Gadoxetic Acid-enhanced Fat suppressed Three-Dimensional T1-weighted MRI Using a Multiecho Dixon Technique at 3 Tesla: Emphasis on Image Quality and Hepatocellular Carcinoma Detection

Mi Hee Lee, MD, PhD, Young Kon Kim, MD, PhD,* Min Jung Park, MD, PhD, Jiyoun Hwang, MD, PhD, Seong Hyun Kim, MD, PhD, Won Jae Lee, MD, PhD and Dongil Choi, MD, PhD

Purpose: To compare the image quality between T1 high-resolution isotropic volume examination using the multiecho Dixon technique (mDixon-eTHRIVE) and that using spectrally adiabatic inversion recovery (SPAIR-eTHRIVE) in gadoxetic acid-enhanced liver MRI, and to evaluate the detectability of hepatocellular carcinoma (HCC) on mDixon-eTHRIVE.

Materials and Methods: Seventy patients with 117 HCCs underwent gadoxetic acid-enhanced liver MRI using mDixon-eTHRIVE. All patients also underwent gadoxetic acid-enhanced MRI using SPAIR-eTHRIVE (mean interval of 96 days). Two radiologists performed a consensus review of MRIs for image quality, homogeneity of fat suppression, artifact, and anatomic sharpness using a four-point scale. The detectability for HCC with mDixon-eTHRIVE was assessed using alternative-free response receiver operating characteristic.

Results: All mDixon-eTHRIVE images received higher scores for homogeneity of fat suppression and image quality ($P < 0.05$) compared with those for SPAIR-eTHRIVE. With respect to artifact and anatomic sharpness, there was no significant difference between two MRIs ($P > 0.05$). Diagnostic accuracy ($Az$) and sensitivity for detecting HCCs with mDixon-eTHRIVE images were mean 0.954 and 93.2%, respectively.

Conclusion: For gadoxetic acid-enhanced liver MRI, mDixon-eTHRIVE showed improved homogeneity of fat suppression and overall image quality compared with SPAIR-eTHRIVE.

Key Words: liver; magnetic resonance imaging; fat suppression; Dixon imaging; hepatocellular carcinoma J. Magn. Reson. Imaging 2013;38:401–410. © 2013 Wiley Periodicals, Inc.

THE IMAGE QUALITY and contrast in liver MRI could be influenced by a variety of factors including sequence parameters, fat suppression techniques and $k$-space ordering. Fat suppression is routinely applied to contrast-enhanced T1-weighted liver MRI to minimize the motion-related artifacts derived from high-signal producing fat and chemical shift artifact, and to enhance the contrast of nonfatty tissue, particularly for better depiction of contrast agent uptake in tissue (1). Fat saturation or its variant has been the most commonly used fat suppression technique for three-dimensional (3D) T1-weighted GRE sequences. With the introduction of 3T in liver MRI, the spectrally adiabatic inversion recovery (SPAIR) technique also has been widely used as an alternative to the conventional fat saturation owing to being insensitive to $B_1$ inhomogeneity (2,3). However, it is sensitive to the $B_0$ magnetic field inhomogeneity and magnetic susceptibility (4). Recently, with technical advances in the Dixon technique, particularly phase correction, the multi-echo Dixon technique has been integrated into the 3D T1-weighted sequence as it efficiently decomposes water and fat images from dual echo acquisition using various postprocessing algorithms (5–7). By compensating for radio frequency (RF) and magnetic field inhomogeneities during image reconstruction, the Dixon technique provides stronger and homogeneous suppression of fat signal across the entire field of view (8–11). Thus, such a technique could be beneficial in a high-field MR system.

Prior studies have demonstrated better image quality and improved fat suppression in body MRI using a two-point Dixon technique including a gadolinium-
enhanced 3D-T1-weighted liver MRI compared with MRI using a conventional fat suppression technique at 1.5 Tesla (T) (12.13). Therefore, we conducted this study to estimate image quality of 3D T1-weighted GRE imaging using the multi-echo Dixon technique by comparing it with the conventional SPAIR technique in gadoxetic acid-enhanced liver MRI at 3.0T. In addition, we aimed to evaluate the capability of gadoxetic acid-enhanced liver MRI using the Dixon technique for the detection of HCCs.

