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Original Article

Dynamic-contrast-enhanced magnetic resonance imaging of cirrhotic liver parenchyma: A comparison between gadolinium–diethylenetriamine pentaacetic acid and gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid

Chun-Yi Lin [a,b], Wei-Chou Chang [a,c], Chen-Te Chou [a,d], Ran-Chou Chen [a,e,*]

[a] *Department of Biomedical Imaging and Radiological Sciences, National Yang-Ming University, Taipei, Taiwan, ROC*
[b] *Department of Radiology, National Yang-Ming University Hospital, Yilan, Taiwan, ROC*
[c] *Department of Radiology, Tri-Service General Hospital and National Defense Medical Center, Taipei, Taiwan, ROC*
[d] *Department of Radiology, Changhua Christian Hospital, Changhua, Taiwan, ROC*
[e] *Department of Radiology, Taipei City Hospital, Taipei, Taiwan, ROC*

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Abstract

Background: The newly developed magnetic-resonance-imaging (MRI) hepatocyte-specific contrast agent, gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid (Gd–EOB–DTPA), has different excretion pathways from the conventional MRI contrast agent, gadolinium–diethylenetriamine pentaacetic acid (Gd–DTPA). In this study, we compare the enhancement effect of the liver and renal parenchyma between these two contrast agents for patients with liver cirrhosis.

Methods: We retrospectively included 49 consecutive patients with liver cirrhosis who underwent Gd–DTPA- and Gd–EOB–DTPA-enhanced MRIs within 3 months. We measured the signal intensity of the liver and kidney, and calculated the enhancement ratio (ER) in the arterial phase, portal venous phase, and venous phase (VP). We also calculated a delayed phase (DP) when Gd–DTPA was used, and a hepatocyte phase (HP) when Gd–EOB–DTPA was used. The ERs were compared between the two contrast agents. The effect of liver function on the ERs was also evaluated.

Results: The ER of the liver with Gd–EOB–DTPA was significantly higher than with Gd–DTPA in the VP ($p = 0.01$) and in the HP/DP ($p = 0.01$). The ER of the kidney in the DP with Gd–DTPA was significantly higher than in the HP with Gd–EOB–DTPA ($p < 0.001$). The ERs of the liver using Gd–EOB–DTPA for patients with normal serum bilirubin were significantly higher than those with abnormal levels ($p = 0.047$), but there was no significant difference using Gd–DTPA.

Conclusion: The enhancement effect of the liver parenchyma using both MRI contrast agents was not affected by the degree of liver cirrhosis or abnormal liver function. However, it was affected by the serum-bilirubin levels in the Gd–EOB–DTPA-enhanced MRIs. Furthermore, enhancement of the liver was higher when using Gd–EOB–DTPA in the VP, DP, and HP. This knowledge is helpful when performing dynamic MRIs to diagnose focal hepatic lesions in the heterogeneous liver parenchyma.

Keywords: Gd–DTPA; Gd–EOB–DTPA; liver cirrhosis; magnetic resonance imaging

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this paper.

* Corresponding author. Dr. Ran-Chou Chen, Department of Radiology, Taipei City Hospital, 12, Fu-Zhou Street, Taipei 100, Taiwan, ROC.
E-mail address: chenranchou@yahoo.com.tw (R.-C. Chen).

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1. Introduction

Magnetic resonance imaging (MRI) has become an important diagnostic modality for hepatic tumors. With advances in hardware and three-dimensional reconstruction techniques, MRIs can shorten the acquisition time and provide better imaging quality.[1−3] Contrast-enhanced images are important for diagnosing hypervascular tumors, such as hepatocellular carcinomas (HCCs).[4−6] The paramagnetic object, gadolinium (Gd), combined with the chelating agent, diethylenetriamine pentaacetic acid (DTPA), has been used as an MRI contrast agent for a long time. When injected intravenously, it distributes throughout the extracellular fluid, producing contrast enhancement in the T1-weighted image, and provides dynamic-enhanced information. Gd−DTPA is then completely excreted by the urinary system.

