Contrast-enhanced CT for the whole body in patients with postoperative digestive malignancy: optimal scan delay for quantitative and qualitative performance

Poster No.: C-1321
Congress: ECR 2012
Type: Scientific Exhibit
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Keywords: Contrast agents, Pelvis, CT, Contrast agent-intravenous, Metastases, Liver
DOI: 10.1594/ecr2012/C-1321

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Purpose

Because CT is an important technique for the detection of hepatic metastases [1], screening and follow-up CT examinations are usually performed to determine the clinical stage in patients with digestive malignancy, including colon, rectum, stomach, and pancreas.

The majority of liver metastases are hypovascular, and the hypovascular metastases are best detected during the portal phase, when the difference in attenuation between lesion and normal tissue is greatest. The scan timing was less crucial than that required for hypervascular lesions in the brief arterial phase. Some literatures described 60-70 second on the portal phase after injection of contrast material (CM) [2-4].

On the other hand, the technical advances of MDCT with rapid acquisition have resulted in an increase of opportunity to scan the body trunk between the chest and pelvis. In addition to evaluation of the hepatic metastases, assessment of lymph nodes and vascular structure in the lower abdomen and pelvis are similarly needed on the same phase.

As Sato Y. et al [5] and Maeda E. et al [6] stated that an increase of images would be under radiologists' overload, and consequently, it might induce a high risk for making oversights to diagnose a number of images during a short time. In the clinical practice on single phasic scan, we attempted to investigate the optimal scan timing in the follow-up body trunk CT; therefore, the attenuation of arterial, venous, and hepatic was assessed quantitatively, and the arterial and venous enhancement in the lower abdomen and pelvis was evaluated qualitatively.

With regard to the CM injection technique, it is well known that the concept of the body-weight-tailored dose of CM decrease variation among patients with different body weight in the degree of contrast enhancement in the aorta and liver [7], and the concept of the fixed injection duration can be more easily standardized the time to peak contrast enhancement in an organ or vessel.

There was several data of the time density curve (TDC) in the liver. Ichikawa T. [8] demonstrated TDCs in liver after initiation of 600 mgI/kg CM injection (2 mL/kg of 300 mgI) with different injection durations (25, 30, 35, 40, 45 s) contrast-enhanced MDCT of the liver.

Because TDC with injection duration of 45s showed an adequate hepatic enhancement [9] (more than 50HU increase enhancement) 80-90 sec after initiation of CM injection, it was expected that TDC with injection duration of 50s can give an adequate hepatic
enhancement (more than 50HU increase enhancement) 100sec after initiation of CM injection.

To obtain the adequate hepatic enhancement, the optimal patients' body-weight tailored dose of CM should range from 1.7 to 2.5 mL/kg with 300 mg I/mL (510-750 mg I/kg) [10]. We employed body-weight-tailored dose of 1.8 mL/kg with 350 mg L/mL (630 mg I/kg) CM, because the hepatic and venous enhancement was assessed from the portal venous phase (80 sec) to the equiligrim phase (120 sec) [11].
Methods and Materials

Patients

This study was approved by our institutional review board.

Patient Population

During a 6-month period (March 2010 to August 2010), 165 consecutive patients with postoperative digestive system underwent contrast-enhanced CT of the chest, abdomen, and pelvis for clinical follow-up. The inclusion criteria for this study were (a) patients, who underwent surgery of the malignant disease in the digestive system at least six months earlier, and follow-up CT was performed for the staging or restaging; (b) patients without conditions that could affect hepatic arterial and portal venous flow (extensive hepatic tumour involvement, cirrhosis, portal vein thrombosis, compression or invasion of hepatic artery or portal vein); (c) patients without congestive heart failure; and (d) patients with no previous allergic reaction to iodinated CM, renal insufficiency (serum creatinine level of 1.5 mg/dl), or previous history of asthma.

We excluded 21 patients from our study for the following reasons: 7 had severe fatty liver (liver attenuation < 90 HU); 3 had undergone partial hepatectomy; 2 had undergone total splenectomy; 2 had metal artifacts due to hip prostheses; one had venous obstruction due to large metastases of bilateral common iliac lymph nodes; one experienced technical failure of the breath holding during CT examination; and 5, who weighed more than 75 kg, were administered contrast material at a fixed amount of 135 mL because that was the largest volume of iodinated contrast material commercially supplied in a syringe. The remaining 144 patients (age range, 42-90 years; mean age, 68.3 ± 9.2 years; BW range, 46-75 kg; mean BW, 61.5 kg ± 7.5, and height rage, 141-176 cm; mean height, 164.0 ± 6.8 cm) formed the study population.

