Comparison of aortic enhancement in dynamic MR imaging using LAVA sequence with fluoroscopic triggering among three different injection rates of Gd-EOB-DTPA

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Purpose

Gadoxetic acid (Gd-EOB-DTPA) is a hepatocyte specific contrast agent. It also distributes into the extracellular fluid space just after injection and it can assess the vascularity of the lesion by dynamic contrast enhanced MRI (DCE-MRI) [1, 2].

The arterial enhancement in Gd-EOB-DTPA-enhanced dynamic MRI is comparable to Gd-DTPA [3, 4]. In animal models, a lower injection rate can compensate for the lower injection volume by stretching the bolus without decreasing the peak aortic enhancement in Gd-EOB-DTPA-enhanced dynamic MRI. It was reported that an injection rate of 1 ml/s showed better arterial enhancement compared with 2 ml/s.

In DCE-MRI using a 3T MR unit, a lower injection rate of Gd-EOB-DTPA (1.5 ml/s) provided good image quality compared with a rate of 3ml/s [Fujinaga Y et al. ACAR 2011].

Dilution method of Gd-EOB-DTPA-enhanced dynamic MRI provided better image quality in comparison with non-dilution methods [6]. However, the dilution method is off-label use. Recently, we can simultaneously administer a contrast medium and saline using a commercially available power injector. It may provide a lower injection rate similar to the dilution method.

LAVA (Liver acquisition with acceleration volume acquisition) is a multi-phase imaging method with high temporal and spatial resolution, large coverage, uniform fat suppression, and refined signal-to-noise ratio [7]. We routinely use 3D LAVA sequence for DCE-MRI of the liver with fluoroscopic triggering.

The purpose of this study is to elucidate the injection rate of Gd-EOB-DTPA best suited for arterial phase of DCE-MRI of the liver with fluoroscopic triggering LAVA sequence.
Methods and Materials

Patients

Sixty-six patients (39 men and 27 women; 28-85, average 66 years) underwent dynamic MRI of the liver. Patients were divided into three groups according the injection rates of Gd-EOB-DTPA (Table 1).

MRI

MRI was performed in all patients using a superconducting magnet unit of 1.5 T with an eight-channel phased array coil. For dynamic MRI, a parallel 3D spoiled GRE sequence (LAVA, Liver Acquisition with Volume Acceleration; GE Healthcare's 15.0M4B version) was used. Scanning at an arterial phase was manually started under fluoroscopic triggering. During the injection, fluoroscopy was used to make a coronal image showing the thoracic aorta. When the contrast medium reached the thoracic aorta, scanning was started. Axial images of 4 mm-thickness and 2 mm-overlap covering the entire liver were obtained at pre-contrast, arterial, portal venous, equilibrium and hepatobiliary phases. Pre-contrast and arterial phase images were subjected to the signal intensity measurement. MR sequence was summarized in Table 2.

Injection of contrast medium

In all three groups, 0.025 mmol/kg body weight of Gd-EOB-DTPA (0.1 ml/kg body weight) was administered through a 22G IV cannula inserted in the antecubital vein using a power injector with dual-head configuration. Following three injection rates of Gd-EOB-DTPA were adopted (Fig. 1).

Group A: 2 ml/s of Gd-EOB-DTPA injection followed by 20 ml of saline injection at a rate of 2 ml/s. (22 patients)

Group B: 1 ml/s of Gd-EOB-DTPA injection followed by 20 ml of saline injection at a rate of 1 ml/s. (21 patients)

Group C: 0.5 ml/s of Gd-EOB-DTPA injection with simultaneous saline injection of the same volume at a rate of 0.5 ml/s, followed by saline injection at a rate of 1 ml/s up to 20 ml of saline in total. (23 patients)
Fig. 1: Three different injection rates of Gd-EOB-DTPA. In a case of 60 Kg of body weight.

References: Department of Radiology, Takaoka City Hospital/ Japan 2012

**Signal intensity measurement**

Signal intensities (SI) of the aorta, the portal vein and the spinodorsal muscle (muscle) were measured in pre-contrast (pre) and arterial phases (post). A circular region of interest (ROI) of 50 mm$^2$ was set in the aorta at the craniocaudal center of the scanning range (Fig. 2). ROI was also set in the main portal vein. ROI in the spinodorsal muscle was set in the same slice of the aorta or the portal vein. To compare the enhancement of the aorta and the portal vein, following two indices were calculated;

$$SIR1 = \frac{SI_{post} - SI_{pre}}{SI_{pre}}$$

$$SIR2 = \frac{SI_{post} - SI_{pre}}{SI_{muscle \, pre-contrast}}$$
Fig. 2: Pre-contrast (left) and arterial phase (right) images. Regions of interest (circles) were set on the aorta, portal vein and the spinodorsal muscle.