**MATERIALS AND METHODS**

**Patients**

This retrospective study was approved by our institutional review board and informed consent was waived. Our institutional database was reviewed retrospectively for liver MRIs conducted on patients suspected of having HCCs based on sonography or CT scan and (ii) patients who underwent liver MRI using a conventional fat suppression technique (SPAIR) before or after MRI using the dual-echo Dixon technique. Out of these patients, only ones that met the following criteria were included in the study. The inclusion criteria were: (i) patients with chronic liver disease who were suspected of having HCC based on sonography or CT scan and (ii) patients who underwent liver MRI using a conventional fat suppression technique (SPAIR) before or after MRI using the dual-echo Dixon technique. The time interval between two MRIs ranged from 30 to 130 days with a mean interval of 96 days. No patient showed change in Child-Pugh score during the interval between two MRI examinations. No patient showed remarkable change in mean body mass index between two MR examinations. Mean body mass index for study populations were 24.75 kg/m² (range, 19.17–29.39 kg/m²) when acquiring mDixon-eTHRIVE and 24.71 kg/m² (range, 19.10–29.41 kg/m²) when acquiring SPAIR-eTHRIVE.

Seventy patients (51 men, 19 women; age range, 30–73 years; mean age, 56 years) satisfied the inclusion criteria. Twenty-nine patients were excluded from our study because they did not perform liver MRI using a conventional fat suppression technique before or after liver MRI using the Dixon technique. A total of 117 HCCs (size range, 0.6–5.0 cm; mean, 1.8 cm) were identified in the 70 patients, as follows: 41 patients had one solitary lesion, 18 patients had two lesions, 6 patients had three lesions, 3 patients had four lesions, and the remaining 2 patients had five lesions. The final diagnosis of a HCC was confirmed by histopathological examination of the surgical specimens for 25 patients (29 HCCs). Four lesions corresponded to well-differentiated HCCs and the remaining 25 lesions were moderately-differentiated HCCs, according to the WHO classification of HCCs. For the 45 patients with 88 HCCs (size range, 1.2–5.0 cm; mean: 2.0 cm) who underwent transarterial chemoembolization (n = 38) or radiofrequency ablation (n = 7), the reference standards were based on the noninvasive criteria for the diagnosis of HCCs recommended by the American Association for the Study of Liver Diseases (14) as they showed arterial hypervascularization and wash-out (with hypointensity on hepatobiliary phase (HBP) on four-phase multidiector row CT. Sixty-three patients had liver cirrhosis or chronic hepatitis associated with viral hepatitis B, and the 7 remaining patients had viral hepatitis C-induced liver cirrhosis.

**MRI Examinations**

All MRIs were acquired using a 3.0T whole-body MR system (Achieva 3.0T TX, Philips Healthcare, Best, The Netherlands) equipped with a dual-source parallel radiofrequency transmission system with a 16-channel phased-array coil used as the receiver coil. The liver was imaged in the axial plane in all sequences. The baseline MRI protocol included a breathhold multi-shot T2-weighted sequence with an acceleration factor of 2 (1796/70: flip angle, 90°; an echo train length of 15: matrix size, 324 × 235; bandwidth, 258.4 Hz/pixel), a respiratory-triggered single-shot heavily T2-weighted sequence with an acceleration factor of 2 (1802/160: flip angle, 90°; matrix size, 252 × 254; bandwidth, 420.9 Hz/pixel), a 5 mm section thickness, no slice gap, and a field of view of 32–38 cm.