The diagnoses of these patients were as follows: gastric carcinoma (n = 23); jejunal gastrointestinal tumor (n = 3); cecal lymphoma (n=1); appendical carcinoma (n=3); pancreatic adenocarcinoma (n=8); colorectal carcinoma including ascending colon (n = 21), transverse colon (n = 16), descending colon (n = 19), sigmoid colon (n = 20), and rectum (n= 30). There were 95 men (age range, 43-90 years; mean, 68.8 years ± 9.8) and 32 women (age range, 38-77 years; mean, 66.4 years ± 9.8).

Contrast Material Injection and Scan Protocols
CT images from the supraclavicular fossa to the lower end of the pubic symphysis were scanned in craniocaudal direction in a 64-MDCT (Light Speed VCT; GE Healthcare, Milwaukee, Wis).

The scanning parameters were as follows: collimation 32 × 1.25 mm; rotation time 0.4 s/rot; pitch 1.375; tube voltage 120 kVp; minimal and maximal tube current thresholds of 10 and 550mA, respectively; a matrix of 512 × 512; and a field of view (FOV) of 30-35 cm. The noise value was defined as 12 for a slice thickness of 5 mm. The images were displayed as 5-mm-thick sections with no intersection gap. The table speed was set at 137.5 mm/s, and scan acquisition time was within 7 seconds. All patients were administered nonionic iodinated contrast material that contained 350 mg of iodine per milliliter (Iomeron 350 [iomeprol]; Esai, Tokyo, Japan) by using a power injector during 50 seconds of the injection duration through a 22-gauge plastic intravenous catheter placed in an antecubital or radial vein. In all 144 patients, the volume of contrast material delivered was 1.8 mL per kilogram of BW, thus resulting in a range of 83-135 mL (mean, 111 mL).

**Image analysis**

To analyze the images, source images which were loaded on a separate workstation (Advantage workstation 4.3; GE Healthcare, Milwaukee, USA) with a window/level setting of 300/60 HU, were utilized in cine mode.

**Quantitative Analysis**

One independent radiologist (Y.K.), who interpreted the images was blinded to the protocol, measured attenuation values in Hounsfield units (HU) of the arterial, venous, and hepatic systems (Fig 1). In the arterial system, regions of interest (ROIs) were placed at the following 4 points: The first level was the descending aorta at Th7; second, the abdominal aorta at L2; third, common iliac arteries at the iliac bifurcation; and, forth, the common femoral arteries at the groin. These values were averaged. In the venous system, circular ROIs were placed in the arteries at three levels as follows: The first level was the infrarenal inferior vena cava (IVC) at L4; second, common iliac veins at the iliac bifurcation; and, third, the common femoral veins at the groin. In the hepatic systems, circular ROIs in hepatic parenchyma were placed in three separate areas (right anterior, right posterior, and left lateral segments) at the level of the porta hepatis, and the values were averaged. Focal hepatic lesions, blood vessels, the bile duct, calcifications, and artifacts were carefully excluded from the measurement areas. In addition, circular ROIs in the portal vein at the level of the porta hepatis were placed.

**Qualitative analysis**
Two experienced radiologists (S.S. and T.H.) evaluated image quality, reaching a consensus for each image. If assessments differed, the grade for the case was determined by consensus. First, arterial enhancement in the lower abdomen and pelvis was assessed qualitatively using a 4-point scale (1, poor; 2, fair; 3, good; 4, excellent). Next, venous enhancement for the detection of iliac and internal obturator lymph node (LN) in the lower abdomen and pelvis was evaluated, using a 4-point scale: (1) Poor corresponded to enhancement similar to that of the surrounding muscle (Fig 2). Careful observation to distinguish venous structures and LN system in the pelvis is needed. (2) Fair corresponded to inhomogenous enhancement slightly higher than that of the surrounding muscle, and intraluminal lamina flow (uneven flow) with greater than 1/2 exists by mixture blood and CM (Fig 3). (3) Good corresponded to heterogenous enhancement moderately higher than that of the surrounding muscle, and intraluminal lamina flow with less than 1/2 exists by mixture blood and CM (Fig 4). (4) Excellent corresponded to entirely homogenous enhancement venous attenuation is close to arterial attenuation (Fig 5).