There are several hepatocyte-specific contrast agents, such as superparamagnetic iron oxide nanoparticles, gadobenate dimeglumine, and gadolinium−ethoxybenzyl−diethylenetriamine pentaacetic acid (Gd−EOB−DTPA).[7−9] Gd−EOB−DTPA is a newly developed hepatocyte-specific contrast agent with combined perfusion and hepatocyte-selective properties. With the lipophilic ethobenzyl group, it can enter hepatocytes via an organic anion-transport system, and is excreted into the biliary system (43.1−53.2%) and urinary system (41.6−51.2%) separately.[8−11]

The information obtained from contrast-enhanced MRIs provides different enhancement features for hepatic tumors and helps in the differential diagnosis. However, contrast uptake of the background liver parenchyma affects the appearance of hepatic tumors. The hepatic and renal functions may lead to different contrast uptakes of the liver parenchyma, especially for hepatocyte-specific contrast agents.[12−14] Most patients undergo Gd−EOB−DTPA-enhanced MRIs for the diagnosis of hepatic tumors, especially HCCs. Most of the HCCs develop in abnormal livers, such as those with diffuse liver disease or liver cirrhosis. The underlying liver disease, liver function, and renal function may play important roles in the diagnostic ability of contrast-enhanced MRIs. The different excretion pathways between Gd−EOB−DTPA and Gd−DTPA may also affect the enhancing pattern. The purpose of this study was to compare the differences in the enhancement of the liver and kidney between Gd−DTPA and Gd−EOB−DTPA for patients with liver cirrhosis.

2. Methods

2.1. Subjects

This study was approved by the Institutional Review Board of our hospital. We retrospectively included consecutive patients with hepatic tumors and liver cirrhosis. The inclusion criteria for patients were (1) having liver cirrhosis and the presence of hepatic tumors; (2) having no previously existing malignancy or treatment history; and (3) having undergone both Gd−DTPA- and Gd−EOB−DTPA-enhanced MRIs within the past 3 months. A total of 49 patients (32 men and 17 women; mean age: 59 years old, range: 28−80 years old) enrolled in this study from December 2009 to March 2012. Among them, all patients had liver cirrhosis (39 hepatitis B virus-related cirrhosis, 5 hepatitis C virus-related cirrhosis, 3 alcoholic cirrhosis, 1 both hepatitis B + C virus related, and 1 hepatitis B virus-related and alcoholic cirrhosis; 38 Child−Pugh class A disease, 9 Child−Pugh class B disease, and 2 Child−Pugh class C disease). Furthermore, we divided the patients into two groups (normal/abnormal) according to their serum-bilirubin levels and aspartate aminotransferase/alanine transaminase (AST/ALT), respectively, to assess the different enhancement effects in the serum bilirubin, AST/ALT, and Child−Pugh classifications.

2.2. Imaging methods

The MRIs were performed with a Achieva 1.5 T MRI scanner (Philips Healthcare, Eindhoven, The Netherlands) and a phased-array body coil. Prior to contrast-agent administration, turbo spin echo T2WI [repetition time/echo time (TR/TE): 1000−1800/110 milliseconds; slice thickness: 8 mm; gap: 0.8 mm; matrix: 192 × 256; turbo-spin-echo factor: 24; number of average (NEX): 2; flip angle: 90°; field of view (FOV): 38−40 cm] with and without fat saturation, and coronal T2WI were obtained under a respiratory trigger. Dual T1WI (TR/TE: 180/2.3/4.6; slice thickness: 8 mm; matrix: 192 × 256; NEX: 1; flip angle: 10°; FOV: 38−40 cm) and fat sat T1WI were performed during one breath hold. Automatic shimming was used for fat-suppression imaging to maximize the magnetic-field homogeneity. Flow compensation was also used.

All patients received 0.1 mmol/kg Gd−DTPA (Magnevist; Bayer Schering Pharma AG, Berlin, Germany) for the Gd−DTPA-enhanced MRI examination. All of them received 0.025 mmol/kg Gd−EOB−DTPA (Primovist; Bayer Schering Pharma AG) for the Gd−EOB−DTPA-enhanced MRI. The contrast agent was injected as a bolus at a speed of nearly 2 mL/second through peripheral veins. Dynamic three-dimensional T1-weighted fast-field-echo sequence (TR/TE: 5−10/3.3 milliseconds; slice thickness: 5 mm; matrix: 192 × 256; NEX: 1; flip angle: 10°; FOV: 38−40 cm) was carried out before, in 8−20 seconds [arterial phase (AP)], 50−55 seconds [portal venous phase (PP)], and 85−90 seconds [venous phase (VP)] following the contrast-agent injection. In addition, delayed-phase (DP) images (180 seconds after the injection of the contrast agent) were acquired when Gd−DTPA was used, and hepatocyte-phase (HP) images (20 minutes after the injection of the contrast agent) were acquired when the Gd−EOB−DTPA was used.

