Pretreatment CT Assessment of Patients with Hepatocellular Carcinoma: Optimization of Bolus Tracking Technique for Tumor Diagnosis and Visualization of Artery

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Authors: T. Yoshikawa¹, N. Negi¹, Y. Ohno¹, K. Sofue¹, N. Sugihara², K. Kagawa¹, Y. Takemoto¹, H. Koyama³, K. Sugimura¹, K. Kagawa¹, Y. Takemoto¹, H. Koyama³, K. Sugimura¹, K. Kagawa¹, Y. Takemoto¹, H. Koyama³, K. Sugimura¹
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Aims and objectives

INTRODUCTION

• The evaluation of arterial blood supply (i.e. vascularity or vascular pattern) is an essential step for diagnosis of various diffuse and focal liver diseases, and it is usually performed by multi-phasic contrast-enhanced CT.
• On the other hand, recent developments of CT systems have made volume-rendering vascular images the modality of choice for preoperative vascular assessments.
• To satisfy both purposes, dual-arterial multi-phasic scans with accurate bolus tracking technique are required.
• Optimization of bolus tracking technique is an urgent problem because high speed scan techniques are already available in the latest CT systems with 64 or more detector rows which can easily mass the contrast bolus.
• However, there are a few previous reports on this issue and there is no previous report on optimization of this technique considering both tumor conspicuity and accurate and efficient rendering of vascular images.

PURPOSE

• The purpose of this study was to optimize bolus tracking in dual-arterial CT for HCC diagnosis and 3D-arteriogram rendering.
Methods and materials

Patients

- 157 patients (male: 126, female: 31, mean: 64.7 years, LC: 66, CH: 91) who were suspected of having HCC (n=136, mean diameter of maximal lesion: 65.8 mm) and underwent dual-arterial contrast-enhanced CT were enrolled.
- The patients were randomly divided into the 3 groups below:

<table>
<thead>
<tr>
<th>Group</th>
<th>Bolus tracking trigger threshold (HU)</th>
<th>Scan delay after trigger (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>200</td>
<td>5</td>
</tr>
</tbody>
</table>

Imaging & Contrast Techniques

- CT examination was performed by using a 64-detector row CT systems (Aquilion 64; Toshiba Medical Systems Co., Otawara, Japan) with the following parameters: 64×0.5 mm detector collimation, reconstructed to transverse slices with a thickness of 5mm, 0.5 sec/gantry rotation, 120 kVp, and 0.94 beam pitch. The tube current was set by automated exposure control (noise level: 10).
- Each subject was first examined with unenhanced CT, and this was followed by the injection of iodinated contrast medium with a power injector.
- Injection dose was 600 mg iodine per kg of body weight and duration was fixed at 25 seconds, hence the injection rate depended on the patient’s body weight.
- No saline chaser was administered.

Bolus Tracking Technique

- A bolus tracking program was used to optimize the scanning delay for dual-arterial scans.
- The trigger point was placed at the abdominal aorta at the level of the celiac axis and the trigger threshold was set at an CT number of more than 100 or 200 Hounsfield units (HU).
- The scan delays were set at 5 or 10 seconds after the trigger and dual-arterial dynamic images were obtained serially during a single breathhold.
- Portal- and delayed-phase images were also obtained 70 and 150 seconds after injection.
- Maximum intensity projection and volume rendering images of abdominal arteries were reconstructed using early arterial-phase (EAP) images.
Patients' Backgrounds & Temporal Parameters

Parameters recorded

- Demographic features of the patients
- Monitoring duration for triggering
- Total scan delay (from the beginning of CM injection to beginning of early arterial phase scan)
- Manipulation time for 3D-arteriogram rendering (seconds)
- The values were compared among the groups.

Quantitative Analysis

- The quantitative analysis was conducted by one observer on axial images using ROI measurements.
- HU values in aorta, liver, and portal vein (PV) were measured on precontrast and EAP images.
- Increases in HU values of aorta, liver, and PV were calculated.
- For evaluation of enhancement in the artery, differences in HU values (aorta-to-liver and PV-to-liver) were measured on EAP images.
- For evaluation of tumor enhancement, HU differences between HCC and normal liver were measured on late arterial phase (LAP) images.
- The ROIs were drawn as large as possible, while vessels were avoided as much as possible in the liver.
- The values were compared among the groups.

