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Citation for published version:

Digital Object Identifier (DOI):
10.15761/LPS.1000102

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Publisher's PDF, also known as Version of record

Published In:
Liver and Pancreatic Sciences

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Test-bolus versus bolus-tracking in the timing of hepatic arterial phase at contrast-enhanced magnetic resonance imaging in patients with hepatocellular carcinoma

Emilio Quaia*

Department of Medical, Surgical and Health Sciences, Operative Unit of Radiology, Cattinara Hospital, Italy

Abstract

Aim: To evaluate test-bolus versus bolus-tracking in the timing of hepatic arterial phase at contrast-enhanced magnetic resonance (MR) imaging in patients with hepatocellular carcinoma (HCC).

Methods: Eighteen patients with HCC were scanned by contrast-enhanced MR imaging with a delay time for the hepatic arterial phase calculated by test-bolus (n=9 patients) or bolus-tracking (n=9 patients).

Results: Test-bolus and bolus-tracking techniques did not differ in SNR (301.2 ± 154.54 vs. 330.77 ± 240.75; P=0.89) and CNR (24.5 ± 18.74 vs. 19.24 ± 13.67; P=0.89).

Conclusions: Test-bolus vs bolus-tracking did not differ in the timing of hepatic arterial phase in patients with HCC.

Introduction

Hypervascularity on hepatic arterial phase after contrast injection is one of the essential features for the diagnosis of HCC according to the American Association for the Study of Liver Disease (ASL) [1] and the European Association for the Study of the Liver (EASL) [2] even though it is a transient phenomenon, and errors of only a few seconds during the image acquisition on hepatic arterial phase may determine a reduced diagnostic confidence and accuracy. Anyway, the determination of the precise timing of optimal contrast enhancement for detection of hepatocellular carcinoma (HCC) is technically challenging because this timing is affected by the patient’s circulation, the contrast injection protocol, and the imaging protocol.

Two methods - arbitrary fixed delay and test-bolus - have been used traditionally to determine the delay time from the start of contrast injection for the hepatic arterial phase at MR imaging. With the arbitrary fixed delay method, MR imaging is initiated 15–20 seconds after the start of the injection. This technique does not take into account injection- or patient-related variables. More properly, with the test-bolus method, 1–2 mL of contrast medium are injected and simultaneous rapid and repetitive MR imaging at one level is performed during free breathing to determine the time to peak aortic enhancement. The delay time is calculated on the basis of the time of peak aortic enhancement, injection volume, and rate. While considered the most accurate, this method requires additional imaging and calculations.

A further method corresponds to real-time bolus-tracking providing hepatic arterial phase images tailored to an individual patient’s cardiac output and peripheral bloodstream kinetic. A real time bolus-triggered method includes breath-hold instructions initiated as the contrast bolus reaches the celiac trunk (trigger point), and imaging initiated at an 5–10 s delay from the trigger point. This method is very used despite it presents some dependence on the operator’s subjective assessment of the contrast arrival in the abdominal aorta.

To our knowledge, only few previous studies [3-5] have been conducted to evaluate the optimal acquisition delay for dynamic contrast-enhanced multiphase MR imaging of the liver and HCC even though no further study compared test-bolus and bolus-tracking techniques.

The aim of this study was to evaluate test-bolus versus bolus-tracking in the timing of hepatic arterial phase at contrast-enhanced MR imaging in patients with HCC.

Materials and methods

Patients

The institutional review board of our hospital approved this single-centre prospective observational study. All patients provided informed content.

We included all patients who met the following inclusion criteria: biopsy-proven diagnosis of liver cirrhosis due to type B, type C, or alcoholic hepatitis; from one to four hypervascular nodules (diameter,
2-4cm; mean ± SD, 3.5 ± 1.2) suspected for HCC at contrast-enhanced CT and referred to contrast-enhanced abdominal MR imaging to improve the diagnostic confidence in the characterization of the dominant HCC nodule(s) or to identify additional nodules; no history of hepatic surgery or thermal ablation or chemoembolization; absence of renal failure (serum creatinine concentration < 1.5 mg/dL); contraindication to use of gadolinium-based contrast material. We initially included 25 patients while seven patients were excluded: three had tumor thrombi in the central portal vein, and four had numerous tumors involving the entire liver that may have changed hepatic hemodynamics.

Thus the final study sample consisted in 18 patients (8 male and 10 female; mean age, 66 years ± 12; body weight range, 33–69 kg; mean, 55.0 ± 8.4 [SD] kg). The age range of men was 48–88 years (mean, 67.5 years), and that of the women was 52–85 years (mean, 71.0 years). The definitive diagnosis of HCC was based on histology (n=2), histopathologic evidence after hepatic surgery (n = 3), on imaging follow-up based on contrast-enhanced dynamic CT showing an increase in tumor size within 3 months (n = 2), or on typical enhancement pattern on contrast-enhanced MR imaging (n=11 patients) based on EASL [1] or ASL criteria [2].