2.3. Imaging analysis

Two experienced radiologists with more than 15 years' experience in abdominal MRI reviewed all the Gd−DTPA- and Gd−EOB−DTPA-enhanced MRI images. Any difference of opinion between the two radiologists was resolved by a third radiologist who was also blinded to the clinical information.

The imaging analysis was performed at a dual-screen diagnostic workstation (GE Healthcare, Milwaukee, WI, USA). The signal intensities (SIs) of the liver and kidney were measured by the radiologists using regions of interest (ROI). Each ROI was a circle or oval. For measurements of the liver parenchyma, the ROI with an area of at least 200 mm^2 was placed at a location in the right posterior segment and devoid of large vessels. For SI measurements of the kidney, the image was magnified up to two times because of the organ's small size. The ROI with an area of at least 10 mm^2 was located in the bilateral renal cortex and medulla. The SIs were measured twice and the measurements averaged. The enhancement ratio (ER) of the liver and kidney at all phases was calculated from the SI measurements before (SI pre) and after (SI post) administration of Gd–DTPA or Gd–EOB–DTPA. The ratio is (SI post − SI pre)/SI pre. The differences in the ERs between the two contrast agents were evaluated.

2.4. Statistical analysis

The data were presented as mean ± standard deviation. The different ERs from the Gd–DTPA and Gd–EOB–DTPA for the liver, renal cortex, and renal medulla at all phases were compared by linear mixed models. The linear mixed model was also used to analyze the differences in the ERs for the Gd–DTPA and Gd–EOB–DTPA in the different serum bilirubin, AST/ALT, and Child–Pugh classifications. Interobserver differences between the two observers were evaluated with the kappa test and interpreted as moderate for $0.4 < \kappa \leq 0.60$, good for $0.6 < \kappa \leq 0.80$, and excellent for $\kappa > 0.80$. Statistical analyses were performed using SAS (version 9.2; SAS Inc., Cary, NC, USA). A p value of <0.05 was considered statistically significant.

3. Results

The interobserver agreement by the kappa analysis showed excellent agreement ($\kappa = 0.91$). The ER results of the liver and kidney at dynamic study, DP, and HP obtained with Gd–DTPA and Gd–EOB–DTPA are summarized in Table 1. Comparing the enhancement effect of the liver between the Gd–DTPA and Gd–EOB–DTPA, the ER of the liver in VP with Gd–EOB–DTPA (0.47 ± 0.46) was significantly higher than with Gd–DTPA (0.32 ± 0.44) ($p = 0.01$). The ER in HP with Gd–EOB–DTPA (0.49 ± 0.53) was significantly higher than in DP with Gd–DTPA (0.33 ± 0.45) ($p = 0.01$) (Figs. 1 and 2). Over all the phases, the average ER of the liver with Gd–EOB–DTPA (0.40 ± 0.42) was significantly higher than with Gd–DTPA (0.28 ± 0.35) ($p = 0.004$).

The ERs of the renal cortex in PP and VP with Gd–EOB–DTPA were significantly higher than with Gd–DTPA ($p = 0.03$; $p = 0.01$). The ER of the renal medulla in VP with Gd–DTPA (1.54 ± 1.03) was significantly higher than with Gd–EOB–DTPA (1.14 ± 0.62) ($p = 0.001$). However, the average ER of the whole kidney (the average ER of the renal cortex and medulla) in DP with Gd–DTPA was significantly higher than in HP with Gd–EOB–DTPA ($p < 0.0001$) (Figs. 1 and 3). Over all the phases, the ER of the whole kidney with Gd–DTPA (1.16 ± 0.86) was significantly higher than with Gd–EOB–DTPA (0.99 ± 0.67) ($p = 0.01$).

