Comparison of Ferucarbotran-Enhanced MRI and Triple-Phase MDCT for the Detection of Hepatocellular Carcinoma in Advanced Liver Cirrhosis

Yong Hwan Jeon, M.D.1,2, Seung Hoon Kim, M.D., Dongil Choi, M.D., Min Ju Kim, M.D., Sam Soo Kim, M.D.1, Jiwon Lee, M.D.1, Heon Han, M.D.2, Jongmee Lee, M.D.3

1Department of Radiology and Center for Imaging Science, Samsung Medical Center, Sungkyunkwan University School of Medicine
2Department of Radiology, Kangwon National University College of Medicine
3Department of Radiology, Korea University Guro Hospital

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Address reprint requests to: Seung Hoon Kim, M.D., Department of Radiology, Samsung Medical Center, 50 Ilwon-dong, Kangnam-ku, Seoul 135-170, Korea
Tel. 82-2-3410-2542 Fax. 82-2-3410-2559 E-mail: shkim@smc.samsung.co.kr

Purpose: To compare the diagnostic performance of ferucarbotran-enhanced MRI at 1.5-T with triple-phase multidetector-row helical CT (MDCT) to detect hepatocellular carcinoma in patients with advanced liver cirrhosis.

Materials and Methods: Twenty patients with advanced liver cirrhosis (Child’s class B:C = 8:12) underwent ferucarbotran-enhanced MRI and triple-phase MDCT prior to liver transplantation. The mean time interval between the two imaging techniques was 18 days (range, 1-35 days). Three radiologists independently reviewed both images on a lesion-by-lesion basis and interpreted them for comparison with the pathologic findings of the explanted livers. As well, the sensitivity and an alternative-free response receiver operating characteristics (ROC) analysis was used to evaluate the diagnostic performance of each technique.

Results: The mean area under the ROC curve (Az) was significantly higher for the triple-phase MDCT (0.766) compared to the ferucarbotran-enhanced MRI (0.675) (p < 0.001). Similarly, the mean sensitivity of the triple-phase MDCT (60.3%) exceeded the ferucarbotran-enhanced MRI (43.1%). The results indicate that the triple-phase MDCT provides significantly greater mean sensitivity than the ferucarbotran-enhanced MRI (p < 0.001).

Conclusion: The triple-phase MDCT provided a better diagnostic performance and higher sensitivity than the ferucarbotran-enhanced MRI for the detection of hepatocellular carcinomas in patients with advanced liver cirrhosis.

Index words: Carcinoma, hepatocellular
Liver cirrhosis
Magnetic resonance (MR)
Tomography, spiral computed
Ferumoxides
The current treatment of choice for patients with advanced liver cirrhosis or unresectable hepatocellular carcinoma is a liver transplantation. Past studies have reported long-term survival in patients with a single hepatocellular carcinoma with diameters of 5 cm or less or a maximum of three tumors with diameters no more than 3 cm, having undergone a liver transplantation [1]. Consequently, an accurate surveillance of an unsuspected hepatocellular carcinoma in transplantation candidates is vital for the diagnosis of hepatocellular carcinoma, and to provide the appropriate treatment, thus preventing an ineffective transplantation [2, 3].

The multidetector-row helical CT (MDCT) is the most frequently used imaging modality to detect hepatocellular carcinomas [4–6]. Recently, the advent of the MDCT, which offers more rapid imaging, thinner slices, and better z-axis resolution, has improved the chances of detecting hepatocellular carcinoma [7–11].

Superparamagnetic iron oxide (SPIO) materials, such as ferumoxides, have been developed as liver-specific particulate magnetic resonance imaging (MRI) contrast agents. The uptake of SPIO occurs primarily in the Kupffer’s cells of the liver, resulting in decreased signal intensity for normal liver tissue because of the susceptibility effect of iron [12, 13]. Some investigators have suggested that ferumoxide-enhanced MRI is more accurate than other imaging modalities, such as multiphase helical CT or gadolinium-enhanced MRI, for the detection of hepatocellular carcinoma [14–17]. Despite this, the authors of previous study have concluded that the detection of hepatocellular carcinoma in patients with liver cirrhosis on SPIO-enhanced MRI may be difficult because of the reduced uptake of SPIO in the chronically injured liver parenchyma [18].

Another recently developed SPIO material, which has also been used in clinical practice, is ferucarbotran particles coated with carboxydextran. The advantage of this material compared to ferumoxides is its practical use in dynamic studies requiring immediate performance following a IV bolus injection [19, 20]. It is however still unclear whether ferucarbotran-enhanced MRI can replace contrast-enhanced MRI with an alternative SPIO material, such as ferumoxides.

