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Comparison of three different injection methods for arterial phase of Gd-EOB-DTPA enhanced MR imaging of the liver

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ABSTRACT

Objective: To compare three different injection methods for optimizing hepatic arterial phase of gadolinium ethoxybenzyl diethylenetriaminepentaacetic acid (Gd-EOB-DTPA) enhanced MR imaging.
Methods: Arterial phase images were obtained after the injection of contrast agent at a rate of 3 mL/s with diluted Gd-EOB-DTPA (dilution method) in 27 patients, 3 mL/s with undiluted Gd-EOB-DTPA (3 mL method) in 26 patients and 1 mL/s with undiluted Gd-EOB-DTPA (1 mL method) in 28 patients. In the quantitative evaluation, signal-to-phantom ratios (SPR) of the liver parenchyma, pancreas, renal cortex, portal vein and aorta were evaluated. In the qualitative evaluation, the seven items for image quality of hepatic arterial phase were assessed, and the total score of all items in each subject was calculated.
Results: The score of enhancement of abdominal aorta and total score of seven items in 1 mL method were significantly higher than those in 3 mL method. The SPR of the liver parenchyma in 3 mL method was significantly higher than that in 1 mL method, suggesting substantial hepatic inflow from portal venous return.
Conclusion: For the optimal arterial phase imaging, injection rate of 1 mL/s with undiluted Gd-EOB-DTPA is convenient and preferable, compared with other two methods, based on our qualitative analysis.

1. Introduction

Gadolinium ethoxybenzyl diethylenetriaminepentaacetic acid (Gd-EOB-DTPA) is a recently introduced liver specific contrast agents for magnetic resonance (MR) imaging of the liver that offers both hepatobiliary phase imaging reflecting specific uptake by the hepatocytes obtained at about 20 min after contrast agent administration and the vascular phase imaging reflecting perfusion obtained at few minutes after contrast agent administration like nonspecific extracellular Gd chelates. In several clinical studies, Gd-EOB-DTPA has demonstrated satisfactory results in the detection and characterization of hepatic tumors. [1–6].

On contrast-enhanced dynamic MR imaging (CE-MRI) using Gd-EOB-DTPA as well as extracellular contrast agents (e.g. gadolinium diethylenetriaminepentaacetic acid (Gd-DTPA)), arterial phase imaging is essential for the detection and the characterization of the hypervascular tumor such as hepatocellular carcinomas and hepatic hemangiomas. The recommended injection dose and injection volume of Gd-EOB-DTPA is one fourth (0.025 mmol/kg of Gd-EOB-DTPA vs. 0.1 mmol/kg of Gd-DTPA) and half of Gd-DTPA (0.1 mL/kg of Gd-EOB-DTPA vs. 0.2 mL/kg of Gd-DTPA), respectively [7], although the T1 relaxivity of Gd-EOB-DTPA measured in human blood at 1.5-T is double, compared with standard gadolinium chelates [8]. Therefore, if Gd-EOB-DTPA is injected at the clinically well used method, that is a rate of high flow (ie, 3 mL/s) with a fixed scan timing (e.g. 30 s after contrast agent administration) like a CE-MRI obtained with Gd-DTPA, the acquisition of the images of optimal timing for arterial phase may be difficult due to the short injection duration and the short peak aortic enhancement time. In addition, because such an inappropriate scan timing of arterial phase with the inflow of high concentration of contrast agent may induce the rapid signal increase in the center of k-space and the magnetic field homogeneity during signal acquisition, the image artifacts such as ringing artifact and ghost artifact may appear [9–13]. For these problems, in some studies, the utilities of the slower injection method such as 1 mL/s [14,15] and the dilution method [16] have been reported. To the best of our knowledge, however, no clinical studies comparing these recommended two methods for optimal scan timing of arterial phase of Gd-EOB-DTPA enhanced imaging have yet been published.

The aim of this study was to compare the dilution method, the slow flow injection method and the high flow injection method for optimizing hepatic arterial phase of CE-MRI obtained with Gd-EOB-DTPA.

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2. Materials and methods

2.1. Subjects

This study was approved by the ethics committee at our institution and informed consent for investigative review of patient medical images was obtained from all subjects.

Between October 2008 and April 2009, 95 consecutive patients underwent Gd-EOB-DTPA-enhanced MR imaging of the liver including CE-MRI at our institution. All cases had been referred for MR imaging on suspicion of liver diseases. 14 patients were excluded based on the following criteria; incomplete examination by apparent body movement ($n = 12$; Group 1 in 5, Group 2 in 4 and Group 3 in 3); presence of multiple liver tumors occupying whole liver parenchyma ($n = 1$); and acute liver injury showing the strong liver parenchymal enhancement in the arterial phase imaging ($n = 1$). The final study population comprised these 81 patients (55 men, 26 women) with a mean age of 65 years (range, 32–88 years). Forty two patients (52%) were diagnosed with no focal liver lesion on MR imaging. Of the remaining 39 patients (48%), 19 had hepatocellular carcinoma (HCC), 1 had suspected hyperplastic nodule, 10 had metastatic liver tumor (breast cancer in 2, esophageal cancer in 1, gastric cancer in 3, small intenstinal carcinoma in 1, and colorectal cancer in 3), 2 had cholangiocarcinoma, 4 had hepatic hemangioma, 2 had suspected intrahepatic biliary cystadenoma, and 1 had suspected focal nodular hyperplasia. Among 81 patients, 50 had chronic liver diseases. Causes of chronic liver disease included type C viral hepatitis ($n = 28$), alcohol abuse ($n = 4$), type B viral hepatitis ($n = 12$), mixed type B and type C hepatitis ($n = 1$), nonalcoholic steatohepatitis ($n = 2$), and cryptogenic cirrhosis ($n = 3$). Twenty eight patients had cirrhosis and the remaining 22 did not. Thirty one patients without a known underlying chronic liver disease had the following clinical histories: known or suspected metastatic liver disease in 17 patients and suspected focal hepatic lesion found incidentally in a previous ultrasound or CT in 14.