References: Department of Radiology, Takaoka City Hospital/ Japan 2012

Timing of the arterial phase image

Ratios in which the arterial phase scanning obtained late arterial phase images (demonstrating substantial portal venous, slight parenchymal, and no hepatic venous enhancement) was also calculated to evaluate the optimal timing of the arterial phase. Signal intensity of the hepatic vein was visually compared with that of the surrounding hepatic parenchyma.

Statistic analysis

The Kruskal-Wallis test was used to compare the differences in SIRs among the three groups. The Mann-Whitney U-test was used to compare the difference between two groups. Comparison of the scanning timing was performed by the chi-square test.
Table 1: Summary of patients. There were no significant differences in gender, age and body weight of the patients.

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<table>
<thead>
<tr>
<th>Group</th>
<th>Injection Rate</th>
<th>Gender (M / F)</th>
<th>Age (mean) yrs</th>
<th>Body Weight (mean) kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>2.0</td>
<td>13 / 9</td>
<td>36 - 83 (66.3)</td>
<td>45.0 - 85.0 (59.1)</td>
</tr>
<tr>
<td>Group B</td>
<td>1.0</td>
<td>11 / 10</td>
<td>33 - 85 (66.9)</td>
<td>31.9 - 79.3 (56.6)</td>
</tr>
<tr>
<td>Group C</td>
<td>0.5</td>
<td>15 / 8</td>
<td>28 - 84 (64.7)</td>
<td>40.0 - 85.0 (61.2)</td>
</tr>
</tbody>
</table>
### Summary of MR sequence

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR / TE / TI</td>
<td>4.68 / 2.08 / 7 msec</td>
</tr>
<tr>
<td>Flip angle</td>
<td>15</td>
</tr>
<tr>
<td>Slice thickness</td>
<td>4 mm</td>
</tr>
<tr>
<td>Spacing</td>
<td>2 mm</td>
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<tr>
<td>Reconstruction diameter</td>
<td>360 mm</td>
</tr>
<tr>
<td>Matrix</td>
<td>320 x 192</td>
</tr>
<tr>
<td>Echo Train Length</td>
<td>1</td>
</tr>
<tr>
<td>Time delay to start of scanning</td>
<td>11 sec</td>
</tr>
<tr>
<td>k-space trajectory</td>
<td>sequential order</td>
</tr>
</tbody>
</table>

**Table 2:** Summary of MR sequence.

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Fig. 1: Three different injection rates of Gd-EOB-DTPA. In a case of 60 Kg of body weight.

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**Fig. 2:** Pre-contrast (left) and arterial phase (right) images. Regions of interest (circles) were set on the aorta, portal vein and the spinodorsal muscle.

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Results

SIR1 of the aorta were 3.09 +/- 1.25 (mean +/- SD) in Group A, 3.20 +/- 1.12 in Group B and 3.89 +/- 1.30 in Group C (p=0.11). SIR2 of the aorta were 2.87 +/- 1.33, 2.94 +/- 1.13 and 3.74 +/- 1.54 in Group A, B and C, respectively (p=0.04). SIR1 and SIR2 of the aorta in Group C were higher than those in Group A (p=0.04 and p=0.02, respectively, Fig. 3 and 4).

Fig. 3: SIR1 of the aorta. SIR1 of the aorta were 3.09 +/- 1.25 (mean +/- SD) in Group A, 3.20 +/- 1.12 in Group B and 3.89 +/- 1.30 in Group C (p=0.11 by Kruskal-Wallis test). SIR1 of the aorta in Group C was higher than that in Group A (p=0.04 by Mann-Whitney U-test).

References: Department of Radiology, Takaoka City Hospital/ Japan 2012
Fig. 4: SIR2 of the aorta. SIR2 of the aorta were 2.87 +/- 1.33 (mean +/- SD) in Group A, 2.94 +/- 1.13 in Group B and 3.74 +/- 1.54 in Group C (p=0.04 by Kruskal-Wallis test). SIR2 of the aorta in Group C was higher than that in Group A (p=0.02 by Mann-Whitney U-test).

References: Department of Radiology, Takaoka City Hospital/ Japan 2012
**Fig. 5:** Arterial phase images of Group A (injection rate 2.0 ml/s, left) and Group C (injection rate 0.5ml/s, right) at the level where the signal intensity of the aorta was measured.