Qualitative Analysis

- For the qualitative analysis, two radiologists independently assessed visualization of upper abdominal arteries (hepatic, gastroduodenal, splenic, and superior mesenteric) using a 4-point scale (4, more than two thirds of the artery was clearly traceable; 3, more than one third was clearly traceable; 2, less than one-thirds was traceable; 1, artery was undetectable) on EAP images.
- Liver enhancement (a total score of slight hepatic parenchymal enhancement, excellent arterial enhancement, heterogeneous PV enhancement, and no hepatic vein enhancement) and HCC conspicuity (4, obviously present; 3: possibly present; 2: equivocal; 1; undetectable) were assessed using the 4-point scales on LAP images.
- Values were compared among the groups.
- Observers’ agreement for arterial anatomy was assessed using Michels classification.
Results

The results of quantitative assessments are shown on figs.1-3.
The results of qualitative assessments are shown on figs.4-5.
The representative cases are shown on figs.6-8.
Sample CTA images and their manipulation times are shown on figs. 9-11.

Patients' backgrounds

- There was no significant difference.

Temporal parameters

- Total scan delay and manipulation time were significantly shortest in group A (fig.1).
- Monitoring duration was significantly longest in group C (fig.1).

Early arterial phase

- HU increases in PV and liver, and HU difference between PV and liver, were significantly lowest in group A (fig.2).
- Visualization scores for hepatic artery were significantly highest in group A (fig.4).
- Readers' agreements for arterial anatomy were 100%.

Late arterial phase

- HU difference between HCC and liver had a trend toward highest in group A (fig.3).
- HCC conspicuity were significantly highest in group A (fig.5).
## RESULTS

### Backgrounds & Temporal Parameters

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=53)</th>
<th>Group B (n=50)</th>
<th>Group C (n=54)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M, F)</td>
<td>M:41, F:12</td>
<td>M:40, F:10</td>
<td>M:45, F:9</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Age</td>
<td>66.9 ± 11.9</td>
<td>63.8 ± 12.4</td>
<td>63.6 ± 12.7</td>
<td>0.31</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.7±8.1</td>
<td>163.3±9.7</td>
<td>164.7±9.3</td>
<td>0.72</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>62.9±13.0</td>
<td>60.7±10.4</td>
<td>61.4±13.2</td>
<td>0.65</td>
</tr>
<tr>
<td>Liver diseases</td>
<td>HCC: 39, LC:17, CH: 31</td>
<td>HCC: 45, LC:28, CH:28</td>
<td>HCC: 52, LC:21, CH:32</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Monitoring duration (s)</td>
<td>6.8 ± 3.5</td>
<td>6.7±3.6</td>
<td>9.5 ± 3.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total scan delay (s) for EAP</td>
<td>21.8±3.9</td>
<td>30.7±28.7</td>
<td>24.5 ± 3.6</td>
<td>0.023</td>
</tr>
<tr>
<td>3D manipulation time (s)</td>
<td>222.7±81.8</td>
<td>366.5±136.1</td>
<td>266.2 ± 71.1</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

- Total scan delay and manipulation time were significantly shortest in group A.
- Monitoring duration was significantly longest in group C.

CH: chronic hepatitis, EAP: early arterial phase, HCC: hepatocellular carcinoma, LC: cirrhosis

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**Fig. 1**

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### RESULTS: Quantitative

**HU Increases of Vessel & Liver on EAP**

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aorta</td>
<td>351.1 ± 209.4</td>
<td>340.2 ± 72.5</td>
<td>339.2 ± 61.7</td>
<td>0.88</td>
</tr>
<tr>
<td>PV</td>
<td>12.9 ± 12.9</td>
<td>66.3 ± 84.6</td>
<td>27.6 ± 21.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Liver</td>
<td>4.5 ± 5.2</td>
<td>11.0 ± 11.0</td>
<td>5.4 ± 4.7</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

• HU increases in the PV and liver were significantly lowest in group A.

### Vessel-to-Liver Contrasts on EAP

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aorta-Liver</td>
<td>335.7 ± 208.3</td>
<td>317.2 ± 75.1</td>
<td>323.7 ± 60.2</td>
<td>0.77</td>
</tr>
<tr>
<td>PV-Liver</td>
<td>-6.5 ± 18.6</td>
<td>38.5 ± 84.1</td>
<td>8.7 ± 20.9</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

• HU difference between PV and liver was significantly lowest in group A.