The differences between the ERs of the liver and kidney in the dynamic phases and HP obtained from Gd–DTPA and Gd–EOB–DTPA for different serum bilirubin, AST/ALT, and Child–Pugh classifications are summarized in Tables 2 and 3. In the Gd–DTPA-enhanced MRI, the ERs of the liver and kidney showed no significant difference between the patients with normal and abnormal liver functions (such as serum bilirubin, AST, and ALT). There were also no significant differences between the patients using the Child–Pugh classification. However, the ERs of the liver in the HP using

Table 1
Enhancement ratios in the liver and kidney in the dynamic study, delayed, and hepatocyte phases obtained with gadolinium–diethylenetriamine pentaacetic acid and gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid.

Organ	Phase	Contrast		p
		Gd–DTPA	Gd–EOB–DTPA	
Liver	AP	0.14 ± 0.20	0.18 ± 0.22	0.52
	PP	0.44 ± 0.24	0.51 ± 0.19	0.25
	VP	0.32 ± 0.44	0.47 ± 0.46	0.01*
	DP/HP	0.33 ± 0.45	0.49 ± 0.53	0.01*
Kidney (cortex + medulla)	AP	1.89 ± 0.93	1.95 ± 0.69	0.76
	PP	2.35 ± 0.98	2.48 ± 0.77	0.53
	VP	2.47 ± 1.75	2.34 ± 1.30	0.54
	DP/HP	2.89 ± 2.43	1.32 ± 1.18	<0.001*
Cortex	AP	1.12 ± 0.53	0.99 ± 0.35	0.19
	PP	1.07 ± 0.50	1.28 ± 0.43	0.03*
	VP	0.94 ± 0.75	1.20 ± 0.69	0.01*
	DP/HP	1.09 ± 1.01	0.62 ± 0.58	<0.001*
Medulla	AP	0.77 ± 0.51	0.96 ± 0.39	0.12
	PP	1.28 ± 0.53	1.20 ± 0.37	0.53
	VP	1.54 ± 1.03	1.14 ± 0.62	0.001*
	DP/HP	1.80 ± 1.43	0.70 ± 0.65	<0.001*

*Statistically significant ($p < 0.05$).
AP = arterial phase; DP = delayed phase; Gd–DTPA = gadolinium–diethylenetriamine pentaacetic acid; Gd–EOB–DTPA = gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid; HP = hepatocyte phase; PP = portal venous phase; VP = venous phase.

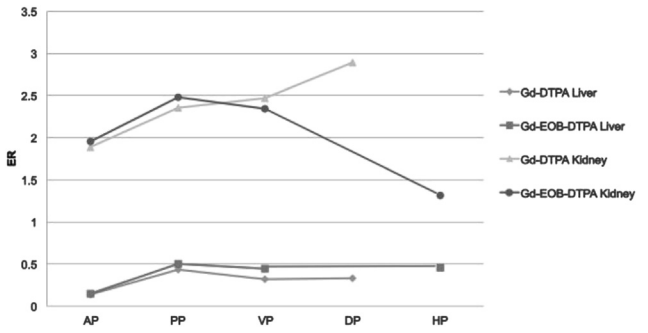

Fig. 1. Time-enhanced curve of enhancement ratios of the liver and kidney obtained with gadolinium–diethylenetriamine pentaacetic acid and gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid. AP = arterial phase; DP = delayed phase; ER = enhancement ratio; Gd–DTPA = gadolinium–diethylenetriamine pentaacetic acid; Gd–EOB–DTPA = gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid; HP = hepatocyte phase; PP = portal venous phase; VP = venous phase.