For gadoxetic acid-enhanced MRI, unenhanced, arterial-phase (20–35 s), portal-phase (60 s), late-phase (3 min), and 20-min HBP were obtained using a T1-weighted 3D turbo-field-echo sequence (enhanced-T1 high-resolution isotropic volume examination, eTHRIVE, Philips Healthcare, Best, The Netherlands) with a dual-echo mDixon fat-water separation technique (Philips Healthcare, Best, The Netherlands) (mDixon-eTHRIVE) (TR, 3.21; TE1, 1.15; TE2, 2.0; flip angle, 10°; matrix size, 252 × 214; bandwidth for TE1, 1851.9 Hz/pixel; bandwidth for TE2, 1914.4 Hz/pixel, a 2-mm section thickness and a field of view of 32–38 cm). The measured voxel size, reconstructed voxel size and mean acquisition time were 1.5 × 1.5 × 0.4 mm, 1.17 × 1.17 × 2.0 mm, and 15 s, respectively. A T1-weighted 3D turbo-field-echo sequence using the SPAIR fat suppression technique (SPAIR-eTHRIVE) was performed using the following parameters: a TR/TE, 3.1/1.5; flip angle, 10°; matrix size, 252 × 214; bandwidth, 724.1 Hz/pixel, a 2-mm section thickness, and a field of view of 32–38 cm, measured voxel size, 1.5 × 1.5 × 0.4 mm; reconstructed voxel size, 1.17 × 1.17 × 2.0 mm and acquisition time of mean 16 s.

Using the data from echoes obtained at the 2 different TEs, the mDixon-eTHRIVE sequence used a proprietary in-line 3D region-growing algorithm for water-fat separation to output a water-only image being analogous to the standard SPAIR-eTHRIVE sequence for a single breathhold acquisition in our institution (5,6). We also acquired an in-phase image and an out-of-phase image using such a technique. The contrast agent was automatically administered intravenously at a rate of 1 mL/s at a dose of 0.025 mmol/kg body weight using a power injector, followed by a 20-ml saline flush. We chose an injection rate of 1 mL/s for the gadoxetic acid-enhanced MRI to
reduce ringing (truncation) artifacts observed during the arterial phase, which may occur if the contrast agent abruptly flows into the imaging field when the central k-space is filled, breaking k-space homogeneity (15,16).

**Image Analysis**

To determine the diagnostic accuracy (Az value) and sensitivity for detecting HCCs with gadoxetic acid-enhanced MRI using mDixon-eTHRIVE, two board-certified gastrointestinal radiologists with 10 and 4 years experience in interpreting liver MRI independently reviewed the MRIs. The two radiologists were blinded to the patients’ history and final diagnosis. All images were evaluated using a Picture Archiving and Communication System (PACS: Pathspeed, GE Medical Systems Integrated Imaging Solutions, MT. Prospect, IL), after adjusting the optimal window setting in each case. To approximate real clinical practice regarding avoiding bias into study results, we selected 20 subjects who underwent liver MRI using the mDixon-eTHRIVE technique for HCC workup, but no HCC was identified, as a control group. For each lesion, the observers recorded the possibility of a HCC by assigning each lesion a confidence level, based on a 4-point scale, as follows: “1” as ‘probably not a HCC’, “2” as ‘possibly not a HCC’, “3” as ‘probably a HCC’, and “4” as ‘definitely a HCC’. Lesions not detected on MRI were given a rating of 0. To obtain an accurate correlation between the findings of the scored lesions and the findings of the reference standard, each observer recorded the individual image number, segmental locations of all lesions, and the maximum diameter of each lesion. The diagnostic criteria for the HCCs on the gadoxetic acid-enhanced MRIs were defined as a nodule showing enhancement foci during the arterial phase and washout during the portal venous phase or 3 min delay image, and hypointensity on HBP (Fig. 1). If a lesion was seen as hypointense only on HBP or a lesion was seen as arterially only enhancing nodules, they were regarded as category 1 or 2, according to subjective judgment. We also considered the internal mosaic appearance and the delayed capsular enhancement as additional criteria for HCC.

