Dynamic MR imaging of kidneys perfused with EOB-Gd-DTPA

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INTRODUCTION

Gadolinium-ethoxybenzyl-diethylenetriamine pentaacetic acid (Gd-EOB-DTPA) is a hepatobiliary contrast agent for MRI1-3. It was reported that Gd-EOB-DTPA is useful to detect liver tumors4,5 and differentially diagnose benign and malignant pathologies in the liver6,7. Since Gd-EOB-DTPA partially accumulates in the hepatocytes and bile via various transporters after intravenous injection, signal intensity in the liver increases on T1-weighted images. The signal intensity of the liver after Gd-EOB-DTPA injection depends on the Gd-EOB-DTPA uptake by hepatocytes and bile excretion. It is known that the Gd-EOB-DTPA accumulating in the kidney is excreted to the urine through glomerular filtration. Because Gd-DTPA is concentrated in the renal tubules after being filtered at the Bowman’s capsule, and since it is neither secreted nor reabsorbed, the concentrating and diluting function of the renal tubules can be studied by imaging techniques10,11. Since renal function can be evaluated with Gd-DTPA MR dynamic perfusion imaging12, it led us to believe that Gd-EOB-DTPA can also be used to evaluate renal function. With the development of MRI equipment and rapid imaging techniques, temporal resolution has improved greatly. However, no previous study has been carried out on renal function using Gd-EOB-DTPA. Therefore, in this study we evaluated kidney perfusion (excretion) using a Gd-EOB-DTPA dynamic MR study that was correlated with estimated glomerular filtration rate (eGFR) and stage of chronic kidney disease (CKD) in the Japan Association of chronic kidney disease initiative.

MATERIALS AND METHODS

From December 2008 to June 2009, Gd-EOB-MRI studies were performed in 112 patients, but with excretion criterion (non-tolerant to breath holding or another protocol) for 50 patients (27 males and 23 females; 31-83 years old; mean 64.5 years). The patients in the study group included hepatocellular carcinoma in 16, liver metastasis in 19, hepatitis/liver cirrhosis in 8, and others in 7. Informed consent was obtained from all patients. The study was performed with the approval of the local ethical committee.
Estimated glomerular filtration ratio (eGFR, mL/min/1.73 m²) was evaluated prior to MRI study. MRI was performed on a 1.5-T unit (Signa HDX 1.5T, Milwaukee, WI, USA). The examination was performed with three-dimension liver acceleration volume acquisition (LAVA) sequences (8-channel phased-array coil, TR/TE/FA = 3.7 ms/1.8 - 11.0 ms/ 12 degrees, 320 x 192 matrix, field of view 360 x 288 x 160-200 mm, 4 mm slice, ASSET factor 1.5, k-space centric order, Band width 83.33 kHz, scan time 20 sec./phase). To evaluate the routine liver examination, Gd-EOB-DTPA (Risovist; Bayer, Berlin, Germany) was injected into the cubital vein (0.1 mL/kg, 2 mL/second) with a saline flush (20 mL, 2 mL/second). A power injector (Sonic Shot 50, Nemoto Kyorindo, Tokyo, Japan) was used in all patients. LAVA sequence was first performed with breath-holding without injection of contrast. For the free breathing interval, using the prep method (smart PrepTM), the following LAVA sequences were performed in each patient. The total LAVA sequences were performed at pre-contrast (0 minute), arterial phase (at 1 minute), with 25 seconds phase interval portal phase (at 2 minutes), with 30 seconds interval venous phase (at 3 minutes) and hepatocyte phase (at 15 minutes).

**DATA ANALYSIS**

Regions of interest (ROIs) were selected in the middle parts of the renal cortex of both kidneys. Measurements were made of ROIs delineating part of the image (signal intensity; SI). Despite the fact that the abdomen was restricted by a cummerbund during scanning, some motion interfered with accurate positioning of ROIs in the cortex. When images were scrolled, ROIs were individually modified to place over the cortex for frames in which they were improperly placed. For each phase, a corresponding circular ROI was placed in the background region just above the abdomen, and the standard deviation (SD) of the signal intensity in the ROI was defined as noise (SDnoise).

Signal noise ratio (SNR) was calculated with the following equation: SNR=SI/SDnoise. The mean SNR of the cortex was calculated with the values of the three ROIs. SNR was plotted as a function of time with EXCEL file (Microsoft, USA). Half time to peak (T1/2) (time from peak SNR to 1/2 peak SNR) was measured. Statistical significance (P<0.05) was calculated using the simple regression method compared with eGFR, and Fisher’s PLSD method compared with CKD stage.