The purpose of this study was in fact to compare the diagnostic performance of the ferucarbotran-enhanced MRI with the triple-phase MDCT for the detection of hepatocellular carcinomas in patients with advanced liver cirrhosis, against the pathologic findings of explanted livers as a standard.

Materials and Methods

Patients
The study population consisted of 118 consecutive patients that underwent a liver transplantation for advanced liver cirrhosis or radiologically proven hepatocellular carcinoma in our institution between January 2003 and August 2004. Prior to transplantation, a triple-phase MDCT was performed on all 118 patients for the pre-transplantational surveillance of the liver. Of these patients, a ferucarbotran-enhanced MRI was performed on 25 of the 118 patients. Five of the 25 patients were excluded from our study: three patients were suspected of having hepatocellular carcinoma as well as having undergone a transarterial chemoembolization before transplantation and two patients had undergone a radiofrequency ablation for the same reason. In the end, a total of 20 patients (16 men and 4 women aged between 43 and 68 years; mean 52.4 years) were subjected to both imaging modalities. Each patient provided written informed consent and the study was approved by our hospital’s institutional review board.

The range of time intervals between the triple-phase MDCT and ferucarbotran-enhanced MRI was 1-35 days (mean, 18 days). Furthermore, the mean interval time between the last imaging study and the liver transplantation was 19 days (range, 1-56 days).

The pathologically proven diagnoses for all 20 patients were cirrhosis of the liver caused by viral hepatitis type B (n = 19), and viral hepatitis type C (n = 1). No cases of alcoholic cirrhosis were observed. Furthermore, the degree of liver cirrhosis was categorized according to the Child-Pugh classification. No patients were categorized under Child-Pugh classification A, eight patients were under classification B, and 12 were under classification C.

Triple-Phase MDCT and Ferucarbotran-Enhanced MRI
The triple-phase MDCT imaging was performed with an MDCT scanner with four (n = 6), eight (n = 7) or 16 (n = 7) detectors (Lightspeed QX/I or Lightspeed Ultra 8 or Lightspeed 16; GE Healthcare, Milwaukee, USA). The scanning parameters were 120 kVp, 175-184 mAs, 5 mm slice thickness, with a table speed of 15.0 mm/sec (pitch, 0.75) for the four detector MDCT, and 17.5 mm/sec (pitch, 0.875) for the eight detector MDCT, and 18.76 mm/sec (pitch, 0.938) for 16 detector MDCT during a single-breath-hold helical acquisition time of 8–10
seconds. The images were obtained in the craniocaudal orientation and were reconstructed every 5 mm to provide contiguous sections. With the bolus-trigger technique, the arterial scanning phase began 20-35 seconds after commencing the IV injection of 120 mL of nonionic iodinated contrast material (Iopamiro 300; Bracco, Milan, Italy) via an antecubital vein, at 4 mL/sec. The scanning portal phase began 70 seconds after commencing of the contrast material injection. The delayed scanning phase began 180 seconds after the commencement of the contrast material injection.

An MRI was performed with 1.5-T units (Signa Horizon; GE Healthcare, Milwaukee, U.S.A.). All images were obtained in the transverse plane using a phased-array multicoil as the receiver coil. For all pulse sequences, a 6- to 8-mm thick section with a 2 mm intersection gap and a field of view ranging from 30-32 cm was used. The saturation bands that were superior and inferior to the imaging volume were applied in all sequences to minimize the number of motion artifacts.

The ferucarbotran (Resovist®; Schering, Berlin, Germany) dose was 1.4 mL for patients with body mass of 60 kg or more and 0.9 mL in patients with body masses below 60 kg (range, 8.0-12.0 µmol of iron/kg). The contrast agent was manually administered intravenously through an in-line 5-µm specific filter with a 1 sec bolus time, followed immediately by a 10 mL saline solution flush. The entire procedure was performed in approximately 5 sec. Prior to injecting of the contrast agent, a fat-suppressed respiratory-triggered fast spin-echo sequence with two echo times (proton density-weighted and T2-weighted images) (TR range/first-echo TE, second-echo TE range, 3,333-8,571/18, 90-117; echo train length of 10-18; two signals acquired; 256×256 matrix; bandwidth of 120 Hz per pixel), a T2*-weighted fast multi-planar gradient-recalled echo acquisition in the steady state (TR/TE range 130/8.4-10.4; flip angle, 30°; bandwidth, 60 Hz per pixel), and a breath-hold in phase, T1-weighted, fast multi-planar, spoiled gradient-recalled echo sequence (TR/TE, 200/4.2; flip angle, 90°; 256×160 matrix) were acquired. After the unenhanced images were taken, enhanced images of the same sequences were taken 10 minutes after injecting of the contrast agent. In addition, the dynamic enhanced T1-weighted fast multi-planar spoiled gradient-recalled echo images were also obtained with delay times of 20 sec, 1 min, 3 min, and 5 min after injecting the contrast agent.

