Optimization of Bolus Tracking Technique in Abdominal Dual-Arterial Multi-Phasic CT for Arteriography and Tumor Diagnosis

Poster No.: C-1332
Congress: ECR 2014
Type: Scientific Exhibit
Authors: N. Negi\textsuperscript{1}, T. Yoshikawa\textsuperscript{1}, Y. Ohno\textsuperscript{1}, N. Kanata\textsuperscript{1}, K. Sofue\textsuperscript{1}, K. Kagawa\textsuperscript{1}, N. Sugihara\textsuperscript{2}, T. Murakami\textsuperscript{1}, K. Sugimura\textsuperscript{1}, \textsuperscript{1}Kobe/JP, \textsuperscript{2}Ohtawara/JP
Keywords: Cancer, Technology assessment, Contrast agent-intravenous, CT-Angiography, CT, Pancreas, Liver, Abdomen
DOI: 10.1594/ecr2014/C-1332

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Aims and objectives

INTRODUCTION

The evaluation of arterial blood supply (i.e. vascularity or vascular pattern) in tumor is an essential step for diagnosis of various abdominal malignancies such as hepatocellular carcinoma (HCC) and pancreatic cancer (PC), and it is usually performed by multi-phasic contrast-enhanced CT.

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 have became available in the latest CT systems with 64 or more detector rows.

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 technique in abdominal dual-arterial phasic CT.

Methods and materials

Patients

153 patients (male:113, female:40, mean age: 65.8 years) suspected of having abdominal malignancies underwent dual-arterial multi-phasic CT.

The patients were randomly divided into 3 groups;

- Group A: trigger threshold: 100HU, scan delay after trigger: 5 seconds
- Group B: trigger threshold: 100HU, scan delay after trigger: 10 seconds
- Group C: trigger threshold: 200HU, scan delay after trigger: 5 seconds
**Imaging & Contrast Techniques**

CT examination was performed by using a 64-detector row CT systems (Aquilion 64; Toshiba Medical Systems Co.) 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**

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 images.

**Backgrounds & Temporal Parameters**

Demographic features, monitoring duration for triggering, total scan delay (between the beginning of CM injection to beginning of early arterial phase scan), manipulation time for 3D-arteriogram (seconds) were recorded.

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, pancreas, and portal vein (PV) were measured on precontrast and early phase images (EAP).

Increases in HU values of aorta, liver, pancreas, and portal vein were calculated.

For evaluation of contrast of artery, differences in HU values (aorta-to-liver, aorta-to-pancreas, portal vein-to-liver, portal vein-to-pancreas) were measured on EAP.

For evaluation of tumor contrast, HU differences between HCC (n=51) and normal liver, and PC (n=39) and normal pancreas were measured on late arterial phase images (LAP).

The ROIs were drawn as large as possible, while vessels were avoided as much as possible in the liver and pancreas.

The values were statistically compared among the groups.

**Qualitative Analysis**

For the qualitative analysis, two radiologists independently assessed visualization of perihepatic and peripancreatic (hepatic, gastroduodenal, splenic, and superior mesenteric) arteries 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, presence of the artery was doubtful) on EAP.

Liver and pancreas enhancement and HCC and PC conspicuities were assessed using a 4-point scale (4, obviously present; 3: possibly present; 2: equivocal; 1; undetectable) on LAP.

Values were compared among the groups.

Interobserver agreements were analyzed by means of Kappa statistics.

Observers' agreement for arterial anatomy was assessed using Michels classification.

**Results**

**Backgrounds & Temporal Parameters**

Monitoring duration, total scan delay, and manipulation time were significantly smallest in group A (fig. 1).

The results of quantitative and qualitative assessments are shown in figs 2-4 and figs 5 and 6, respectively.
CT arteriograms with shortest manipulation times for each group are shown in figs 6-9.

**Early arterial phase**

HU values and increases in the vessels and organs, and HU differences between aorta or PV and liver, were significantly smallest in group A (figs. 2,3).

Visualization scores had trends toward highest in group A in both observers (fig. 5).

**Late arterial phase**

HU difference of HCC was significantly highest in group A (fig. 4).

Arterial visualizations and conspicuity of HCC had trends toward highest in group A (figs. 5, 6).

Conspicuity of PC was significantly lowest in group A (fig. 6).

**Observers’ agreements**

Agreements for arterial visualizations and tumor conspicuities were substantial or almost perfect (range: 0.75 - 0.97).

Agreements for arterial anatomy were 100%.