**Statistical analysis**

Statistical analysis was performed using SPSS 15.0 (Chicago, IL). Characteristic parameters, and attenuation values of the arterial, venous, and hepatic systems were compared using one-way analysis of variance to investigate intergroup differences among the three groups (Tables 1 and 2). When the overall differences were significant, post hoc analysis was performed using the Tukey-Kramer test for multiple comparisons among the three groups (Fig 6, 7, 8, 9, 10, and 11). Sex distribution for the three protocols was analyzed by x2 test. For qualitative analysis, the Kruskal-Wallis test was applied to examine intergroup differences among the three groups (TableS 3 and 4), and differences between two groups were then assessed by the Mann-Whitney U test. Probability values less than 0.05 were considered significant.
Fig. 1: Attenuation value at the hepatic systems, abdominal aorta at L2, and infrarenal IVC was measured.

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Fig. 2: Pelvic CT showed score 4 at the arterial enhancement, and score 1 at the venous enhancement.

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Fig. 3: Pelvic CT showed in score 3 at the arterial enhancement, and score 2 at the venous enhancement.

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**Fig. 4:** Pelvic CT showed in score 3 at the arterial enhancement, and score 3 at the venous enhancement.

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Fig. 5: Pelvic CT showed in score 4 at the arterial enhancement, and score 4 at the venous enhancement.

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Table 1 shows that patient characteristics were not significantly different among the three groups.

In Table 2, multiple-group comparisons of each portion of the mean attenuation in the arterial system, venous system, and hepatic system show significant differences ($p < 0.01$). In the arterial system, the mean attenuation values in aorto-ileofemoral artery were $180 \pm 16$, $159 \pm 13$, and $147 \pm 9$ HU for groups A, B, and C, respectively, and post hoc tests confirmed that there were significant differences ($p < 0.01$) between groups A and B, A and C, or B and C (Fig. 6).

In the venous system, the mean attenuation values of the infrarenal IVC were $115 \pm 20$, $129 \pm 14$, and $124 \pm 14$ for groups A, B, and C, respectively. Post hoc tests confirmed that although there was no significant difference between groups B and C ($p = 0.438$), there were significant differences ($p < 0.01$) between groups A and B and between groups A and C (Fig. 7). The mean attenuation values of the iliac vein were $108 \pm 23$, $120 \pm 14$, and $123 \pm 17$ for groups A, B, and C, respectively. Post hoc tests confirmed that although there was no significant difference between groups B and C ($p = 1.00$), there were significant differences ($p < 0.01$) between groups A and B and between groups A and C (Fig. 8). The mean attenuation values of the femoral vein were $90 \pm 24$, $105 \pm 21$, and $113 \pm 20$ for groups A, B, and C, respectively. Post hoc tests confirmed that although there was no significant difference between groups B and C ($p = 0.168$), there were significant differences ($p < 0.01$) between groups A and B and between groups A and C (Fig. 9).

In the hepatic system, the mean attenuation values in the liver parenchyma were $196 \pm 21$, $167 \pm 15$, and $152 \pm 12$ HU for groups A, B, and C, respectively, and post hoc tests confirmed that there were significant differences ($p < 0.05$) between groups A and B, A and C, or B and C (Fig. 10). The mean attenuation values in the portal vein were $122 \pm 15$, $116 \pm 10$, and $110 \pm 7$ HU for groups A, B, and C, respectively, and post hoc tests confirmed that there were significant differences ($p < 0.01$) between groups A and B, A and C, or B and C (Fig. 11).

Because the mean CT number of the normal liver parenchyma is about 60 HU on unenhanced images, the suggested enhancement of the liver parenchyma should be greater than 110 HU as Heiken HP. described that the 50-HU increase of hepatic enhancement was an adequate hepatic enhancement qualitatively.
In group A, attenuation value of the liver parenchyma was lower than 110 HU in 20.1% (29/144) of all measurements, which was found in 11 of 47 patients (23.4%). In group B, arterial attenuation was lower than 300 HU in 26.5% (39/147) of all measurements, which was found in 10 of 49 patients (20.4%). In group C, arterial attenuation was lower than 300 HU in 45.4% (64/141) of all measurements, which was found in 21 of 48 patients (43.8%).