### Image Analysis

The triple-phase MDCT images and ferucarbotran-enhanced MR images were independently analyzed by three radiologists in random order in a blind study. In addition, the radiologists were informed that only the patients with liver cirrhosis were referred for a pretransplantational assessment of hepatocellular carcinoma. The time interval between the reviews of the MDCT and MRI was at least 1 month and all images were evaluated using a 2,000×2,000 picture archiving and communication system (PACS) monitor, which allowed for adjustment of the optimal window setting in each case.

For each patient, the image review was conducted on a lesion-by-lesion basis for the entire liver. Each observer independently recorded the presence, size (maximum diameter), and location (Couinaud segment) of all lesions, and stated whether the observer was able to determine the presence of a hepatocellular carcinoma based on a five-point confidence scale: 1- definitely not a tumor, 2- probably not a tumor, 3- a possible tumor, 4- a probable tumor, and 5- a definite tumor. To prevent the misallocation of the scored lesions for each imaging modality as well as those found during surgery, we used standardized markers (1- circular ROI, 2- a shorter linear line, 3- a longer linear line, 4- a shorter arrow, and 5- a longer arrow). The observer indicated the location of each lesion and at the time of the image review, the observers were aware that the sensitivity was calculated using the number of lesions allocated at a confidence level of 3, 4 or 5.

For the triple-phase MDCT, a nodule showing the enhancement and visualization of the intratumoral arteries during hepatic arterial phase, high, iso- or low attenuation on the portal venous phase and low attenuation on the delayed phase, and with or without capsular enhancement, was regarded as hepatocellular carcinoma. In addition, a nodule of mixed attenuation located at the hepatic arterial and portal venous phases displayed a low attenuation on the delayed phase. Moreover, a nodule size larger than 2 cm provided low attenuation on the portal venous and delayed phases, without definite enhancement on the arterial phase, and was similarly regarded as hepatocellular carcinoma (4, 6, 16).

For the ferucarbotran-enhanced MRI, any nodule seen as having high signal intensity or any prominent nodule with a diameter exceeding 2 cm despite the uptake of ferucarbotran was considered to be hepatocellular carcinoma. The high signal intensity lesions visible on a feru-
carbotran-enhanced MRI image other than hepatocellular carcinoma, were diagnosed as hemangioma when they showed high signal intensity on unenhanced proton density-weighted and T2-weighted MR images, and peripheral globular enhancement on ferucarbotran-enhanced dynamic MR images. Moreover a cyst was confirmed with typical imaging findings on unenhanced T1- and T2-weighted MR images with no enhancement of the ferucarbotran-enhanced images.

**Lesion Confirmation**

The explanted liver specimens were serially sectioned into 5-6 mm intervals at the transverse or coronal planes, depending on the anatomy of the liver and the location of the nodule. Any nodule with a diameter exceeding 1 cm, or any bulging nodule different in color from the surrounding liver, regardless of size, was examined under a microscope.

The pathologic examinations of the 20 explanted livers revealed 58 hepatocellular carcinomas in 17 patients. The hepatocellular carcinomas ranged between 4 to 90 mm in diameter (mean, 16.7 mm). Moreover, of the 17 patients with hepatocellular carcinomas, six patients had one lesion, two had two lesions, one had three lesions, one had four lesions, and seven had five or more lesions.

All the lesions detected by a triple-phase MDCT or a ferucarbotran-enhanced MRI were compared with the corresponding lesions in the pathologic reports of explanted livers in relation to their location, size, and count. When a nodule of the triple-phase MDCT or ferucarbotran-enhanced MRI did not correlate with pathologic findings, the pathologic reports were considered as the gold standard. The analysis of the observers’ interpretations was performed using the review of the combined MR and CT images and the pathologic reports by the study coordinator.

