Automatic bolus tracking
in monophasic spiral CT of the liver:
liver-to-lesion conspicuity

Florian Mehnert
Philippe L. Pereira
Jochen Trübenbach
Andreas F. Kopp
Claus D. Claussen

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Abstract The aim of this study was to evaluate the value of automatic bolus tracking for monophasic spiral CT of the liver and to assess the liver-to-lesion conspicuity in comparison with time-delay examinations. In 40 patients scheduled for therapy control of known hypovascular hepatic metastases a monophasic spiral CT was completed either with time delay of 65 s (n = 20) or with automatic bolus tracking in the liver parenchyma (n = 20). Examinations were performed with 120 ml of contrast material and a flow rate of 3.0 ml/s. For automatic bolus tracking a parenchymal enhancement threshold of 40 HU was used. Contrast enhancement in the liver parenchyma and in liver lesions was obtained by means of regions of interest (ROI). Mean parenchymal enhancement was not significantly different between time delay and bolus-tracking group. In 4 of 20 patients in the bolus-tracking group the threshold level of 40 HU was not reached. With automatic bolus tracking a significantly higher liver-to-lesion density difference was observed (P < 0.0001). Automatic bolus tracking allows a better liver-to-lesion conspicuity in monophasic spiral CT. Contrary to recent studies, a significantly higher parenchymal enhancement was not found using automatic bolus tracking.

Key words Helical CT · Liver lesions · Monophasic bolus tracking

Introduction

Computed tomography of hypovascular liver lesions is usually performed in the portal-venous phase of hepatic enhancement. In this phase contrast enhancement of the liver is at peak giving the best contrast to hypovascular lesions [1]. Nevertheless, there has been controversy in the literature about the optimal time delay as well as the volume and rate of contrast material administration [2, 3, 4, 5]. Spiral CT scanners with short acquisition time can optimize the contrast and allow multiphasic examinations [6, 7, 8, 9, 10]. The shortness of the spiral scan, however, can lead to a more difficult timing of the different perfusion phases.

Automatic bolus tracking is a computer-assisted technology that allows automatic initiation of a spiral scan upon the contrast enhancement itself using low-dose scans. This technique promises easier timing by individualization of the time delay [11, 12, 13]. It has been shown that this technique can improve timing of the hepatic arterial phase in biphasic spiral CT of the liver [14]. For scanning in the portal-venous phase a higher parenchymal enhancement has been demonstrated using bolus tracking, thus permitting a volume reduction of contrast material [15].

The purpose of this study was to examine if automatic bolus tracking could lead to higher parenchymal enhancement and better focal liver-to-lesion conspicuity in the portal-venous phase.
Patients and methods

We prospectively examined 40 patients (24 men and 16 women; age range 21–77 years, median age 62 years) with known hypovascular liver metastases. Patients were referred for control of lesion size in the course of disease under treatment. In the first randomized group (n = 20) monophasic spiral CT in the portal-venous phase was performed with a constant time delay of 65 s after contrast material administration (group 1). The second group (n = 20) underwent monophasic spiral CT of the liver with an individual delay determined by automatic bolus tracking in the liver parenchyma (group 2). Average weight was 69.1 ± 12.0 kg in group 1 and 72.8 ± 14.3 kg in group 2. The underlying primary malignancies were colorectal carcinoma (n = 27), breast carcinoma (n = 8), pancreatic carcinoma (n = 1), bronchial carcinoma (n = 1), oropharyngeal cancer (n = 1), Hodgkin’s disease (n = 1), and malignant thymoma (n = 1).

After giving their informed consent, all patients were examined using a spiral CT scanner (Somatom Plus 4, Siemens, Erlangen, Germany). Scan parameters were: collimation 8 mm; pitch 1.5; rotation time 0.75 s; 120 kV, and 240 mA. Images were reconstructed at 7-mm increments using a standard reconstruction kernel and 180° linear interpolation.

Automatic bolus tracking was performed with assistance of the software CARE Bolus (Siemens, Erlangen, Germany) which is implemented at the CT scanner. This procedure is based on repetitive monitoring scans at one slice level during respiration and analysis of a time–density curve in a chosen ROI to determine the optimal individual time delay. The monitoring scans are performed at 50 mA with scan time of 0.5 s. As soon as a predefined contrast enhancement threshold within the ROI is reached, the spiral scan is initiated. There is a technically required time interval of 7–10 s between initiation and beginning of the scan which is used for repositioning of the table and breathing command to the patient.

