3D Contrast-Enhanced MR Angiography of the Abdominal Aorta and Its Distal Branches: Interobserver Agreement of Radiologists in a Routine Examination[1]

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Rationale and Objectives. To evaluate the quality of images of the aorta and visceral arteries made at a high level of spatial resolution with thin slices and an optimized acquisition time by three-dimensional contrast-enhanced magnetic resonance angiography (3D CE-MRA).

Materials and Methods. 3D CE-MRA with a 1.4-mm slice thickness and 512-pixel base matrix was done on 62 consecutive patients with a 1.5-T magnetic resonance imaging MRI unit. A bolus test with a power injector was used to calculate the optimal scan delay time. For quantitative evaluation, the signal-to-noise ratio (SNR) was measured in 3 regions of interest. Qualitative image analysis was evaluated independently by two radiologists and graded on a scale of 0–3. Separate analyses were done for the aorta and distal visceral arterial branches.

Results. The means SNR values were respectively 56.2 ± 15.2 (mean ± SD) for the aorta, 59.2 ± 15.1 for the celiac trunk, and 57 ± 15.2 for the superior mesenteric artery, with a homogeneous distribution ($P = .99$). Consistent enhancement was confirmed by the lack of statistically significant differences between the SNR values. The average score for vessel visualization on source images ranged from good to excellent for different segments. After post-processing of images, the average score for distal arterial segments was significantly improved. The overall agreement between the 2 reviewers in the visualization of definite artery segments was excellent ($k = .91$).

Conclusion. 3D CE-MRA with a 512-pixel base matrix and thin slices can be applied in a reproducible way with excellent depiction and delineation of small vessels. Such a protocol could be used routinely.

Key Words. Angiography; aorta; magnetic resonance; visceral arteries.

The safety and accuracy of abdominal magnetic resonance (MR) angiography make it an ideal choice to evaluating the abdominal aorta and its major branches. Diagnostic methods for evaluating the hepatic blood supply gain importance because of the growing number of surgical and interventional treatment options for patients with liver cirrhosis and malignant liver or pancreatic disease. However, spatial resolution with MR angiography is still lower than with conventional angiography for the identification of distal arterial branches, and manual bolus injection of contrast medium does not allow accurate timing, creating a potential lack of arterial enhancement of multiple, successively enhancing structures, including parenchyma and veins. Since the early work of Prince et al. (1), 3D contrast-enhanced (CE)-MRA has been incorporated into clinical practice. In general, 3D CE-MRA is a

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useful method for the imaging of large vessels such as the aorta and its main branches, including the celiac, superior mesenteric, and renal arteries. Several strategies have been proposed to standardize the scanning approach for the different vascular territories (2–6). Nevertheless, 3D-CE-MRA remains complex, and the literature provides little consensus on the many different parameters used for timing of the bolus injection of contrast material, spatial resolution, scan orientation, and post-processing. The advantage of 3D CE-MRA of splanchnic arteries was previously described in studies done with a 256-pixel base matrix and a slice thickness of 2–3 mm (2,7–9). Good assessment was achieved with 3D CE-MRA for proximal segments of splanchnic arteries as compared to conventional angiography, which has been recommended for the imaging of distal segments because of poor 3D CE-MRA depiction (2).

As previously reported by others (1,2), we observed large discrepancies when using the same parameters as they used for evaluating distal branches of the celiac, mesenteric, and hepatic arteries. On the basis of this issue, we have implemented our own approach to 3D CE-MRA of these vessels by using high spatial resolution (a 512-base matrix), thin slices, and an optimized image-acquisition time. The purpose of the present study was to validate our routine protocol. In this validation, two radiologists evaluated image quality over a large population of patients for visualization of the aorta and visceral arteries.

MATERIALS AND METHODS

Patient Population

Between August 2002 and June 2003, 62 consecutive patients (42 men and 20 women; age, 57.1 ± 11.5 years [mean ± SD]; age range, 33–82 years) were referred to our institution for MR imaging, including MR angiography for various abdominal applications, including preoperative imaging of the pancreas (n = 21) and the liver and biliary tract (n = 18); and angiography following liver transplantation or for the assessment of partial hepatectomy (n = 6), for liver lesions seen with other imaging modalities (n = 8), and for miscellaneous other purposes (n = 9).

MR examinations included in the study were done for accepted clinical indications with respect to patient care. The sequences used in the MR examinations were part of our standard imaging protocol for the liver and pancreas. No patients were excluded.

Imaging Technique

All 3d CE-MRA examinations were done with a 1.5-T Symphony system (Siemens, Erlangen, Germany) with a 20 mT/m maximum gradient strength and 400 μsec minimum rise time. A body phased-array coil was used and was positioned so as to cover the volume of interest. Each patient included in the study was informed about the breath-hold requirements for imaging, and was instructed to hyperventilate before data acquisition and to breath-hold for as long as possible on end-inspiration during data acquisition. A 20-gauge venous catheter was placed in an antecubital or forearm vein before starting the MRA examination, and was attached to an MR-compatible power injector. First, gradient-echo scout MR images were made (TR/TE = 15/6 msec; flip angle = 30°; 128 × 256 matrix; 500-mm field of view [FOV]; 10-mm slice thickness; 5 slices). Images were made in three orthogonally oriented planes and were used for localization to allow accurate prescription and positioning of MR angiographic slabs.

For MRA examination, we used a 3D spoiled-gradient echo sequence with intermittent fat-saturation pulsing, performed in the coronal plane with two protocols in accordance with the indication of liver (L) or pancreatic (P) analysis. The imaging parameters were: TR/TE = 5.2/2 msec; flip angle = 25°; matrix = 192 × 512 pixels (L) and 177 × 512 pixels (P); mean FOV = 400 mm [range, 380 to 420 mm]; 6/8 rectangular FOV ratio; 80 (P) to 100 (L) mm slab thickness; 64 (L) and 56 (P) partitions; 1.79 mm (L) and 1.43 mm (P) slice thickness; 325 Hz-per-pixel receive bandwidth; and 22–25-second acquisition time. The pixel sizes were then: 1.78 × 0.82 mm^2 (L) and 1.42 × 0.75 mm^2 (P). To get such pixel sizes in a relatively short acquisition time, we performed an asymmetric k-space sampling in the readout and phase-encoding directions. Additionally, volume was interpolated in slices by using the zero filling technique, reducing the acquisition to only 32 phase encoding for 64 partitions. Gadopentate dimeglumine (0.2 mmol/kg body weight) was intravenously administrated intravenously as a bolus with a power injector, followed immediately by the injection of 20 mL of normal saline solution. The imaging protocol was completed with one contiguous data acquisition procedure (venous phase), with a 12-second delay between the arterial and venous acquisition.

Timing of Examination

Before the acquisition of MRA images, a timing sequence was performed to determine the arrival time of the contrast material at the sites of interest. This was done