**Statistical Analysis**

Alternative-free response receiver operating characteristics (ROC) curves were generated by using a maximum likelihood estimation program (ROCKET 0.9B, Charles E. Metz) and calculated for each observer and imaging modality by plotting the true-positive fraction against the likelihood of obtaining a false-positive image at each confidence level (21). The diagnostic accuracy of each imaging modality and observer was determined by calculating the areas under each alternative-free response ROC curve (Az). The differences between imaging modalities, with respect to the mean Az values, were

| Table 1. Az and p-values for Ferucarbotran-Enhanced MRI and Triple-Phase MDCT in Detection of Hepatocellular Carcinoma |
|---|---|---|---|---|
| Imaging Modality | Observer 1 | Observer 2 | Observer 3 | Mean |
| Ferucarbotran-enhanced MRI | 0.681 ± 0.046 | 0.703 ± 0.045 | 0.641 ± 0.048 | 0.675 ± 0.027 |
| Triple-phase MDCT | 0.792 ± 0.041 | 0.789 ± 0.041 | 0.718 ± 0.048 | 0.766 ± 0.025 |
| p | < 0.001 | 0.021 | 0.044 | < 0.001 |

Note – Az values (area under receiver operating characteristic curve) are expressed as the mean ± 1 standard deviation.

| Table 2. Sensitivity of Ferucarbotran-Enhanced MRI and Triple-Phase MDCT for Diagnosis of 58 Hepatocellular Carcinomas |
|---|---|---|---|---|
| Imaging Modality | Observer 1 | Observer 2 | Observer 3 | Total |
| Triple-phase MDCT | 60.3 [35/58] | 60.3 [35/58] | 60.3 [35/58] | 60.3 [105/174] |
| p | < 0.001 | 0.039 | 0.011 | < 0.001 |

Note – The values in parentheses represent the number of lesions assigned a score of 3, 4 or 5, divided by the total number of lesions (n = 58) for pathologically proven hepatocellular carcinoma.

| Table 3. Sensitivity of Ferucarbotran-Enhanced MRI and Triple-Phase MDCT in Detection of Hepatocellular Carcinoma according to Tumor Size |
|---|---|---|---|---|---|---|
| Tumor Size (cm) | Total Number of Tumors | Observer 1 | Observer 2 | Observer 3 | Total |
| | MRI | CT | MRI | CT | MRI | CT | MRI | CT |

Note – The values indicate the hepatocellular carcinoma counts, whereas the values in parentheses represent the percentages relative to the total number of observed tumors.
statistically analyzed using a two-tailed student’s t-test for paired data. A two-tailed p-value less than 0.05 was considered significant. The sensitivity of each imaging modality and each observer was determined by the number of lesions assigned at a confidence level of approximately 3, 4 or 5 of the 58 pathologically proven hepatocellular carcinomas. The difference in the sensitivity between the MDCT and MRI was assessed with the McNemar test.

Kappa statistics were used to measure for the interobserver agreement in the detection of hepatocellular carcinoma for each imaging modality. The degree of agreement was categorized as follows: Kappa values of 0.41-0.60, moderate agreement; 0.61-0.80, good agreement; and 0.81-1.00, excellent agreement. The statistical analyses were calculated using SPSS version 12.0 (Chicago, Illinois, U.S.A.).

Results

Overall, a total of 269 lesions were identified for both the imaging modalities by all three observers. For the 58 pathologically proven hepatocellular carcinomas, the calculated Az values of each observer and each imaging modality along the standard of reference was compared to the pathologic findings of explanted livers (Table 1). The diagnostic accuracy of hepatocellular carcinoma was higher for all three observers with the triple-phase MDCT, as compared to the ferucarbotran-enhanced MRI. Moreover, the mean Az for MDCT (0.766) was significantly greater than the Az for the MRI (0.675) \( p < 0.001 \).

Hence, our data suggests that the sensitivity of the triple-phase MDCT was higher in the ferucarbotran-enhanced MRI. In addition, the mean sensitivity of the
triple-phase MDCT images (60.3%) was significantly greater than the ferucarbotran-enhanced MRI (43.1%) \(p < 0.001\) (Table 2).

In the detection of hepatocellular carcinoma equal to or less than 1 cm, both imaging modalities showed low sensitivities (7% in MRI, 32% in MDCT) compared to the sensitivities observed for the larger hepatocellular carcinomas (Table 3). Despite this finding, all observers detected all of the 11 hepatocellular carcinomas greater than 2 cm in diameter for both imaging modalities.

