Automatic bolus tracking (ABT) vs fixed duration contrast injection (FDCI) at 64-row multidetector computed tomography (MDCT) of the upper abdomen: a comparative study

Poster No.: C-1625  
Congress: ECR 2011  
Type: Scientific Paper  
Authors: G. Como, R. Girometti, L. Cereser, D. Bagatto, S. Fapranzi, C. Zuiani, M. Bazzocchi; Udine/IT  
Keywords: Abdomen, Contrast agents, CT, Comparative studies, Contrast agent-intravenous, Technical aspects, Metastases  
DOI: 10.1594/ecr2011/C-1625

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Purpose

Background

Multidetector-row Computed Tomography (MDCT), is a rapidly evolving technology suited for high demanding diagnostic skills, especially in cardiovascular and body imaging [1]. Because of the extremely rapid scan speed inherent to MDCT, acquisition protocols must be adjusted accordingly. In particular, since most abdominal examinations require intravenous (i.v.) administration of contrast medium (CM) to enhance lesions' conspicuity, proper selection of contrast injection technique and acquisition timing represent major technical issues [2,3,4]. Especially for liver imaging, many studies have been focused to achieve optimal CM injection protocol, in order to obtain proper timing and contrast properties of each vascular phase [5,6,7,8].

At present, fixed rate CM injection monitored by automatic bolus-tracking (ABT) is the most commonly used technique in multiphasic liver imaging [6]. ABT compensates for individual variations in circulation time that may affect arterial phase. Nonetheless, this approach determines adjunctive radiation exposure [9]. In the last years, fixed duration contrast injection (FDCI) has been advocated as a valid alternative to ABT in achieving optimal arterial phase without additional radiation dose and by simplifying examinations work-flow [5]. A large amount of literature compares ABT vs. FDCI for liver imaging, mostly on 8 or 16-row MDCT [6,9,10,11,12]. To our knowledge, no previous studies investigated whether these techniques provide comparable liver contrast enhancement by using 64-row MDCT, i.e. at even faster acquisition time.

Purpose

On these basis, the purpose of our study was to quantitatively and qualitatively evaluate ABT vs. FDCI contrast enhancement of the liver by using a 64-MDCT scanner.
Methods and Materials

Populations of study

Ethical approval by institutional review board was obtained for this prospective study.

During a 6-month period (January to June 2010), we consecutively enrolled all oncologic patients addressed to a routine follow-up MDCT examination in our Department. Overall, one-hundred-eight-six subjects were randomized into two different examination protocols, as detailed below, to form two populations of study: a) group 1 (46 male, 48 female; mean age, 61.04 years; age range, 29-81 years; standard deviation, 13.26 years), who underwent the examination with the ABT protocol; b) group 2 (44 male, 48 female; mean age, 65.19 years; age range, 29-89 years; standard deviation, 12.60 years), who underwent the FDCI protocol. Excluded were subjects with other indications to MDCT or showing at least one focal liver lesions larger than 5 cm in diameter, to permit quantitative analysis on a more homogeneous liver parenchyma as possible.

CM dose and injection protocols

Examinations were performed on a 64-row MDCT scanner (HD DISCOVERY 750, General Electric, Milwaukee, USA), by using the institutional standard protocol for oncologic patients, including late arterial (limited to the upper abdomen), venous and delayed phases (extended to the pelvis). Main acquisition parameters are shown in Table 1 on page 6.

Irrespective of the injection protocol, all patients were administered nonionic iodine contrast material containing 400 mgI/mL (Iomeron 400 Bracco SpA, Milan, Italy), at the established dose of 600 mgI/kg [5]. Corresponding injection volume was calculated according to three ranges of patients body weight, as follows: a) patients # 60 kg (n=38) received 102 mL of CM at fixed injection rate of 3.4 mL/sec; b) patients between 61 and 80 Kg (n=102) received 111 mL of CM at fixed injection rate of 3.7 mL/sec; c) patients >80 Kg (n=46) received 129 mL of CM at fixed injection rate of 4.3 mL/sec. A power injector (CT-Injector Missouri XD 2001, Ulrich medical, Ulm, Germany) administered CM followed by a saline chase bolus of 60 mL.