For the intra-individual comparison of the image qualities between mDixon-eTHRIVE and SPAIR-eTHRIVE images obtained before or after mDixon-eTHRIVE, two gastrointestinal radiologists retrospectively reviewed five phases of two MRIs (unenhanced, arterial phase, portal phase, 3 min late and 20 min HBP) by consensus in two reading sessions and in a random order. Two observers reviewed the images by independent evaluation at an initial reading session, followed by joint evaluation until a consensus was reached on the results; disagreements were minimal and easily resolved. There was a 2-week interval between the blinded interpretations of mDixon-eTHRIVE and SPAIR-eTHRIVE images. Two MRIs were reviewed subjectively with regard to homogeneity of fat suppression, overall image quality regarding noise and contrast, artifact and anatomic sharpness of liver margin and intrahepatic vessels (portal vein and hepatic vein).

Figure 1. Gadoxetic acid-enhanced mDIXON-eTHRIVE image of nodular HCC in a 63-year-old man with chronic hepatitis B. a: An arterial phase image shows hyperenhancing liver mass (arrow). b: A portal venous phase shows rim enhancement of the lesion (arrow). c: On 20-min hepatobiliary phase image, the lesion (arrow) is seen as hypointense and the surrounding liver parenchyma shows homogeneous enhancement.

For each of these measures, a score was assigned from 0 to 3 as follows: "grade 3" as excellent; "grade 2" as good, not impairing diagnostic quality; "grade 1" as fair, somewhat impairing diagnostic quality; and "grade 0" as poor, considered nondiagnostic. In addition, to avoid introducing bias into the results of subjective scoring for individual MRI, a matched-pairs comparison of mDixon-eTHRIVE and SPAIR-eTHRIVE for each
patient was conducted in consensus with regard to overall image quality including homogeneity of fat suppression and was recorded as one image being markedly better, or slightly better, or equivocal.

**Statistical Analysis**

Statistical analyses were performed using statistical software programs (MedCalc, version 11.4, MedCalc Software, Mariakerke, Belgium; SPSS, version 19.0, SPSS, Chicago, IL). The Mann-Whitney test was used for the comparison of differences in the qualitative degree of homogeneity of fat suppression, overall image quality regarding noise and contrast, artifact, and anatomic sharpness of liver margin and intrahepatic vessels between two MRIs. A $P < 0.05$ was considered statistically significant.

An alternative-free response receiver operating characteristic (ROC) curve analysis was performed on a lesion-by-lesion basis using the reviews submitted by the two observers (17). The diagnostic accuracy of each imaging set was assessed by calculating the area under the ROC curve ($A_z$), and a pair wise comparison was made between the imaging sets for each observer and the consensus board using the variance z-test. Considering possible influences of lesion clustering on the diagnostic accuracy of imaging modalities, nonparametric analysis of clustered ROC curve data was performed using the method proposed by Obuchowski (18). The sensitivity of each image set was then calculated. The sensitivity for each image set was evaluated according to the number of lesions assigned a confidence level of 3 or above among the 117 HCCs evaluated. Before image analysis, the observers were aware that only those lesions that had been assigned a confidence level of 3 or above would be included in separate sensitivity calculations. The sensitivities of the image sets were then compared using a McNemar test. A $P < 0.05$ was considered statistically significant. To provide a range of plausible sensitivity differences, the 95% confidence intervals (CIs) were also calculated (19). The kappa statistic for the two observers was calculated to assess the inter-observer agreement for the evaluation of the two imaging modalities (20). Kappa values $< 0.20$ indicated positive but poor agreement; $0.21$–$0.40$ indicated fair agreement; $0.41$–$0.60$ indicated moderate agreement; $0.61$–$0.80$ indicated good agreement; and values $> 0.81$ indicated excellent agreement.