EAP: early arterial phase, PV: portal vein

Fig. 2

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### RESULTS: Quantitative

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=39)</th>
<th>Group B (n=45)</th>
<th>Group C (n=52)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCC Diameter (mm)</td>
<td>57.7±40.4</td>
<td>64.4±47.3</td>
<td>75.7±48.5</td>
<td>0.18</td>
</tr>
<tr>
<td>HCC-Liver HU difference</td>
<td>37.3±26.7</td>
<td>28.4±31.5</td>
<td>36.7±28.7</td>
<td>0.29</td>
</tr>
</tbody>
</table>

- HCC-Liver HU difference had a trend toward highest in group A.
- HCC: hepatocellular carcinoma, LAP: late arterial phase images

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**Fig. 3**

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## RESULTS: Qualitative

### Arterial visualization on EAP

<table>
<thead>
<tr>
<th>Observer 1</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatic</td>
<td>3.9 ± 0.3</td>
<td>3.8 ± 0.4</td>
<td>3.6 ± 0.5</td>
<td>0.002</td>
</tr>
<tr>
<td>Gastro-duodenal</td>
<td>3.1 ± 0.6</td>
<td>2.9 ± 0.8</td>
<td>2.9 ± 0.8</td>
<td>0.43</td>
</tr>
<tr>
<td>Splenic</td>
<td>3.9 ± 0.4</td>
<td>4.0 ± 0.1</td>
<td>3.9 ± 0.4</td>
<td>0.21</td>
</tr>
<tr>
<td>Superior mesenteric</td>
<td>3.8 ± 0.5</td>
<td>3.9 ± 0.3</td>
<td>3.8 ± 0.4</td>
<td>0.59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observer 2</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatic</td>
<td>3.9 ± 0.3</td>
<td>3.7 ± 0.4</td>
<td>3.6 ± 0.8</td>
<td>0.006</td>
</tr>
<tr>
<td>Gastro-duodenal</td>
<td>3.0 ± 0.6</td>
<td>2.8 ± 0.8</td>
<td>3.0 ± 0.9</td>
<td>0.43</td>
</tr>
<tr>
<td>Splenic</td>
<td>3.9 ± 0.4</td>
<td>3.9 ± 0.3</td>
<td>3.8 ± 0.4</td>
<td>0.58</td>
</tr>
<tr>
<td>Superior mesenteric</td>
<td>3.7 ± 0.5</td>
<td>3.9 ± 0.3</td>
<td>3.8 ± 0.4</td>
<td>0.08</td>
</tr>
</tbody>
</table>

*Scores for hepatic artery were significantly highest in group A.*

---

**Fig. 4**

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RESULTS: Qualitative

Liver Enhancements on LAP

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer 1</td>
<td>3.5 ± 0.7</td>
<td>2.5 ± 1.0</td>
<td>2.2 ± 1.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Observer 2</td>
<td>3.5 ± 0.7</td>
<td>2.6 ± 0.9</td>
<td>3.0 ± 0.8</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

- Subjective liver enhancement score was significantly highest in group A.

HCC-to-Liver Contrasts on LAP

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=39)</th>
<th>Group B (n=45)</th>
<th>Group C (n=52)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer 1</td>
<td>3.4 ± 0.7</td>
<td>3.1 ± 0.7</td>
<td>3.0 ± 0.8</td>
<td>0.02</td>
</tr>
<tr>
<td>Observer 2</td>
<td>3.4 ± 0.6</td>
<td>3.1 ± 0.7</td>
<td>3.2 ± 0.7</td>
<td>0.16</td>
</tr>
</tbody>
</table>

- Conspicuity of HCC was significantly highest in group A in one observer and a trend toward highest in another.

HCC: hepatocellular carcinoma, LAP: late arterial phase images

Fig. 5

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CT-Angiography

Group A (100HU • 5s)  Group B (100HU • 10s)

• Visualization of arteries are poorer in group B technique because of enhancements in PV and organs.

Fig. 6

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CT-Angiography

Group A (100HU · 5s)  Group C (200HU · 5s)

- Visualization of arteries are poorer in group C technique because of enhancements in PV and organs.

Fig. 7

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Late Arterial Phase: HCC

Group A (100HU • 5s)  Group B (100HU • 10s)

- HCC conspicuity is higher in group A technique because of lower enhancement in the liver.

Fig. 8

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Fig. 9

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3D Manipulation Times: Group B

Fig. 10

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Fig. 11

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Conclusion

DISCUSSION

- Our results showed that bolus tracking with lower threshold and shorter delay makes volume-rendering of arteries easier and visualization of them better possibly due to stingy enhancement of the organs and PV.
- Also this parameter setting increased HCC-liver contrast and conspicuity.

Limitations

- The numbers of patients with HCC were relatively small.
- We only evaluated limited trigger conditions and liver diseases.
- Further studies with larger population separately for various diffuse or focal liver diseases are needed to confirm our results.

CONCLUSION

- Bolus tracking with smaller threshold HU and shorter delay decreases PV and liver enhancement, and makes arterial visualization better and easier, and improves HCC conspicuity.
References