After the injection, scan timing was established by ABT in patients of group 1, and by FDCI in patients of group 2. ABT protocol was performed with a commercially available software (Smart Prep, GE Healthcare), by starting to monitor contrast arrival in the abdominal aorta 8 sec after the injection beginning. Scanning started 25 sec after a threshold level of 70 Hunsfield Units (HU). FDCI protocol was performed with a fixed duration injection of 30 seconds, followed by pre-scanning delay of 10 seconds (Fig. 1 on page 6). Consequently, timing for arterial, venous and delayed phases was of 40, 70, and 180 sec, respectively [13].
**Image Analysis**

Images were analyzed on a dedicated console (Aycan Workstation OsirixPro, Wurzburg, Germany). Quantitative analysis was performed, for each vascular phase, by two radiologists in consensus (D.B., S.F.), who placed circular regions of interest (ROIs) of 10-15 mm in diameter on the following structures: liver parenchyma, aorta (at the level of the hepatic dome), portal vein trunk, and inferior vena cava. Each structure was covered by a single ROI, except for: a) the liver, on which 3 ROIs were placed at the right anterior segment, the right posterior segment, and the left lobe, respectively; b) the inferior vena cava, on which two ROIs were placed at the retrohepatic level and above the origin of renal arteries, respectively. In each patient, ROIs positioning was the same on images from different vascular phases. Readers recorded the attenuation values in Hounsfield Units (HU). In case of measurements from multiple ROIs, averaged values were considered. Focal hepatic lesions, blood vessels, bile ducts, calcifications, and artifacts were carefully excluded from all measurement areas.

Other two radiologists, with five (L.C.; reader 1) and ten (G.C.; reader 2) years of experience in abdominal imaging, respectively, performed qualitative analysis by reviewing arterial and portal phase images in separate and independent reading sessions. Readers were blinded to patients’ clinical information and to the injection protocol that was used. Moreover, images from the two injection protocols were randomly presented. Readers attributed a score on a 1-5 scale to express overall image quality, based on the presence or absence of five features characterizing each phase (i.e., each feature corresponded to 1 point). Features for the arterial phase were: presence of a regular effect of portal inflow, strong enhancement of hepatic artery visible in the porta hepatis, absence of venous enhancement within the liver, tiger spleen appearance, and proper cortico-medullary enhancement of the kidneys. Feature for the portal phase were: proper enhancement of main portal trunk, presence of homogeneous venous enhancement within the liver, homogeneous liver parenchyma enhancement, homogeneous spleen parenchyma enhancement, and proper nephrographic enhancement of the kidneys. Scores corresponded to image quality judgment as follows: 1=poor; 2=fair; 3=adequate; 4=good and 5=excellent.

**Statistical Analysis**

Differences in the attenuation obtained with ABT vs. FDCI protocols were assessed with a Mann-Whitney U test. Within each injection protocol, differences in the attenuation of considered structures at arterial, portal and venous phases were assessed with the Kruskal-Wallis test. In case of significant results, correlated pairwise comparisons were performed with the Wilcoxon test. Finally, inter- and intra-readers comparison between qualitative scores were performed with the Wilcoxon and Mann Whitney U tests, respectively.
A p value of less than 0.05 was considered statistically significant. Statistical analysis was performed by using a commercially available software (Med-Calc, version 9.2.0.1, Mariakerke, Belgium).
**Table 1.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kv</td>
<td>120</td>
</tr>
<tr>
<td>mA (automatic)</td>
<td>200-500</td>
</tr>
<tr>
<td>Tube rotation time</td>
<td>0.50 s</td>
</tr>
<tr>
<td>Collimation</td>
<td>0.625 mm</td>
</tr>
<tr>
<td>Reconstruction width</td>
<td>5 mm</td>
</tr>
<tr>
<td>Reconstruction Interval</td>
<td>5 mm</td>
</tr>
<tr>
<td>Pitch</td>
<td>0.984</td>
</tr>
<tr>
<td>Noise index</td>
<td>11-12.50</td>
</tr>
<tr>
<td>Superior limit</td>
<td>Diaphragmatic dome</td>
</tr>
<tr>
<td>Inferior limit</td>
<td>Pubis</td>
</tr>
</tbody>
</table>