**RESULTS**

**Valuation of HCC Detection**

For the 117 HCCs, the areas under the ROC curves (Az value) for each observer were $0.950 \pm 0.044$ (95% CI: 0.894–0.981) for observer 1 and $0.958 \pm 0.034$ (95% CI: 0.906–0.986) for observer 2. For the sensitivity of HCC detection, the gadoxetic acid-enhanced MRI allowed 110 lesions (94.0%, 95% CI: 88.1–97.6%) to be verified by observer 1 and 108 lesions (92.3%, 95% CI: 85.9–96.4%) by observer 2. There were 7 and 9 HCCs that were not verified by each observer, respectively. Seven of them (0.6–1.9 cm) were confirmed by pathologic analysis of surgical specimens. In the retrospective review, they were observed as hypointense on HBP with or without faint arterial enhancement ($n = 9$) or as arterially enhancing nodules with faint hypointensity on HBP ($n = 3$). Four of them were not verified by any observer and were rated as a confidence level 1 or 2 by each observer. On retrospective reviewing, they were seen as hypointense on HBP with no arterial enhancement. In all 70 study patients and 20 control patients with no HCC, there were no false-positive findings with a confidence rating of 3 or 4 by either observer. The kappa values for the two observers was 0.861, indicating excellent inter-observer agreement with regard to the presence of lesions.

**Valuation of Image Quality**

The results of the subjective valuation of image quality for the SPAIR-eTHRIVE and mDixon-eTHRIVE images (unenhanced, arterial-phase, portal-phase, late-phase, and 20-min HBP images) by the two observers in consensuses are shown in Table 1. All five phases for the mDixon-eTHRIVE images received significantly higher scores for both homogeneity of fat suppression ($P = 0.02$) and overall image quality ($P = 0.01$) than did the SPAIR-eTHRIVE images (Fig. 2). mDixon-eTHRIVE images received a score of 2 or 3 for these categories in unenhanced images for 67 patients and 52 patients, respectively; in arterial-phase images for 67 patients and 52 patients, respectively; in portal-phase images for 70 patients and 57 patients, respectively; in 3-min late-phase images for 70 patients and 56 patients, respectively; and in 20-min HBP images for 70 patients and 60 patients, respectively. Meanwhile, SPAIR-eTHRIVE images received scores of 2 or 3 for unenhanced images for 62 patients and 41 patients, in arterial-phase images for 61 patients and 37 patients, respectively; in portal-phase images for 62 patients and 42 patients, respectively; in 3 min late-phase images for 65 patients and 50 patients, respectively; and in 20-min HBP images for 65 patients and 49 patients, respectively. There was a tendency for the mDixon-eTHRIVE images to be assigned higher scores than SPAIR-eTHRIVE images with regard to artifact and sharpness of liver parenchyma and intrahepatic vessels (anatomic sharpness) (Fig. 3; Table 2). However, there was no significant difference between the two MRIs ($P > 0.05$) (Table 1).

In a matched-pairs comparison of mDixon-eTHRIVE and SPAIR-eTHRIVE images with regard to overall image quality including homogeneity of fat suppression, a considerable number of study cases showed slightly better results with mDixon-eTHRIVE than with SPAIR-eTHRIVE: 8 cases for unenhanced image, 11 cases for the arterial phase and portal phase, 6 cases for the 3-min delayed phase and 9 cases for the HBP images. In the three patients, the susceptibility artifacts derived from perihepatic colonic gas were minimized in mDixon-eTHRIVE compared with SPAIR-eTHRIVE (Fig. 4). The remaining cases were equivalent for all phases. No case showed better overall...
image quality with SPAIR-eTHRIVE than with mDixon-eTHRIVE.

**DISCUSSION**

In partial accordance with previous reports (12,13), our study demonstrated that all five phases of gadoxetic acid-enhanced MRI with mDixon-eTHRIVE were better than those with SPAIR-eTHRIVE with regard to the homogeneity of fat suppression and image quality as homogeneous and complete fat suppression was demonstrated in mDixon-eTHRIVE images for nearly all patients. In a matched-pairs comparison of two MRIs with regard to overall image quality including homogeneity of fat suppression, a considerable number of study cases showed a slightly better image quality with mDixon-eTHRIVE than with SPAIR-eTHRIVE and no case showed inferior overall image quality with mDixon-eTHRIVE than with SPAIR-eTHRIVE. However, with regard to artifact and anatomic sharpness, our study was not in line with a previous report (12) as no significant difference was found between two MRIs.