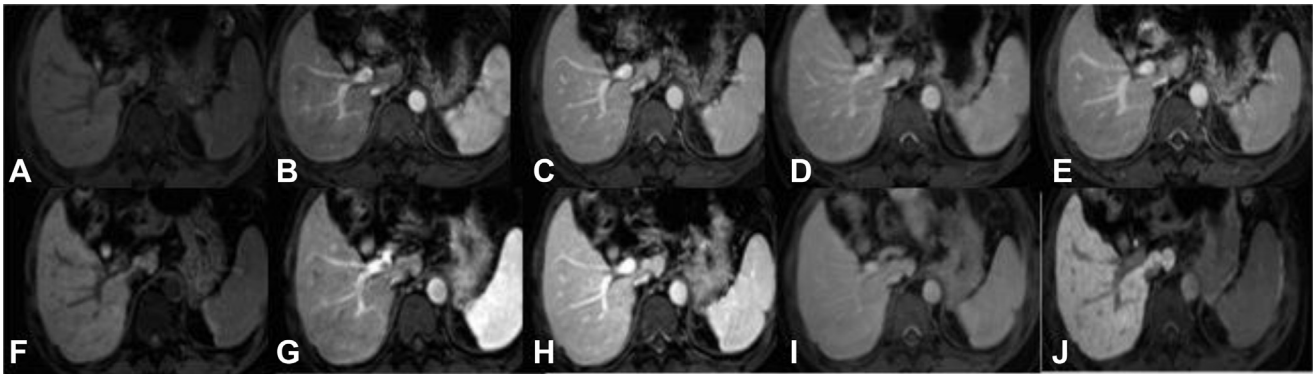

Fig. 2. A 42-year-old man. (A) Precontrast image, (B) arterial phase, (C) portal venous phase (PP), (D) venous phase, and (E) delayed phase of the liver with a gadolinium–diethylenetriamine pentaacetic acid (Gd–DTPA)-enhanced magnetic resonance imaging, and (F) precontrast image, (G) arterial phase, (H) PP, (I) venous phase, and (J) hepatocyte phase of a gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid (Gd–EOB–DTPA)-enhanced magnetic resonance imaging. The enhancement ratios (ERs) of the liver with Gd–DTPA reached peak enhancement in PP, and then decreased. However, the ERs of the liver with Gd–EOB–DTPA maintained enhancement. The ERs of the liver in hepatocyte phase with Gd–EOB–DTPA were significantly higher than in delayed phase with Gd–DTPA.

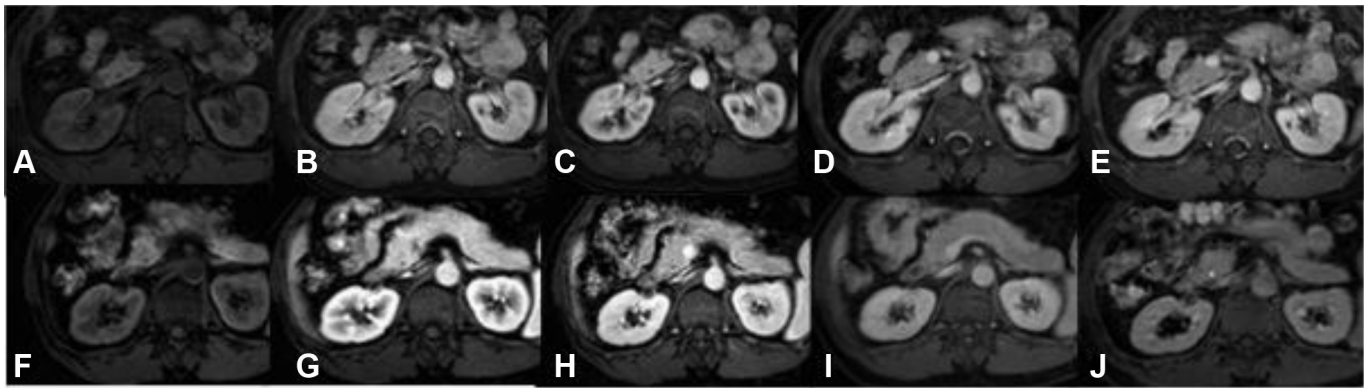

Fig. 3. A 42-year-old man. (A) Precontrast image, (B) arterial phase, (C) portal venous phase (PP), (D) venous phase, and (E) delayed phase (DP) of the kidney with a gadolinium–diethylenetriamine pentaacetic acid (Gd–DTPA)-enhanced magnetic resonance imaging, and (F) precontrast image, (G) arterial phase, (H) PP, (I) venous phase, and (J) hepatocyte phase of a gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid (Gd–EOB–DTPA)-enhanced magnetic resonance imaging. The enhancement ratios (ERs) of the kidney with Gd–DTPA maintained enhancement and reached peak enhancement in DP. However, the ERs of the kidney with Gd–EOB–DTPA reached peak enhancement in PP, and then decreased. The ERs of the kidney in DP with Gd–DTPA were significantly higher than in hepatocyte phase with Gd–EOB–DTPA.