**Main 64-MDCT technical acquisition parameters**

**Fig. 0:** Tab. 1 - Main 64-MDCT technical acquisition parameters.

© Institute of Diagnostic Radiology, University of Udine - Udine/IT
Fig. 0: Fig. 1 - ABT protocol was performed, by starting to monitor contrast arrival in the abdominal aorta 8 sec after the injection beginning; scanning started 25 sec after a threshold level of 70 Hounsfield Units (HU) was reached (incognite x in the equation). FDCI protocol was performed with a fixed duration injection of 30 seconds; the scanning started 10 seconds after the end of the injection.

© Institute of Diagnostic Radiology, University of Udine - Udine/IT
Results

Quantitative analysis

Irrespective of the vascular phase (arterial, venous, and delayed), the comparison between ABT and FDCI showed no significant differences in the attenuation values measured at the liver parenchyma (Tab. 2 on page 9), aorta (Tab. 3 on page 9), portal vein (Tab. 4 on page 10) and inferior vena cava (Tab. 5 on page 11) (p>0.05). The only exception was represented by a significantly larger aortic contrast enhancement obtained with ABT (340.98±92.91) than FDCI (288.66±102.19) (p=0.01) during the arterial phase (Tab. 3 on page 9). However, on same vascular phase the difference in liver parenchyma enhancement between ABT and FDCI was nearly to statistical significance (90.74±17.44 vs. 98.93±22.80, respectively) (p=0.0578).

For both ABT and FDCI protocols, significantly larger attenuation values as compared to the other vascular phases (p<0.05) were found in the venous phase for the hepatic parenchyma, in the arterial phase for the aorta, and in the venous phase for the portal vein and inferior vena cava. Thus, contrast enhancement peaks of reported structures occurred as expected.

Qualitative analysis

Intra-reader analysis showed that both experienced and less experienced radiologists attributed higher qualitative score to the ABT than FDCI protocol images, either for the arterial or venous phase (Tab. 6 on page 12). Difference was minimal, without statistical significance, except for that shown for the arterial phase according to expert reader (4.53±0.66 vs. 4.02±0.83, p=0.0054).

Inter-reader analysis showed that qualitative scores were attributed similarly by readers (p>0.05), irrespective of their experience.
Table 2

Hepatic parenchyma

<table>
<thead>
<tr>
<th>Phase</th>
<th>ARTERIAL</th>
<th>VENOUS</th>
<th>DELAYED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>range</td>
<td>mean</td>
<td>range</td>
</tr>
<tr>
<td>ABT</td>
<td>48.07-137.84</td>
<td>90.74±17.44</td>
<td>68.64-171.82</td>
</tr>
<tr>
<td>FDCI</td>
<td>53.75-154.34</td>
<td>98.93±22.80</td>
<td>63.44-161.86</td>
</tr>
<tr>
<td>Mann Whitney test</td>
<td>0.058</td>
<td>0.425</td>
<td>0.293</td>
</tr>
</tbody>
</table>

Fig. 0: Tab. 2 - Attenuation values expressed in Hounsfield Units (HU) measured at the liver parenchyma. For each vascular phase (arterial, venous and delayed) the range values and mean value ± s.d. are reported. Differences in the attenuation obtained with ABT vs. FDCI protocols were assessed with a Mann-Whitney U test. Within each injection protocol, differences in the attenuation at arterial, portal and venous phases were assessed with the Kruskal-Wallis test.