One plausible explanation for such a discrepancy between studies might be the difference in 3D GRE techniques used in various manufacturers. We used the recently developed eTHRIVE technique for 3D T1-weighted GRE liver MRI. As compared to the conventional THRIVE technique using elliptical centric k-space ordering, eTHRIVE makes use of partial Fourier and linear k-space ordering in both the phase and slice directions. Thereby, such a technique allows for the acquisition of the k = 0 line in a more steady-state phase, in which minimizing the impact of signal variations on image quality at the beginning of the scan or at the beginning of each shot owing to signal non-steady state effects derived from a fat suppression pulse applied for each segment (21). Thereby, eTHRIVE could minimize low spatial frequency (or bulk) artifacts related to suboptimal anatomic sharpness or general artifacts that are exhibited in centric-ordering THRIVE in which the center of k-space is acquired at the beginning of the scan. In addition, we used a dual-source parallel radiofrequency transmission technique for a 3.0T MR system, which makes it possible to significantly improve B1 uniformity in high-field MRI by eliminating dielectric shading (22).

Nevertheless, in three patients, the susceptibility artifact derived from pericolic colonic gas could be minimized in mDixon-eTHRIVE due to improved phase correction as compared to SPAIR-eTHRIVE (4).

With respect to HCC detection, we did not make an intra-individual comparison between mDixon-eTHRIVE and SPAIR-eTHRIVE images. Thus, we could not provide reliable data for the relative efficacy of mDixon-eTHRIVE to the conventional technique. In our study, the Az value and sensitivity for detection of HCC using mDixon-eTHRIVE images were 0.950 and 0.958 (mean: 0.954) as well as 94.0% and 92.3% (mean: 93.2%), respectively, for each observer. With regard to the presence of lesions, the kappa value indicated excellent inter-observer agreement. In a
Figure 2. A 68-year-old man with chronic hepatitis B underwent gadoxetic acid-enhanced liver MRI using mDixon-eTHRIVE technique after MRI using SPAIR-eTHRIVE with an interval of 126 days between two MRIs. Gadoxetic acid-enhanced SPAIR-eTHRIVE images show incomplete fat suppression within the anterior perihepatic space (wide arrows) on arterial (a), portal (b), 3 min late (c), and hepatobiliary phase (d) with susceptibility artifact (narrow arrow on A, B, and C). Gadoxetic acid-enhanced mDIXON-eTHRIVE images show better image quality with homogeneous dark fat signal on arterial (e), portal (f), 3 min late (g), and hepatobiliary phase (h).
Figure 3. A 63-year-old man with liver cirrhosis underwent gadoxetic acid-enhanced liver MRI using mDixon-eTHRIVE tech-
nique after MRI using SPAIR-eTHRIVE with an interval of 101 days between two MRIs. Gadoxetic acid-enhanced arterial, por-
tal, 3 min late, and 20 min hepatobiliary phase images obtained by SPAIR-eTHRIVE (a–d) and mDIXON-eTHRIVE (e–h) show
liver parenchyma at the level of central portal vein. The mDIXON-eTHRIVE image shows superior image quality with better
depiction of intrahepatic vessels, especially portal vein of segment 2 (arrows).
previous study reported by Kim et al (23), the Az values and sensitivities for the detection of 183 HCCs in 62 patients using the SPAIR-eTHRIVE images were 0.971, 0.959 and 0.967 (mean, 0.966), and 94%, 94%, and 91.6% (mean: 93.2%) for the three observers. Therefore, the diagnostic performance of mDixon-eTHRIVE images for HCC detection is within acceptable range. The greatest advantage of using gadoxetic acid in HCC workup is that HBP images better depict HCC as hypointense compared with dynamic images using conventional gadolinium chelates (24,25). This characteristic could contribute to improving the detection of small HCC, which can be unrecognized on early dynamic phases, as well as the characterization of equivocal lesions such as only arterial enhancement without washout by differentiating it from arterio-portal shunt (24–26). In this study, most of lesions not verified by both observers were identified but were assigned a low confidence level as four HCCs not verified by any observer were seen as hypointense only on HBP without arterial hypervascularization. As for HBP-only hypointense nodules, there has been no established guideline for distinguishing between hypovascular HCC and cirrhosis-associated benign nodules because benign nodules can also appear as hypointense only on HBP (24–26).