**RESULTS**

eGFRs were calculated in all patients and ranged from 37.4 - 121.2 (mean 80.0) mL/min/1.73 m². According to the CKD staging, 19 patients were in stage 1 (eGFR > 90), 24 patients were in stage 2 (60<eGFR<90), and 7 patients were in stage 3 (30 < eGFR < 60).

The cortical signal intensity values were 49 in the right kidney and 47 in the left kidney. Three kidneys were excluded from measurement because they were not in field of view. T1/2 in right and left kidneys were: 38 - 799 (mean 318), and 36 - 839 (300) seconds, respectively. For patients in CKD stages 1&2, five phases were defined using dynamic contrast-enhanced MRI during the passage of contrast agent through the kidney, and excretion to the ureter. Clear corticomedullary differentiation was seen in the portal to venous phase. For CKD stage 3 patients, cortex tended to be atrophic, enhancement of the cortex and medulla tended to decline, and corticomedullary differentiation was blurry or lost.

Scattering figures (Fig.1) indicated a correlation tendency for lower eGFR in longer T1/2 and there was a significant correlation between eGFR and T1/2 (p<.05). Compare with CKD stages (Fig.2), there was a significant difference between stages and T1/2 (p<.05).
DISCUSSION

In this study, the three-dimension LAVA sequence was used because the liver image was evaluated in all patients. Most of the patients’ kidneys were in the field of LAVA view and these images were used for studying kidney morphology and function. LAVA sequence has a high temporal and spatial resolution in our protocol, and therefore can be used for dynamic study of renal function.

In the same way as scintigraphy, MR can evaluate the morphology and function of both kidneys. A LAVA sequence was used that provided better temporal resolution of the time-intensity curve. At the same time, using SNR plot protocol, the glomerular filtration function of each kidney was evaluated using T1/2 and was then correlated with the eGFR and the stage of CKD. Distal urological pathology can also be evaluated when the lesion is in the field of view. It might be useful also as another way in studying renal function.

In CKD patients, we found renal cortical atrophy or decline of cortical enhancement and delay of or unmeasurable T1/2, suggesting that pathologic changes resulted in decline of renal function. T1/2 delay was also correlated with decreasing eGFR and worsening of CKD staging. These results suggest that Gd-EOB-DTPA MR imaging can be useful in consistently demonstrating the degree of renal insufficiency and reflecting renal function.

Gd-EOB-DTPA was used for evaluating renal function. It is known that the Gd-EOB-DTPA transport correlates with liver function. The signal intensity of the liver after Gd-EOB-DTPA injection depends on the Gd-EOB-DTPA uptake by hepatocytes and bile excretion. Still undefined in Gd-EOB-DTPA imaging is what its effect on liver function has on renal function. When the patient has decreased liver function, resulting in a decreased or even non-visualization of the biliary extraction, renal excretion may be increased. Gd-EOB-DTPA cannot be used in the patients with severely damaged livers, wherein both liver and kidney functions are decreased. Further study is needed to evaluate the liver - kidney relation in Gd-EOB-DTPA MR imaging in multiple clinical conditions.

Certain problems were encountered in the course of this study. First, some patients could not hold their breaths and had to be excluded, because their kidneys moved in a cranial-dorsal to caudal-ventral direction, and rotated around the hilar vessels. For the renal function test, this is a disadvantage compared with scintigraphy. Second, when a patient’s torso is big and the kidney is outside of the field of view when evaluating the liver, the kidney cannot be evaluated with MR dynamic study. Clearly, MR renal function study, in itself, can be evaluated as previously reported.

We used the Gd-EOB-MR study in patients who were evaluated for liver images. Using this dynamic image, we wanted to examine the possibility of performing the renal function study in the same time as evaluating liver imaging. Third, when the patient has a CKD, contrast-enhanced MR study cannot be evaluated. Finally, for the patient who is claustrophobic, a MR study alone is difficult to perform.

CONCLUSION

A dynamic Gd-EOB-DTPA MR study was performed to evaluate renal function by measuring the SNR in the renal cortex and calculating its T1/2. This functional index consistently demonstrated the degree of renal insufficiency and reflected the eGFR.

SUMMARY

Gadolinium-ethoxybenzyl-diethylenetriamine pentaacetic acid (Gd-EOB-DTPA) is hepatobiliary contrast agent used for evaluation of Gd-EOB-DTPA. In this study, the three-dimension LAVA sequence was used that provided better temporal resolution of the time-intensity curve. At the same time, using SNR plot protocol, the glomerular filtration function of each kidney was evaluated using T1/2 and was then correlated with the eGFR and the stage of CKD. Distal urological pathology can also be evaluated when the lesion is in the field of view. It might be useful also as another way in studying renal function.

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REFERENCE