© Institute of Diagnostic Radiology, University of Udine - Udine/IT
**Fig. 0:** Tab. 3 - Attenuation values expressed in Hounsfield Units (HU) measured in the aorta at the level of hepatic dome. For each vascular phase (arterial, venous and delayed) the range values and mean value ± s.d. are reported. Differences in the attenuation obtained with ABT vs. FDCI protocols were assessed with a Mann-Whitney U test. Within each injection protocol, differences in the attenuation at arterial, portal and venous phases were assessed with the Kruskal-Wallis test.

© Institute of Diagnostic Radiology, University of Udine - Udine/IT
Table 4: Portal Vein

<table>
<thead>
<tr>
<th>Phase</th>
<th>ARTERIAL</th>
<th>VENOUS</th>
<th>DELAYED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>range</td>
<td>mean</td>
<td>range</td>
</tr>
<tr>
<td>ABT</td>
<td>98.79-372.54</td>
<td>±48.62</td>
<td>136.44-273.58</td>
</tr>
<tr>
<td>FDCI</td>
<td>51.79-327.36</td>
<td>±55.31</td>
<td>133.55-264.87</td>
</tr>
<tr>
<td>Mann Whitney test</td>
<td>0.268</td>
<td>0.751</td>
<td>0.155</td>
</tr>
</tbody>
</table>

**Fig. 0**: Tab. 4 - Attenuation values expressed in Hounsfield Units (HU) measured in the portal vein trunk. For each vascular phase (arterial, venous and delayed) the range values and mean value ± s.d. are reported. Differences in the attenuation obtained with ABT vs. FDCI protocols were assessed with a Mann-Whitney U test. Within each injection protocol, differences in the attenuation at arterial, portal and venous phases were assessed with the Kruskal-Wallis test.

© Institute of Diagnostic Radiology, University of Udine - Udine/IT
Table 5

*Inferior Vena Cava*

<table>
<thead>
<tr>
<th>Phase</th>
<th>ARTERIAL</th>
<th>VENOUS</th>
<th>DELAYED</th>
<th>Kruskal Wallis test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>range</td>
<td>mean</td>
<td>range</td>
<td>mean</td>
</tr>
<tr>
<td></td>
<td>82.17-254.19</td>
<td>144.97 ±39.34</td>
<td>95.46-225.51</td>
<td>142.49 ±26.10</td>
</tr>
<tr>
<td>ABT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>72.63-241.60</td>
<td>156.09 ±39.33</td>
<td>71.47-195.08</td>
<td>141.91 ±23.33</td>
</tr>
<tr>
<td>FDCI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mann Whitney test</td>
<td>0.100</td>
<td>0.930</td>
<td>0.298</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 0:** Tab. 5 - Attenuation values expressed in Hounsfield Units (HU) measured in the inferior vena cava. For each vascular phase (arterial, venous and delayed) the range values and mean value ± s.d. are reported. Differences in the attenuation obtained with ABT vs. FDCI protocols were assessed with a Mann-Whitney U test. Within each injection protocol, differences in the attenuation at arterial, portal and venous phases were assessed with the Kruskal-Wallis test.

© Institute of Diagnostic Radiology, University of Udine - Udine/IT
Table 6.