Firstly, an unenhanced spiral CT of the liver was performed before contrast administration in all patients included in the study. For contrast enhancement, 120 ml of Iopromid (Ultravist 300, Schering, Berlin, Germany) was injected in an antecubital vein with a power injector at a flow rate of 3.0 ml/s.

In group 1 the standardized delay for the scan in the portal-venous phase was 65 s after beginning of contrast media administration. In group 2 the slice level of the monitor scans during bolus tracking was chosen 3 cm below the diaphragm as shown on the inspiratory tophogram. At this slice level the liver is shown on all images during quiet breathing. A circular ROI with an area of 5 cm² was placed within the parenchyma at a ventrolateral part of the liver avoiding large vessels and hepatic lesions. The enhancement threshold for initiation of the diagnostic scanning was set at a parenchymal enhancement of 40 HU. The low-dose monitoring scans were started with a delay of 40 s after beginning of contrast injection, and the scans were repeated every 5 s. The diagnostic portal-venous scan began 7–10 s after passing of the threshold level.

The precontrast hepatic density was measured by calculating the mean of six ROI measurements (area of each ROI: 5–15 cm²) determined at six slice levels. On the postcontrast scans the mean attenuation of normal parenchyma for each slice separately was assessed by the mean of three ROI measurements with area of at least 3 cm². At the most three upper and three lower liver scans only two ROI measurements were performed. At all ROI measurements in the liver parenchyma large intrahepatic vessels, liver lesions, or partial-volume effects were avoided. The overall mean hepatic density was calculated.

In all patients of group 1 and 2 postcontrast attenuation of the hepatic lesions was assessed. Every lesion with at least 1.0 cm in diameter was included. The ROI measurement of each lesion was done at the slice level that showed the lesion most centrally avoiding calcifications and any peripheral rim enhancement. Lesion-to-liver density differences were calculated subtracting the attenuation of the lesion from parenchymal attenuation at the same slice level.

Statistical analysis was performed by Student’s t-test for unmatched samples with comparison of group 1 (time delay) and group 2 (automatic bolus tracking). The significance level was considered significant at p < 0.05.

Results

In the group of 20 patients who received a bolus-triggered monophasic spiral CT (group 2) bolus tracking in the liver parenchyma was effective only in 16 cases. In 4 patients the threshold level of 40 HU was not reached in the liver parenchyma. The maximum contrast enhancement of these patients measured in the ROI were 39.7, 35.8, 34.1, and 25.2 HU, respectively. In these patients the spiral scan was started manually when peak parenchymal enhancement was passed. There were no cases of failure, because the ROI was displaced out of the liver parenchyma during quiet breathing. In 16 patients where bolus-tracking technique was successful, the threshold of 40 HU was reached between 40 and 65 s (mean 51.9 ± 7.9 s). The time between initiation and start of the spiral scan was 8.4 ± 1.0 s. In these 16 patients the automatically triggered start delay for the monophasic spiral scan was 59.9 ± 7.7 s (range 49–73 s).

The number of low-dose scans was 3.4 ± 1.6 (range from 1 to 6) in these patients (n = 16) and 7.8 ± 1.0 in patients where automatic bolus tracking failed (n = 4), corresponding to an additional exposure of 106 ± 58 mAs.

The precontrast hepatic density of the patients was not significantly different (P = 0.31) between group 1 (60.1 ± 9.8 HU) and group 2 (58.1 ± 12.0 HU). The 4 cases in group 2, in which automatic bolus tracking failed, had a mean precontrast density of the liver of 60.3 ± 1.0 HU, and the 16 cases with successful bolus triggering of 60.0 ± 11.0 HU. The mean postcontrast density of normal liver parenchyma was 116.2 ± 18.4 HU in the time delay group and 116.9 ± 21.0 HU in the bolus-tracking group (Table 1). The mean parenchymal contrast enhancement was not significantly different: 58.2 ± 12.5 HU in time delay group vs 56.9 ± 17.5 HU in bolus-triggered group (P = 0.39). Considering only the 16 patients with successful bolus tracking, the mean parenchymal contrast enhancement (62.3 ± 15.1 HU) was also not significantly different compared with the time-delay group (P = 0.19). For the 20 patients in group 1 we included a total number of 189 liver lesions for evaluation. The 20 patients in group 2 showed 109 lesions that met the above-mentioned inclusion criteria. The average lesion density was 80.5 ± 16.1 HU for patients examined with time delay and 68.5 ± 16.3 HU for bolus-