterative Reconstruction (IR) images to this phantom using Iterative Reconstruction in X-ray CT.
Methods and materials

Development of phantom to cerebral infarction

Using a Cerebral Infarction phantom, which had been developed by the authors, an imitation disease with 34 HU was set to be visualized. The phantom, prepared with polyurethane resin and epoxy resin, the developed phantom mimicked the head shape and was composed of three sections: brain, cranium, and imitation disease. In the brain section, sphere-shaped imitation diseases (acute-stage cerebral infarction) of 30 mm in diameter were allocated in the middle cerebral artery region. The CT value of the brain section was 36 HU and that of the cranium was 900 HU. The imitation disease section was composed of two balls. The CT values of the two balls were 32, 34 HU reflected acute-stage cerebral infarction and their CT values were lower than that of the brain by 4 and 2 HU, respectively (Fig. 1, Fig. 2).

Development of cerebral infarction phantom of measurement

Using a cerebral infarction phantom of measurement, which had been developed by the authors, our phantom developed for dose measurement in the head (patented in Japan\(^{10}\)) precisely mimics the head shape and consists of brain and cranium sections with CT values of approximately 36 and 900-1500 HU, respectively (Fig. 3). The phantom consists of six slice cross sections (30 mm thickness) obtained from the orbital to the parietal region at an angle along the orbitomeatal line. Each slice cross section has 11 cavities for insertion of a thermoluminescent dosimeter (TLD) (Fig. 4, Fig. 5).

Imaging conditions

Using tube voltages at 120 kV, which were assumed to be used clinically in X-ray CT imaging (Discovery 750 HD in GE Corporation, Fig. 6) and a Tube current at 200, 400, 600 mA, and 1.0 s, Tube current time products at 200, 400, 600 mAs in images with a slice thickness of 10 mm were obtained.

Adaptive Statistical Iterative Reconstruction
Adaptive Statistical Iterative Reconstruction (ASiR) images were created using IR in X-ray CT from 10 to 100 % at every 10 % in blending ratio, under conditions of 120 kV, 200, 400, 600 mA, 1.0 s. Calculation of the contrast-to-noise ratio (CNR) values allowed us to evaluate the visualization of acute-stage cerebral infarction.

**Imaging evaluation**

The CNR value at the 30-mm-diameter imitation disease section in each ASiR image was obtained using the formula \(|\text{ROI}_M - \text{ROI}_B|)/\text{SD}_B\), and the ability to visualize acute-stage cerebral infarctions were evaluated. In the formula, \(\text{ROI}_M\) represents the CT value, obtained of circular ROI size of 170 mm\(^2\) at the center of the imitation disease section, \(\text{ROI}_B\) represents the CT value, obtained of circular ROI size 170 mm\(^2\) at the normal brain parenchyma section, and \(\text{SD}_B\) represents the standard deviation (SD) value of the normal brain parenchyma section. In addition, an image with a CNR value exceeding 1.0 was defined as the ability to visualize acute-stage cerebral infarction\(^{11}\).

**Dosimetry of absorbed dose**

In this study, the tube voltages with a 120 kV; the tube current time products were 100, 200, 300, 400, 500, 600, 700 and 800 mAs; and the scanning range was 120 mm from the orbitomeatal line to the parietal region. The dose was measured three times using TLD (TLD element; MSO-S, TLD Reader; TD-1000, in TORECK Corporation), and the absorbed dose was obtained from the average.
### Images for this section:

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Data are in wt %

**Fig. 1:** Elemental compositions of the X-ray CT phantom to evaluate cerebral stroke.

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Fig. 2: Plans and Photograph for the X-ray CT phantom to evaluate cerebral stroke. The phantom was prepared to have a cranium, a composition and a size similar to those of the brain section and the acute cerebral stroke section.

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<td>0.00</td>
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<td>5.56</td>
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</table>

Data are wt %. 
**Fig. 3:** Elemental compositions of the X-ray CT phantom of measurement to evaluate cerebral stroke.

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**Fig. 4:** Plans and Photograph for the X-ray CT phantom of measurement to evaluate cerebral stroke. The phantom was prepared to have a cranium, a composition and a size similar to those of the brain section.

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**Fig. 5:** Slice cross section (A to F cross section) of the X-ray CT phantom of measurement to evaluate cerebral stroke.

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Fig. 6: External appearance of X-ray CT apparatus used in this experiment. Discovery 750 HD in GE Corporation.

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Results

IR images

Fig. 7, Fig. 8, and Fig. 9 shows the simulation results of IR images and the simulation results of each Adaptive Statistical Iterative Reconstruction images. The CNR were with a slice thickness of 10 mm greater than 1.0, which we defined as the ability to visualize acute-stage cerebral infarction, obtained at 70 % under 200 mA, at 30 % under 400 mA, and at 20 % under 600 mA (Fig. 10, Fig. 11). These CNR values were greater than 1.0, which was defined as the ability to visualize acute-stage cerebral infarctions by the authors. In this study, by using IR images, and Adaptive Statistical Iterative Reconstruction images noise could be reduced while maintaining contrast at a specified level.

Absorbed dose

Fig. 12 shows the simulation results of the average of the measured values of D slice cross-section has been graphed. Absorbed dose were obtained at 13.18 mGy under 200 mA, at 24.96 mGy under 400 mA, and at 37.79 mGy under 600 mA.

Compared with 120 kV, 400 mA (routine image), the absorbed dose could be reduced by approximately 50 % at 120 kV, 200 mA. If an absorbed dose of approximately 1.5 times that at 120 kV, 600 mA was deemed acceptable, the contrast was significantly improved in IR in X-ray CT and effectively detected acute-stage cerebral infarction.
Fig. 7: Adaptive Statistical Iterative Reconstruction images from 0 to 90 % obtained at 120 kV, 200mA, with of 10 mm slice thickness.

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Fig. 8: Adaptive Statistical Iterative Reconstruction images from 0 to 90 % obtained at 120 kV, 400 mA, with a 10 mm slice thickness.

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Fig. 9: Adaptive Statistical Iterative Reconstruction images from 0 to 90 % obtained at 120 kV, 600mA, with of 10 mm slice thickness.

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<table>
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<th>Blending ratio</th>
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<tr>
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<td>ASiR (20%)</td>
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<td>ASiR (30%)</td>
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<td>ASiR (50%)</td>
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<td>ASiR (100%)</td>
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**Fig. 10:** CNR under each Adaptive Statistical Iterative Reconstruction condition.

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Fig. 11: Comparison of routine condition (400mAs) and image of Adaptive Statistical Iterative Reconstruction (Blending ratio 70 %).

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Fig. 12: Absorbed dose using the average value of TLD of D slice cross section, obtained of 10mm slice thickness.

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Conclusion

We were able to detect acute ischemic stroke at its early stage by using Iterative Reconstruction in X-ray CT to apply Adaptive Statistical Iterative Reconstruction imaging to a phantom. The CNR values of ASiR images at blending ratio of between 20 and 70% were significantly higher. IR in CT images could be used clinically to judge whether thrombolytic therapy with the use of rt-PA is applicable to acute-stage cerebral infarction. Our dose measurement for visualizing acute-stage cerebral infarction revealed that the dose could be reduced with Iterative Reconstruction in CT compared with CT at 120 kV, 400 mA (routine image). Therefore, optimal conditions for visualizing acute-stage cerebral infarction were achievable.

Acknowledgments

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Images for this section:

Fig. 13: first author

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References