Qualitative analysis – Phase proper features

Inter- and intra-readers comparison between qualitative scores performed with the Wilcoxon and Mann Whitney U tests, respectively

<table>
<thead>
<tr>
<th></th>
<th>READER 1</th>
<th></th>
<th>READER 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABT</td>
<td>FDCI</td>
<td>p</td>
<td>ABT</td>
</tr>
<tr>
<td>Arterial</td>
<td>4.46 ± 0.69</td>
<td>4.15 ± 0.82</td>
<td>0.090</td>
<td>4.53 ± 0.66</td>
</tr>
<tr>
<td></td>
<td>P = 0.497</td>
<td></td>
<td>P = 0.243</td>
<td></td>
</tr>
<tr>
<td>Venous</td>
<td>4.84 ± 0.42</td>
<td>4.73 ± 0.61</td>
<td>0.575</td>
<td>4.73 ± 0.44</td>
</tr>
<tr>
<td></td>
<td>P = 0.195</td>
<td></td>
<td>P = 0.813</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 0: Tab. 6 - Mean qualitative score values ± s.d. estimating overall image quality determined by the readers for both methods at arterial and venous phases.

© Institute of Diagnostic Radiology, University of Udine - Udine/IT
Conclusion

Study limitation

The study is not targeted on focal liver lesions. Accordingly, generalization of the results to scenarios with hypovascular or hypervascular lesions is hypothetical.

Conclusions

1. Like previous studies [7,13,15,16], ours showed no significant difference between ABT and FDCI at the quantitative analysis of the liver venous phase. We obtained similar results about the delayed phase. Moreover, image quality of the upper abdomen was high, and comparable regardless of readers' experience and the injection method. Thus, despite some patients with reduced cardiac output may have been included in the study (like occurs in real clinical practice), it is arguable that ABT and FDCI are comparable when performing 64-row MDCT liver examinations in which arterial phase is not planned (e.g., follow-up of hypovascular metastases). FDCI might be preferable in order to simplify the work-flow [9], and reduce patients exposure [9].

2. Proper arterial phase was better achieved by using ABT as compared to FDCI. First, ABT provided significantly higher aortic contrast enhancement, similarly to previous experiences with 8 to 16-row MDCT [3,9,11]. Second, enhancement of the liver parenchyma was higher by using FDCI rather than ABT, with a difference in HU nearly to statistical significance. Accordingly, it could be hypothesized that liver-to-lesion contrast of hypervascular lesions may be reduced by using FDCI. Third, the expert radiologist found that features characterizing image quality are better defined with the ABT injection method. Consequently, even focal lesions are expected to be perceived with more proper enhancement characteristics than in the FDCI protocol. In summary, in our opinion ABT should not be replaced as the injection method of choice for imaging the liver in the arterial phase.
References

4. Ertuk SM et al. Effect of duration of contrast material injection on peak enhancement times and values of the aorta, main portal vein, and liver at dynamic MDCT with the dose of contrast medium tailored to patient weight Clinical Radiology 2008; 63, 263-271
5. Ichikawa T et al. Multiphasic contrast-enhanced multidetector-row CT of liver: Contrast-enhancement theory and practical scan protocol with a combination of fixed injection duration and patients' body-weight-tailored dose of contrast material European Journal of Radiology 2006; 165-176
6. Awai K et al. Effect of contrast material injection duration and rate on aortic peak time and peak enhancement at dynamic CT involving injection protocol with dose tailored to patient weight. Radiology 2004; 230:142-50
12. Sheiman J Comparison of tailored and empiric scan delays for CT angiography of the abdomen AJR 1996;167:725-729
13. Laghi A Multidetector CT (64 Slices) of the liver: examination techniques Eur Radiol 2007; 17: 675-683
14. Awai K et al Effect of contrast injection protocol with dose tailored to patient weight and fixed injection duration on aortic and hepatic enhancement at multidetector-row helical CT Eur Radiol 2003; 13:2155-2160
16. Awai K Moderate versus high concentration of contrast material for aortic and hepatic enhancement and tumor-to-liver contrast at multi-detector row CT. Radiology 2004; 233: 682-688
Personal Information

First Author
Dr. GiuseppeComo

Presenting Author
Dr. Rossano Girometti

Istituto di Radiologia Diagnostica
Università di Udine
via Colugna, 50
33100 - Udine
Italy

Correspondance to: rgirometti@sirm.org