Gd–EOB–DTPA for patients with normal serum bilirubin were significantly higher than for patients with abnormal serum bilirubin ($p = 0.047$). In the different AST/ALT and Child–Pugh classifications, the ERs of the liver and kidney using Gd–EOB–DTPA showed no significant differences.

4. Discussion

In contrast-enhanced imaging studies, the enhancement of the liver parenchyma influences the detection of hepatic lesions. To diagnose nodular lesions in patients with liver cirrhosis is difficult in daily practice due to the heterogeneous enhancement of the background liver. Gd–EOB–DTPA is a hepatocyte-specific MRI contrast agent, and is excreted through both the biliary and urinary systems. It is different from the traditional extracellular MRI contrast agent, Gd–DTPA, which is excreted exclusively through the urinary system. Many studies have discussed the enhancement patterns of different lesions with Gd–EOB–DTPA,[7,15] but few have discussed the enhancement of the liver and kidney parenchyma.[16] In the present study, we compared the enhancement effect of the liver and renal parenchyma between these two contrast agents for patients with liver cirrhosis. Our results showed that the ER of the liver with Gd–EOB–DTPA was significantly higher than with Gd–DTPA in the VP ($p = 0.01$) and in the HP/DP ($p = 0.01$). The ER of the kidney in the DP with Gd–DTPA was significantly higher than in the HP with Gd–EOB–DTPA ($p < 0.001$). The different enhancement may be due to their different excretion pathways.[10]

Tamada et al[17] compared the AP, VP, and DP (about 180 seconds after the injection of the contrast agent) between these two contrast agents. Their results showed that the enhancements of the liver parenchyma and whole kidney in the AP with Gd–EOB–DTPA were lower than those with Gd–DTPA. Conversely, the enhancement of the liver parenchyma during the DP with Gd–EOB–DTPA was higher.[17] Our results were similar in the PP and VP, but there was no significant difference in the AP. According to the American Association for the

Table 2
Enhancement ratios in the liver and kidney in the dynamic study, delayed, and hepatocyte phases obtained with gadolinium–diethylenetriamine pentaacetic acid and gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid according to Child–Pugh classification.

Contrast	Organ	Phase	Child–Pugh classification		
			A ($n = 38$)	B ($n = 9$)	C ($n = 2$)
Gd–DTPA	Liver	AP	0.11 ± 0.18	0.21 ± 0.19	0.47 ± 0.37
		PP	0.42 ± 0.24	0.53 ± 0.25	0.45 ± 0.16
		VP	0.26 ± 0.44	0.50 ± 0.42	0.68 ± 0.32
		DP	0.23 ± 0.39	0.68 ± 0.51	0.63 ± 0.32
	Kidney	AP	1.81 ± 0.89	2.13 ± 1.09	2.37 ± 1.45
		PP	2.31 ± 0.98	2.42 ± 1.09	2.68 ± 0.72
		VP	2.37 ± 1.83	2.85 ± 1.64	2.61 ± 0.42
		DP	2.61 ± 2.27	4.23 ± 2.98	2.32 ± 0.53
Gd–EOB–DTPA	Liver	AP	0.17 ± 0.62	0.14 ± 0.33	0.58 ± 0.21
		PP	0.52 ± 0.14	0.44 ± 0.27	0.79 ± 0.32
		VP	0.44 ± 0.50	0.56 ± 0.29	0.77 ± 0.24
		HP	0.46 ± 0.58	0.54 ± 0.33	0.69 ± 0.07
	Kidney	AP	2.00 ± 0.1	1.85 ± 1.02	1.45 ± 0.20
		PP	2.56 ± 0.73	2.28 ± 0.96	1.93 ± 0.32
		VP	2.28 ± 1.36	2.77 ± 1.03	1.48 ± 0.92
		HP	1.25 ± 1.31	1.63 ± 0.59	1.35 ± 0.47

All the data were not statistically significant ($p > 0.05$).
AP = arterial phase; DP = delayed phase; Gd–DTPA = gadolinium–diethylenetriamine pentaacetic acid; Gd–EOB–DTPA = gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid; HP = hepatocyte phase; PP = portal venous phase; VP = venous phase.