On qualitative analysis of arterial enhancement, multiple-group comparisons demonstrated significant differences (p < 0.01) (Table 3). With regard to two-group comparison, the arterial enhancement showed significant difference between groups A and B, and A and C (Table 4), and it show no significant difference between groups B and C (p = 0.279).

On qualitative analysis of venous enhancement, multiple-group comparisons demonstrated significant differences (p < 0.01) (Table 3). With regard to two-group comparison, venous enhancement showed a significant difference between groups A and B (p < 0.01), A and C (p < 0.01), and B and C (p = 0.012) (Table 4).
TABLE 1. Patient characteristics and scan parameters

<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>Number of patients</td>
<td>48</td>
<td>49</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>35/12</td>
<td>41/8</td>
<td>36/12</td>
<td>0.473</td>
</tr>
<tr>
<td>Age (year)</td>
<td>68.8 ± 9.6</td>
<td>67.1 ± 9.5</td>
<td>68.6 ± 8.1</td>
<td>0.538</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>62.1 ± 6.9</td>
<td>61.6 ± 7.2</td>
<td>61.1 ± 7.3</td>
<td>0.851</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.8 ± 6.7</td>
<td>165.0 ± 6.6</td>
<td>162.1 ± 7.4</td>
<td>0.172</td>
</tr>
</tbody>
</table>

Data are the mean ± standard deviation.

Table 1
### TABLE 2. Quantitative evaluation of the arterial, venous and hepatic system

<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>Arterial systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal thoracic aorta</td>
<td>185 ± 18</td>
<td>165 ± 14</td>
<td>152 ± 10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Abdominal aorta</td>
<td>175 ± 17</td>
<td>159 ± 14</td>
<td>144 ± 10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Iliac artery</td>
<td>178 ± 15</td>
<td>156 ± 14</td>
<td>144 ± 11</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Femoral artery</td>
<td>183 ± 13</td>
<td>157 ± 15</td>
<td>148 ± 12</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Mean attenuation value</strong></td>
<td>180 ± 16</td>
<td>159 ± 13</td>
<td>147 ± 9</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Venous systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrarenal IVC</td>
<td>115 ± 20</td>
<td>129 ± 14</td>
<td>124 ± 14</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Iliac vein</td>
<td>108 ± 23</td>
<td>120 ± 14</td>
<td>123 ± 17</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Femoral vein</td>
<td>90 ± 24</td>
<td>105 ± 21</td>
<td>113 ± 20</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Hepatic systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portal vein</td>
<td>196 ± 21</td>
<td>187 ± 15</td>
<td>152 ± 12</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Liver parenchyma</td>
<td>122 ± 15</td>
<td>116 ± 10</td>
<td>110 ± 7</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Data are the mean ± standard deviation.
IVC shows the inferior vena cava.

Table 2

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TABLE 3. Qualitative assessment for the arterial and venous system in the lower abdomen and pelvis

<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>Arterial enhancement</td>
<td>3.9 ± 0.4</td>
<td>3.5 ± 0.5</td>
<td>3.3 ± 0.5</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Venous enhancement</td>
<td>2.1 ± 0.5</td>
<td>3.3 ± 0.8</td>
<td>3.6 ± 0.6</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

Data are the mean ± standard deviation.

Table 3

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TABLE 4. Comparison of the qualitative evaluation among the three groups in the lower abdomen and pelvis

<table>
<thead>
<tr>
<th></th>
<th>p value</th>
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<tr>
<td>Arterial enhancement</td>
<td></td>
</tr>
<tr>
<td>Group A vs Group B</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Group A vs Group C</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Group B vs Group C</td>
<td>0.279</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venous enhancement</td>
<td></td>
</tr>
<tr>
<td>Group A vs Group B</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Group A vs Group C</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Group B vs Group C</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Table 4

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Fig. 6

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Fig. 7

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**Fig. 8**

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Fig. 9

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Fig. 10

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Fig. 11

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Conclusion

Setting scan delay between 100 and 120 sec after initiation of CM injection can produce the best performance both quantitatively and qualitatively.
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