**References:** Department of Radiology, Takaoka City Hospital/ Japan 2012

SIR1 of the portal vein were 2.77 +/- 0.71, 2.92 +/- 0.97 and 2.97 +/- 0.89 in Group A, B and C, respectively (p=0.86, Fig. 5). SIR2 of the portal vein were 3.21 +/- 0.76, 3.20 +/- 0.97 and 3.49 +/- 1.79 in Group A, B and C, respectively (p=0.97, Fig. 6).
Fig. 6: SIR1 of the portal vein. SIR1 of the portal vein were 2.77 +/- 0.71 (mean +/- SD) in Group A, 2.92 +/- 0.97 in Group B and 2.97 +/- 0.89 in Group C (p=0.86 by Kruskal-Wallis test).

References: Department of Radiology, Takaoka City Hospital/ Japan 2012
Fig. 7: SIR2 of the portal vein. SIR2 of the portal vein were 3.21 +/- 0.76 (mean +/- SD) in Group A, 3.20 +/- 0.97 in Group B and 3.49 +/- 1.79 in Group C (p=0.97 by Kruskal-Wallis test).

References: Department of Radiology, Takaoka City Hospital/ Japan 2012

In all patients, the portal vein showed contrast enhancement suggesting that there were no cases of too early scan timing. The hepatic vein was hypointense to the surrounding hepatic parenchyma in 11 of 22 patients in Group A, 13 of 21 in Group B and 16 of 23 in Group C (p=0.52, Table 3, Fig. 8).
Fig. 8: Both are arterial phase images of Group C (injection rate 0.5 ml/s). In the left image, the hepatic vein (arrow) was hypointense to the surrounding liver suggesting an optimal late arterial phase. Meanwhile, in the right image, the hepatic vein was hyperintense to the surrounding liver suggesting that the scan timing was too late.

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Fig. 3: SIR1 of the aorta. SIR1 of the aorta were 3.09 +/- 1.25 (mean +/- SD) in Group A, 3.20 +/- 1.12 in Group B and 3.89 +/- 1.30 in Group C (p=0.11 by Kruskal-Wallis test). SIR1 of the aorta in Group C was higher than that in Group A (p=0.04 by Mann-Whitney U-test).

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Fig. 4: SIR2 of the aorta. SIR2 of the aorta were 2.87 +/- 1.33 (mean +/- SD) in Group A, 2.94 +/- 1.13 in Group B and 3.74 +/- 1.54 in Group C (p=0.04 by Kruskal-Wallis test). SIR2 of the aorta in Group C was higher than that in Group A (p=0.02 by Mann-Whitney U-test).

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**Fig. 6:** SIR1 of the portal vein. SIR1 of the portal vein were 2.77 +/- 0.71 (mean +/- SD) in Group A, 2.92 +/- 0.97 in Group B and 2.97 +/- 0.89 in Group C (p=0.86 by Kruskal-Wallis test).

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**Fig. 5:** Arterial phase images of Group A (injection rate 2.0 ml/s, left) and Group C (injection rate 0.5ml/s, right) at the level where the signal intensity of the aorta was measured.

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### Signal intensity of hepatic vein

<table>
<thead>
<tr>
<th>Group</th>
<th>Hypo</th>
<th>Iso</th>
<th>Hyper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>11</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Group B</td>
<td>13</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Group C</td>
<td>16</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Hypo, Iso and Hyper mean that the signal intensities of the hepatic vein were hypointense, isointense and hyperintense to the surrounding hepatic parenchyma, respectively.

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**Table 3**: Signal intensity of the hepatic vein at an arterial phase of dynamic MRI.

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Conclusion

- The aortic enhancement in Group C (0.5 ml/s) was higher than Group A (2 ml/s).
- There were no significant differences among three groups in the portal venous enhancement at a late arterial phase.
- There were no significant differences among three groups in the ratio of optimal scan timing at a late arterial phase.

The injection rate of 0.5 ml/s of Gd-EOB-DTPA was best suited for arterial phase of dynamic MRI of the liver with fluoroscopic triggering LAVA sequence.

- A slow flow has the advantage of stretching the bolus of a contrast medium. If the bolus is too narrow, there is a possibility that the central k-space of the imaging sequence was incorrectly filled.
- From another perspective, a stretched bolus is increasing the probability to achieve proper timing of an arterial phase of DCE-MRI for the liver. Although there were no significant differences in this study, a stretched bolus might facilitate to start scanning under fluoroscopic triggering.

Limitations:

- Small number of patients.
- The ratio of optimal scan timing was not satisfactory, and it tended to be slightly late. Triggering at the thoracic aorta might not be a suboptimal position.
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References