**Images for this section:**
### RESULTS: Quantitative Backgrounds & Temporal Parameters

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=52)</th>
<th>Group B (n=49)</th>
<th>Group C (n=52)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>64.8 ± 11.8</td>
<td>64.3 ± 11.9</td>
<td>68.3 ± 11.1</td>
<td>0.17</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.5 ± 8.1</td>
<td>163.2 ± 8.8</td>
<td>163.2 ± 8.2</td>
<td>0.90</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>61.0 ± 11.8</td>
<td>58.2 ± 10.1</td>
<td>59.6 ± 11.6</td>
<td>0.47</td>
</tr>
<tr>
<td>Abdominal diseases</td>
<td>HCC: 22, PC: 9</td>
<td>HCC: 13, PC: 13</td>
<td>HCC: 16, PC: 17</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Monitoring duration (s)</td>
<td>6.2 ± 3.3</td>
<td>7.0 ± 2.8</td>
<td>10.0 ± 3.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total scan delay (s) for EAP</td>
<td>21.3 ± 3.8</td>
<td>27.0 ± 2.8</td>
<td>25.0 ± 3.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3D manipulation time (s)</td>
<td>261.1 ± 72.6</td>
<td>368.9 ± 96.2</td>
<td>287.8 ± 72.0</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

EAP: early arterial phase images, HCC: hepatocellular carcinoma, PC: pancreatic cancer

- Monitoring duration, total scan delay, and manipulation time were significantly smallest in group A.

Fig. 1
## RESULTS: Quantitative

### HU values & Increases of Vessel & Organ on EAP

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=52)</th>
<th>Group B (n=49)</th>
<th>Group C (n=52)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HU values on EAP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aorta</td>
<td>373.9 ± 68.0</td>
<td>417.3 ± 58.2</td>
<td>395.6 ± 53.3</td>
<td>0.018</td>
</tr>
<tr>
<td>Portal vein</td>
<td>57.1 ± 14.3</td>
<td>91.0 ± 39.8</td>
<td>74.7 ± 25.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Liver</td>
<td>59.5 ± 7.4</td>
<td>67.6 ± 11.8</td>
<td>63.6 ± 8.5</td>
<td>0.001</td>
</tr>
<tr>
<td>Pancreas</td>
<td>80.6 ± 21.8</td>
<td>106.0 ± 20.3</td>
<td>96.0 ± 21.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Increases in HU on EAP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aorta</td>
<td>330.8 ± 68.5</td>
<td>373.4 ± 57.5</td>
<td>352.2 ± 53.4</td>
<td>0.002</td>
</tr>
<tr>
<td>Portal vein</td>
<td>17.3 ± 14.3</td>
<td>51.4 ± 40.8</td>
<td>34.1 ± 25.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Liver</td>
<td>5.2 ± 4.5</td>
<td>10.4 ± 11.0</td>
<td>6.9 ± 5.0</td>
<td>0.002</td>
</tr>
<tr>
<td>Pancreas</td>
<td>39.3 ± 17.4</td>
<td>63.7 ± 17.3</td>
<td>54.2 ± 19.5</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*EAP: early arterial phase images*

- HU values and increases in the vessels and organs were significantly smallest in group A.

---

**Fig. 2**
**RESULTS: Quantitative Tumor Vessel-to-Organ Contrasts on EAP**

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=52)</th>
<th>Group B (n=49)</th>
<th>Group C (n=52)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HU differences on EAP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aorta-Liver</td>
<td>314.5 ±69.0</td>
<td>349.0 ±56.8</td>
<td>332.0 ±55.0</td>
<td>0.019</td>
</tr>
<tr>
<td>Aorta-Pancreas</td>
<td>293.3 ±62.4</td>
<td>312.0 ±58.5</td>
<td>300.0 ±56.5</td>
<td>0.28</td>
</tr>
<tr>
<td>Portal vein-Liver</td>
<td>-2.4±15.9</td>
<td>22.6 ±37.1</td>
<td>11.2 ±24.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Portal vein-Pancreas</td>
<td>-23.6 ±19.6</td>
<td>-15.8 ±43.3</td>
<td>-21.3 ±24.2</td>
<td>0.43</td>
</tr>
</tbody>
</table>

EAP: early arterial phase images

• HU differences between aorta or PV and liver, were significantly smallest in group A.