Study of Liver Diseases, the typical enhancing pattern of HCC is hypervascular in the AP and washout in the late phase or DP.[18] Lesion detection is influenced by contrast enhancement of the lesions themselves and the background tissue. According to our results, there may be no difference in the detection of arterial hypervascularity in the liver using both contrast agents. However, the higher enhancement of the liver parenchyma in the late phase and DP in the Gd–EOB–DTPA-enhanced MRI may increase the liver-to-lesion contrast and help in detecting the washout phenomenon of HCC. In the HP of the Gd–EOB–DTPA-enhanced MRI, our results were similar to those of previous studies. The uptake of the liver parenchyma in the HP increased the liver-to-lesion contrast and increased the detection of liver lesions.[16,19–22] We suggest that Gd–EOB–DTPA could provide better diagnostic information than Gd–DTPA in the VP, DP, and HP. Some studies have indicated that insufficient liver enhancement is related to the patient's liver dysfunction.[23,24]

Some studies have also evaluated the impact of liver-function factors for liver parenchymal enhancement with Gd–EOB–DTPA with different conclusions.[12,13,25,26] In this study, we assessed the ERs in the liver in the dynamic study, DP, and HP obtained from Gd–DTPA and Gd–EOB–DTPA based on the serum-bilirubin level, AST/ALT, and Child–Pugh classifications. There was no difference between the normal and abnormal AST/ALT. However, a higher ER was found in patients with normal serum-bilirubin level significantly. Gd–EOB–DTPA is a hepatocyte-specific MRI contrast agent approximately 50% of which is excreted through the biliary system.[10] Previous literature had reported that serum-bilirubin levels are related to the function of excretion; they may affect the liver enhancement in Gd–EOB–DTPA-enhanced MRIs.[25,26] Our study used a serum-bilirubin level of 1.2 mg/dL to divide the patients into normal and abnormal groups, while Tajima et al[13] used 1.3 mg/dL. The liver enhancements were lower in patients with abnormal bilirubin levels than in those with normal bilirubin levels in both our study and in previous ones; the abnormal serum-bilirubin levels may affect the lesion-detection ability of Gd–EOB–DTPA-enhanced MRIs.

Table 3
Enhancement ratios in the liver and kidney in the dynamic study, delayed, and hepatocyte phases obtained with gadolinium–diethylenetriamine pentaacetic acid and gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid according to the total bilirubin and aspartate aminotransferase/alanine transaminase.

Contrast	Organ	Phase	Total bilirubin[a]		p	AST/ALT[b]		p
			Abnormal ($n = 32$)	Normal ($n = 17$)		Abnormal ($n = 20$)	Normal ($n = 29$)	
Gd–DTPA	Liver	AP	0.19 ± 0.19	0.11 ± 0.21	0.45	0.13 ± 0.21	0.15 ± 0.19	0.45
		PP	0.52 ± 0.20	0.40 ± 0.25	0.26	0.45 ± 0.25	0.43 ± 0.21	0.26
		VP	0.44 ± 0.48	0.26 ± 0.42	0.09	0.29 ± 0.43	0.37 ± 0.47	0.09
		DP	0.45 ± 0.51	0.26 ± 0.40	0.07	0.29 ± 0.43	0.39 ± 0.48	0.07
	Kidney	AP	1.97 ± 0.94	1.84 ± 0.95	0.79	1.94 ± 0.94	1.80 ± 0.95	0.79
		PP	2.60 ± 1.09	2.23 ± 0.92	0.51	2.30 ± 1.09	2.42 ± 0.79	0.51
		VP	2.80 ± 1.84	2.29 ± 1.70	0.31	2.44 ± 1.79	2.52 ± 1.72	0.31
		DP	3.45 ± 2.70	2.60 ± 2.26	0.08	2.79 ± 2.40	3.08 ± 2.52	0.08
Gd-EOB-DTPA	Liver	AP	0.16 ± 0.29	0.19 ± 0.17	0.80	0.17 ± 0.23	0.19 ± 0.20	0.84
		PP	0.47 ± 0.25	0.54 ± 0.14	0.53	0.53 ± 0.19	0.49 ± 0.18	0.75
		VP	0.42 ± 0.36	0.50 ± 0.51	0.43	0.44 ± 0.44	0.53 ± 0.50	0.46
		HP	0.34 ± 0.45	0.56 ± 0.56	0.047*	0.40 ± 0.51	0.56 ± 0.57	0.27
	Kidney	AP	1.82 ± 0.77	2.02 ± 0.64	0.51	1.95 ± 0.69	1.96 ± 0.70	0.96
		PP	2.34 ± 0.89	2.56 ± 0.70	0.48	2.43 ± 0.81	2.57 ± 0.72	0.63
		VP	2.34 ± 1.20	2.34 ± 1.36	0.98	2.31 ± 1.22	2.40 ± 1.46	0.78
		HP	1.35 ± 1.28	1.31 ± 1.15	0.90	1.27 ± 1.14	1.41 ± 1.28	0.68