**MR imaging**

The MR imaging examination was performed within one month from contrast-enhanced CT using a superconducting magnet operating at 1.5 T (Achieva, 1.5T release 2.1.3.4, Philips Healthcare, Best, The Netherlands) with a peak gradient amplitude of 30 mT/m and a peak slew rate of 150 T/m/sec. Images were acquired in the transverse plane with a combined four-channel anteroposterior phased-array surface coil. Parallel imaging with a sensitivity-encoding (SENSE) technique with a factor of 1.5 − 1.7 was employed. A three-quarter field of view was used in the phase-encoding direction. Presaturation pulses were applied above and below the imaging volume to diminish flow artifacts.

The baseline MR imaging examination included a breath-hold fast spin-echo T2-weighted MR imaging sequence, a fat-suppressed T2-weighted sequence, a T1-weighted in-phase and out-of-phase sequence, and a fast-field echo T2-weighted sequence. Dynamic MR imaging was performed before and after gadobenate dimeglumine (Gd-BOPTA, 0.1 mmol/kg; 2 mL/sec) injection via a forearm or antecubital vein at 2 mL/sec through a 18-gauge intravenous catheter employing an automated agent injection. The delay time after i.v. contrast injection for the hepatic arterial phase was calculated by test – bolus and bolus – tracking techniques. Test – bolus versus bolus – tracking technique. Inter-observer agreement was considered as slight for an ICC of <0.21, fair for a value of 0.21–0.40, moderate for a value of 0.41–0.60, good for a value of 0.61–0.80, and optimal for a value of 0.81–1.00.

For all tests a P value < .05 was considered to indicate a statistically significant difference.

**Results**

Tables 1 show the results of SNR and CNR of test - bolus and bolus - tracking techniques.

Test - bolus and bolus - tracking techniques did not differ in the estimation of the correct delay time for the hepatic arterial phase at contrast-enhanced MR imaging in patients with HCC in liver cirrhosis. There was good correlation (r=0.85) and agreement (ICC=0.9) between the delay times (25-27 seconds) for the hepatic arterial phase calculated by test – bolus and bolus – tracking techniques. Test – bolus versus bolus – tracking techniques did not differ both in SNR (301.2 ± 154.54 vs. 330.77 ± 240.75; P=0.89 Mann-Whitney U test) and CNR (24.5 ±
Table 1a. Test - Bolus data.

<table>
<thead>
<tr>
<th>Patient</th>
<th>ROI Liver</th>
<th>ROI Lesion</th>
<th>ROI Air</th>
<th>SNR</th>
<th>CNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>640 ± 96.6</td>
<td>802.4 ± 10</td>
<td>14.5 ± 17.2</td>
<td>162.4</td>
<td>11.2</td>
</tr>
<tr>
<td>2</td>
<td>869.4 ± 10.4</td>
<td>1041.1 ± 88.9</td>
<td>20.1 ± 12.8</td>
<td>171.7</td>
<td>8.54</td>
</tr>
<tr>
<td>3</td>
<td>597.5 ± 72.2</td>
<td>989.8 ± 30.9</td>
<td>1.5 ± 9.8</td>
<td>392.3</td>
<td>41.29</td>
</tr>
<tr>
<td>4</td>
<td>762 ± 32.3</td>
<td>1278.2 ± 60.9</td>
<td>14.4 ± 16.6</td>
<td>516.2</td>
<td>35.84</td>
</tr>
<tr>
<td>5</td>
<td>450.6 ± 26.6</td>
<td>760 ± 54.9</td>
<td>12.3 ± 16.8</td>
<td>309.4</td>
<td>25.15</td>
</tr>
<tr>
<td>6</td>
<td>715.9 ± 31.1</td>
<td>1020 ± 59.6</td>
<td>216 ± 16.8</td>
<td>304.1</td>
<td>14.48</td>
</tr>
<tr>
<td>7</td>
<td>564.1 ± 54.3</td>
<td>664.7 ± 26.3</td>
<td>14 ± 9.3</td>
<td>100.6</td>
<td>7.18</td>
</tr>
<tr>
<td>8</td>
<td>769.2 ± 65.6</td>
<td>990.2 ± 21.2</td>
<td>15.7 ± 11.8</td>
<td>221</td>
<td>14.07</td>
</tr>
<tr>
<td>9</td>
<td>201.9 ± 5.6</td>
<td>735 ± 11</td>
<td>8.5 ± 12.3</td>
<td>533.1</td>
<td>62.71</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>618.96 ± 200.42</td>
<td>920.16 ± 194.16</td>
<td>13.71 ± 3.17</td>
<td>301.2 ± 154.54</td>
<td>24.5 ± 18.74</td>
</tr>
</tbody>
</table>

Table 1b. Bolus - Tracking data.