Two similar previous studies (12,13) comparing conventional fat suppression with Dixon methods for postcontrast 3D images of abdomen including liver demonstrated no difference in the detection of abdominal pathology, despite improvements in fat suppression and overall image quality using the Dixon technique. Thus, we could not speculate whether better image quality of the mDixon-eTHRIVE could lead to better detection of liver lesions compared with MRI using conventional fat suppression technique. However, besides the fact that overall image quality and fat suppression in the mDixon-eTHRIVE was never inferior to the SPAIR-eTHRIVE, mDixon technique, with no need for separate imaging acquisition, generates additional in-phase image and out-of-phase images as well as water-fat imaging in one breath hold. In addition, given the susceptibility artifact derived from colonic gas was minimized with mDixon-eTHRIVE in three study patients, mDixon-eTHRIVE might be beneficial in setting of advanced liver cirrhosis with liver atrophy that might worsen artifacts due to colonic interposition. Therefore, based on our results, we could reach the conclusion that mDixon-eTHRIVE technique could be promising for contrast-enhanced 3D liver MRI that could replace conventional SPAIR-eTHRIVE technique due to its robust fat suppression and image quality as well as higher scanning efficiency.

This study had limitations; as mentioned, owing to the retrospective study design, we did not make an intra-individual comparison between the mDixon-eTHRIVE and SPAIR-eTHRIVE techniques with respect to the detection of HCCs. However, there have been increased concerns regarding safety associated with gadolinium-based contrast agents (27). In addition, we could not provide the results of the quantitative analysis for the lesion-to-liver contrast ratio for

| Category | mDIXON-Pre | mDIXON-Arterial | mDIXON-Portal | mDIXON-3 min | mDIXON-20 min | SPAIR-Pre | SPAIR-Arterial | SPAIR-Portal | SPAIR-3 min | SPAIR-20 min |
|----------|------------|----------------|--------------|--------------|--------------|----------|---------------|--------------|--------------|--------------|
| Homogeneity of fat suppression | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Overall image quality | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Anatomic sharpness | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Artifact | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
A 68-year-old man with chronic hepatitis B underwent gadoxetic acid-enhanced liver MRI using mDixon-eTHRIVE technique after MRI using SPAIR-eTHRIVE with an interval of 84 days between two MRIs. Gadoxetic acid-enhanced arterial (a), portal (b), 3 min late (c), and 20 min hepatobiliary phase images (d) obtained by SPAIR-eTHRIVE show susceptibility artifact (arrows) burring adjacent liver and lateral abdominal wall. Gadoxetic acid-enhanced arterial (e), portal (f), 3 min late (g), and 20 min hepatobiliary phase images (h) obtained by mDIXON-eTHRIVE show no susceptibility artifact. In addition, overall image quality of mDIXON-eTHRIVE image is better than that of SPAIR-eTHRIVE image.
both MRI techniques. Although we provided the data regarding qualitative analysis for comparison of image qualities between two MRIs, the time intervals between the two MRIs were long (mean, 96 days) for an exact comparison. Second, we included only patients with HCCs, so we could not reach any conclusion on whether the mDixon technique would be beneficial for improving the detection of other hepatic tumors such as metastases in patients with no underlying chronic liver disease compared with the conventional fat suppression technique.

In conclusion, mDixon-eTHRIVE images showed an improved image quality and fat suppression compared with SPAIR-eTHRIVE images for gadoxetic-acid-enhanced 3D liver MRI. For the detection of HCCs in patients with chronic liver disease, mDixon-eTHRIVE showed a comparable range of diagnostic accuracy and sensitivity to conventional images in the gadoxetic acid-enhanced MRI.

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