Fig. 3
### RESULTS: Quantitative Tumor Enhancement & Contrast 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><strong>HU on LAP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCC</td>
<td>134.0 ± 27.1 (n=22)</td>
<td>138.1 ± 25.4 (n=13)</td>
<td>123.0 ± 17.4 (n=16)</td>
<td>0.21</td>
</tr>
<tr>
<td>PC</td>
<td>62.6 ± 13.3 (n=9)</td>
<td>122.5 ± 31.5 (n=13)</td>
<td>72.5 ± 18.6 (n=17)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>HU differences on LAP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCC-Liver</td>
<td>69.6 ± 25.4</td>
<td>50.2 ± 25.8</td>
<td>52.1 ± 17.7</td>
<td>0.03</td>
</tr>
<tr>
<td>PC-Pancreas</td>
<td>63.9 ± 24.5</td>
<td>66.9 ± 28.1</td>
<td>64.6 ± 28.8</td>
<td>0.96</td>
</tr>
</tbody>
</table>

HCC: hepatocellular carcinoma, LAP: late arterial phase images, PC: pancreatic cancer

- **HU difference** of HCC was significantly highest in group A.
### RESULTS: Qualitative Arterial visualization on EAP

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=52)</th>
<th>Group B (n=49)</th>
<th>Group C (n=52)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observer 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatic</td>
<td>3.8 ± 0.4</td>
<td>3.7 ± 0.5</td>
<td>3.7 ± 0.5</td>
<td>0.34</td>
</tr>
<tr>
<td>Gastro-duodenal</td>
<td>3.1 ± 0.7</td>
<td>2.9 ± 1.0</td>
<td>3.0 ± 0.7</td>
<td>0.49</td>
</tr>
<tr>
<td>Splenic</td>
<td>3.8 ± 0.5</td>
<td>3.8 ± 0.5</td>
<td>3.7 ± 0.5</td>
<td>0.63</td>
</tr>
<tr>
<td>Superior mesenteric</td>
<td>3.6 ± 0.5</td>
<td>3.5 ± 0.5</td>
<td>3.5 ± 0.5</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>Observer 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatic</td>
<td>3.8 ± 0.5</td>
<td>3.7 ± 0.4</td>
<td>3.7 ± 0.5</td>
<td>0.43</td>
</tr>
<tr>
<td>Gastro-duodenal</td>
<td>3.0 ± 0.7</td>
<td>2.8 ± 1.0</td>
<td>2.9 ± 0.9</td>
<td>0.60</td>
</tr>
<tr>
<td>Splenic</td>
<td>3.8 ± 0.5</td>
<td>3.7 ± 0.5</td>
<td>3.7 ± 0.6</td>
<td>0.41</td>
</tr>
<tr>
<td>Superior mesenteric</td>
<td>3.4 ± 0.5</td>
<td>3.4 ± 0.6</td>
<td>3.4 ± 0.6</td>
<td>0.95</td>
</tr>
</tbody>
</table>

EAP: early arterial phase images

*Visualization scores had tends toward highest in group A.*

Fig. 5
## RESULTS: Qualitative Tumor-to-Organ Contrasts on LAP

<table>
<thead>
<tr>
<th>Observer</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCC (n=22)</td>
<td>3.8 ± 0.4</td>
<td>3.6 ± 0.5</td>
<td>3.6 ± 0.7</td>
<td>0.75</td>
</tr>
<tr>
<td>PC (n=9)</td>
<td>2.6 ± 0.5</td>
<td>3.4 ± 0.7</td>
<td>3.3 ± 0.8</td>
<td>0.02</td>
</tr>
<tr>
<td>HCC (n=13)</td>
<td>3.7 ± 0.5</td>
<td>3.6 ± 0.5</td>
<td>3.6 ± 0.7</td>
<td>0.89</td>
</tr>
<tr>
<td>PC (n=17)</td>
<td>2.7 ± 0.5</td>
<td>3.4 ± 0.7</td>
<td>3.3 ± 0.8</td>
<td>0.04</td>
</tr>
</tbody>
</table>

HCC: hepatocellular carcinoma, LAP: late arterial phase images, PC: pancreatic cancer

- Conspicuity of HCC had trends toward highest in group A.
- Conspicuity of PC was significantly lowest in group A.

**Fig. 6**
Cases in Group A

Manipulation times

2:29  2:31

2:30

Fig. 7
Cases in Group B

Fig. 8

Manipulation times

\[
\begin{array}{c|c}
3:51 & 4:20 \\
4:11 & \\
\end{array}
\]
Cases in Group C

Fig. 9

<table>
<thead>
<tr>
<th>Manipulation times</th>
<th>3:19</th>
<th>3:37</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3:21</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

DISCUSSION

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

On the other hand, our results suggest serial acquisitions of dual-arterial images during a single breathhold is potentially not adequate for preoperative assessments of PC.

Limitations

The numbers of patients with HCC or PC were relatively small.

We only evaluated limited trigger conditions and abdominal diseases.

Further studies with larger population separately for various organs or diseases are needed to confirm our results.

For patients with PCs, separate acquisitions of dual-arterial images should be considered to achieve both excellent visualization of artery and tumor conspicuity.

CONCLUSION

Bolus tracking with lower threshold and shorter delay makes arterial visualization easier and has potential for better HCC conspicuity.

Personal information

References