*Statistically significant ($p < 0.05$).
ALT = alanine transaminase; AP = arterial phase; AST = aminotransferase; DP = delayed phase; Gd–DTPA = gadolinium–diethylenetriamine pentaacetic acid; Gd–EOB–DTPA = gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid; HP = hepatocyte phase; PP = portal venous phase; VP = venous phase.
[a] Serum-bilirubin level <1.2 mg/dL was defined as normal, and ≥1.2 mg/dL was defined as abnormal.
[b] AST/ALT level <42 U/L was defined as normal, and ≥42 U/L was defined as abnormal.

Motosugi et al[12] reported that the Child−Pugh classification, which combines five factors (serum albumin, bilirubin levels, prothrombin activity, ascites levels, and the presence or absence of hepatic encephalopathy), was able to indicate liver function more accurately and significantly correlated with liver enhancement. Kim et al[26] indicated that the liver parenchymal enhancement of Gd−EOB−DTPA was affected by the Child−Pugh classification. Chou et al[19] showed that the enhancement of the liver for patients with Child−Pugh class C was lower than for those of class A and class B, but no significant difference was found. In our study, there were no significant differences between the Child−Pugh classes, but the number of patients with Child−Pugh classes B and C was relatively small as compared to class A. Therefore, we suggest that future studies should include more patients with classes B and C for further evaluation.

The ER data of renal cortex and medulla were different in every phase for both contrast agents. However, the significant differences were noted mainly in VP and DP/HP. Overall, the ERs of the kidney with Gd−DTPA were significantly higher than with Gd−EOB−DTPA at DP/HP, which may be due to the excretion of Gd−DTPA exclusively into the urinary system. The serum bilirubin, AST/ALT, and Child−Pugh classifications did not affect the enhancement of the kidney with either Gd−DTPA or Gd−EOB−DTPA.

This study had several limitations. First, the number of Child−Pugh class B and class C patients was relatively small in the present study; however, the proportions of patients based on the Child−Pugh score represent a similar distribution for the general population. Other studies showed a similar distribution.[12,19,26] Future studies with a large-enough number of patients to cover all the Child−Pugh classifications could define a clearer relationship between the liver enhancement and the Child−Pugh classification. Second, the delay time of the two contrast agents was different. The delay time for Gd−DTPA is 180 seconds, and the delay time for Gd−EOB−DTPA is 20 minutes. This may be due to the different excretion routes of the two contrast agents. Previous studies also suggested using the different delay times for daily practice.[9,27] Therefore, using different delay times to compare the two contrast agents is acceptable.

In conclusion, the enhancement effect of the liver with Gd−EOB−DTPA was higher than with Gd−DTPA in the VP and DP. Conversely, the enhancement effect of the kidney with Gd−DTPA was significantly higher than with Gd−EOB−DTPA in the DP. The enhancement effect of the liver was not affected by liver cirrhosis or abnormal liver function. However, the enhancement of the liver in the HP of Gd−EOB−DTPA-enhanced MRI could be affected by the serum-bilirubin levels. Gd−EOB−DTPA is helpful when performing dynamic MRIs and in the HP for diagnosing focal hepatic lesions in the heterogeneous liver parenchyma.

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