2.2. MR imaging technique

MR imaging was performed using a 1.5-T scanner (Signa Excite High speed; General Electric, Milwaukee, WI; maximum gradient amplitude, 33 mT/m; maximum slew rate, 77 mT/m/s). An 4-channel phased-array torso coil was used for signal reception. Imaging was performed under fasting conditions in all subjects.

The liver was scanned along with a phantom (1.00 g/L nickel chloride) placed in a fixed position in the posterior side of the subject in the magnetic field. The length of the phantom was 15 cm, covering almost the whole liver in the z-axis direction. CE-MRI was performed before and after administration of Gd-EOB-DTPA (Primovist; Bayer Schering Pharma, Osaka, Japan) using a three-dimensional (3D) T1-weighted GRE sequence (repetition time (TR), 4.7 ms; echo time (TE), 2.2 ms; flip angle, 12°; bandwidth, 62.5 kHz; parallel imaging factor, 2; field of view (FOV), 35×35 cm; slice thickness, 2.2 or 2.5 mm; matrix, 320×192; k-space trajectory, centric order) with fat-suppression technique covering the liver and the bilateral kidneys. The images were obtained in the axial plane. Acquisition time was 20 s. After the acquisition of unenhanced MR images, Gd-EOB-DTPA at a dose of 0.025 mmol/kg body weight was injected into an antecubital vein through a 22-gauge catheter using a power injector (Sonic Shot 50; Nemoto Kyorindo, Tokyo, Japan) while the patient was in the bore of the magnet. Arterial phase imaging was started after the visually confirmed arrival of the contrast agent to the abdominal aorta using a fluoroscopic triggering injection method. Subsequent CE-MRI was initiated at 70 s, 3 min, 10 min, 15 min, and 20 min after the start of bolus injection to obtain multiphasic images (representing portal phase (PP), equilibrium phase (EP), and three times in the HP, respectively).

2.3. Gd-EOB-DTPA injection methods

These patients were divided into three groups according to the following Gd-EOB-DTPA injection methods.

Group 1: Contrast agent dilution method (dilution method, $n = 27$): before injection, Gd-EOB-DTPA was diluted with saline of double dose of contrast agent to make a 33% of diluted Gd-EOB-DTPA. The diluted Gd-EOB-DTPA was administered at the rate of 3 mL/s.

Group 2: Contrast agent undilution with high flow method (3 mL method, $n = 26$): The undiluted Gd-EOB-DTPA was administered at the rate of 3 mL/s.

Group 3: Contrast agent undilution with slow flow method (1 mL method, $n = 28$): The undiluted Gd-EOB-DTPA was administered at the rate of 1 mL/s.

In each group, a 30-mL flush with normal saline at the same rate of Gd-EOB-DTPA injection was performed.

2.4. Image analysis

In quantitative analysis, CE-MR images obtained at arterial phase were reviewed using a PACS monitor in all subjects.

The signal intensities (SIs) of liver, pancreas, adrenal gland, renal cortex, portal vein, aorta and phantom were measured using regions of interest (ROIs). Two radiologists with 11 (T.T.) and 7 years (H.H.) of experience in abdominal MR imaging set all ROIs by consensus. Each ROI was a circle or oval since the ROI placement was performed by free hand using the circle item of PACS. The size of each ROI was chosen as large as possible. For SI measurements of liver parenchyma, the ROI was placed at a location in both the right and the left lobe, avoiding liver tumors, if present. When the ROI was set, great care was also taken to exclude the large vessels to reduce any errors in SI measurements from macroscopic flow, and the ROI placement in the patients with chronic liver disease including liver cirrhosis was performed at the region with most homogeneous liver parenchymal SI considering liver inhomogeneity, excluding the nodular areas or shunts. If a lesion such as cyst, hemangioma or HCC as well as dilated intrahepatic bile ducts was present in the liver with reference to images from other MR sequences, the lesion was excluded from the ROI placement. For SI measurements of other organs, the ROI was placed at a location of the body for pancreas, and a location of bilateral renal cortex for kidney. For SI measurements of portal vein, the ROI was placed in the main branch or right branch. For SI measurement of the aorta, ROI placement was performed at a level with homogeneous signal intensity considering flow phenomenon, excluding the vessel wall. The SI of the liver parenchyma and renal cortex was defined as the mean of the SIs in both the left and right region of the liver and the renal cortex. The ROI placement of the phantom was performed in a same slice where the each ROI of liver parenchyma, pancreas, renal cortex, portal vein, and aorta was set.

Signal-to-phantom ratios (SPRs) of the liver parenchyma, the pancreas, the renal cortex, the portal vein and the aorta at arterial phase were calculated from SI values of liver parenchyma (SI liver), pancreas (SI pancreas), renal cortex (SI kidney), portal vein (SI PV), aorta (SI aorta) and phantom (SI phantom) as: (SI liver/SI phantom, SI pancreas/SI phantom, SI kidney/SI phantom, SI PV/SI phantom, and SI aorta/SI phantom).

For qualitative analysis, CE-MR images acquired before and after administration of contrast agent (arterial phase) were reviewed in all subjects to visually assess the seven items for image quality. Areas of apparent malignant liver tumors or regions peripheral to the tumor were not considered in this visual assessment. The