<table>
<thead>
<tr>
<th>Patient</th>
<th>ROI Liver</th>
<th>ROI Lesion</th>
<th>ROI Air</th>
<th>SNR</th>
<th>CNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>428.4 ± 80.6</td>
<td>604.2 ± 70.2</td>
<td>11.9 ± 10.3</td>
<td>175.8</td>
<td>14.77</td>
</tr>
<tr>
<td>11</td>
<td>484 ± 96.2</td>
<td>811.40 ± 17.6</td>
<td>19.6 ± 11.8</td>
<td>327.4</td>
<td>16.7</td>
</tr>
<tr>
<td>12</td>
<td>1032.7 ± 53.7</td>
<td>1270.6 ± 86.6</td>
<td>16.1 ± 22.3</td>
<td>237.9</td>
<td>14.77</td>
</tr>
<tr>
<td>13</td>
<td>1003.8 ± 37.9</td>
<td>1041 ± 92.3</td>
<td>15.1 ± 13.1</td>
<td>37.2</td>
<td>2.46</td>
</tr>
<tr>
<td>14</td>
<td>772.6 ± 28.1</td>
<td>1427 ± 28.8</td>
<td>20.5 ± 7.1</td>
<td>654.4</td>
<td>31.92</td>
</tr>
<tr>
<td>15</td>
<td>705.7 ± 61.2</td>
<td>1468.8 ± 66.3</td>
<td>16.3 ± 9.5</td>
<td>763.1</td>
<td>46.81</td>
</tr>
<tr>
<td>16</td>
<td>527.5 ± 21.6</td>
<td>636.8 ± 34.7</td>
<td>23.9 ± 18</td>
<td>109.3</td>
<td>4.57</td>
</tr>
<tr>
<td>17</td>
<td>866 ± 45.6</td>
<td>1156.5 ± 35.8</td>
<td>17.2 ± 13</td>
<td>290.5</td>
<td>16.88</td>
</tr>
<tr>
<td>18</td>
<td>276.8 ± 14.7</td>
<td>658.1 ± 13.2</td>
<td>15.7 ± 7.5</td>
<td>381.3</td>
<td>24.28</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>677.5 ± 264.7</td>
<td>1008.27 ± 343.13</td>
<td>17.37 ± 3.5</td>
<td>330.77 ± 240.75</td>
<td>19.24 ± 13.67</td>
</tr>
</tbody>
</table>

18.74 vs. 19.24 ± 13.67; P=0.89).

Discussion

The first finding of our study was that test – bolus and bolus – tracking techniques did not differ in the estimation of the correct delay time for the hepatic arterial phase at contrast-enhanced MR imaging to visualize hypervascular HCC nodules in a background of liver cirrhosis. The test – bolus and bolus – tracking techniques present a good correlation and agreement for the timing of hepatic arterial phase. Bolus chase may be applied in the place of the bolus test, for those sequences with an early filling of the center of the K-space, to calculate the correct delay time for the hepatic arterial phase at contrast-enhanced MR imaging. This study shows evidence that accurate capture of liver arterial phase can be attributed mostly to the ability of real-time bolus tracking to resolve the strong variance in contrast arrival time into the aorta.

Theoretically, test - bolus technique provides the most accurate determination of the acquisition delay time for the hepatic arterial phase. The use of fluoroscopic triggering is appropriate only for MR sequences with which the high-contrast central portion of k-space is filled first, at the beginning of the acquisition, as in the present study. Contrary to the 3D THRIVE sequences with centric K-space acquisition used in this study, conventional 3D gradient-echo sequences typically employ a sequential k-space acquisition with data acquired linearly or radially over many segments while the center of k-space is passed multiple times over the scan duration. As a consequence this averages the dynamic image contrast, such that the middle of the acquisition is representative of the peak contrast on the MR images. For these methods of K-space acquisition the test – bolus technique remains the most appropriate technique to be used in the calculation of the timing for the correct hepatic arterial phase in cirrhotic patients with HCC.

The second finding of the present study was the absence of difference between the SNR and CNR of HCC between test – bolus and bolus – tracking techniques. This can allow to use undifferently the two timing techniques if centric K-space acquisition is employed in dynamic contrast-enhanced MR imaging.

The main limitation of the present study is that an independent patient sample analysis was performed instead of paired data analysis with intra-individual comparison.

In conclusion test - bolus vs. bolus - tracking did not differ in the timing of hepatic arterial phase in patients with HCC.

References

prospective randomized study in patients with chronic liver damage. *Radiology* 225: 407–415. [Crossref]