### Table 4. Interobserver Agreement Regarding Presence of Hepatocellular Carcinoma

<table>
<thead>
<tr>
<th>Imaging Technique</th>
<th>Observer 1 vs. Observer 2</th>
<th>Observer 2 vs. Observer 3</th>
<th>Observer 1 vs. Observer 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferucarbotran-enhanced MRI</td>
<td>0.759</td>
<td>0.626</td>
<td>0.674</td>
</tr>
<tr>
<td>Triple-phase MDCT</td>
<td>0.859</td>
<td>0.677</td>
<td>0.683</td>
</tr>
</tbody>
</table>

Note: Data are \(\kappa\) values.

Seven small (range, 6-13 mm; mean, 10.6) lesions which were not detected by all observers on the ferucarbotran-enhanced MRI were detected using the triple-phase MDCT for all observers (Fig. 1). However, two (8- and 14-mm) lesions were not detected by any of the observers via the triple-phase MDCT, but were detected by the ferucarbotran-enhanced MRI by all observers (Fig. 2). A retrospective analysis revealed that five of the seven undetected lesions on the ferucarbotran-enhanced MRI revealed a decreased signal intensity for

**Fig. 2.** A 60-year-old-man with a pathologically proven hepatocellular carcinoma in liver segment VIII. 

**A, B.** The arterial (A) and delayed phase (B) MDCT images show no visible liver lesion. 

**C, D.** A ferucarbotran-enhanced image from T2*-weighted fast multi-planar gradient-recalled echo acquisition in steady state (C) and a ferucarbotran-enhanced delay image from breathhold in-phase T1-weighted fast multi-planar spoiled gradient-echo sequence (D) show a hyperintense nodule (arrow).
the ferucarbotran uptake, whereas, other lesions were misdiagnosed as vessels. A triple-phase MDCT resulted in two missed lesions by all observers, and showed no significant differences for the attenuation of surrounding liver parenchyma, which was later substantiated upon examining the explanted liver specimen.

The sum of all false-positive lesions (range, 4-24 mm; mean, 11.2 mm) recorded by the triple-phase MDCT images was 39, as opposed to 27 (range, 5-20 mm; mean 10.6 mm) for the ferucarbotran-enhanced MRI. For the triple-phase MDCT, the major cause of false-positive lesions was an arteriportal shunt [Fig. 3]. Due to the ferucarbotran-enhanced MRI, false positive results were primarily due to misinterpreting the overlying vascular structures, such as branches of the hepatic or portal vein (Fig. 4).

The kappa values among the three observers showed good and excellent agreement for both imaging modalities (Table 4).

**Fig. 3.** A 48-year-old woman with a false-positive lesion on MDCT.
A. An arterial phase MDCT image shows a small low density lesion (arrowhead) and another small enhancing nodule (arrow) in segment VIII. Two of the three observers considered the enhancing nodule to be hepatocellular carcinoma.
B. A ferucarbotran-enhanced image from fat-suppressed, respiratory triggered T2-weighted fast spin-echo MRI shows no visible nodule at the same level as A. A small high signal intensity lesion (arrowhead) in segment VIII was proven to be a hepatic cyst.

**Fig. 4.** A 58-year-old man with a false-positive lesion on MRI.
A. A ferucarbotran-enhanced MR image from fat-suppressed, respiratory triggered T2-weighted fast spin-echo shows a subtle high signal intensity lesion with an irregular margin (arrow). Two of the three observers considered this lesion to be hepatocellular carcinoma.
B. The portal venous phase MDCT image shows a branch of segment VIII portal vein (arrow) at the same level as A.
Discussion

Liver transplantations are widely accepted as an effective therapeutic modality for a variety of irreversible acute and chronic liver diseases when no other satisfactory therapy is available. The selection of appropriate patients for transplantation is important because of high morbidity and mortality during and after surgery, and particularly following the shortage of donor livers. Thus, it is important to screen hepatocellular carcinomas to determine their eligibility for transplantation in liver transplant candidates.

Many investigators have compared the detection rates of hepatic tumors, particularly hepatocellular carcinoma, using a variety of imaging modalities, such as CT during arterial portography (CTAP), contrast-enhanced CT, gadolinium-enhanced MRI, ferumoxide-enhanced MRI, and PET (13-17, 19, 22-30). Moreover, several investigators reported that ferumoxide-enhanced MRI appeared to be superior to CTAP and dual- or triple-phase helical CT to detect hepatocellular carcinoma (16, 22, 23). In addition, Reimer et al. reported that the ferucarbotran-enhanced MRI appeared to be superior to the dual- or triple-phase helical CT images for the detection of hepatic lesions (20).

In this study, the comparison of the triple-phase MD-CT and the ferucarbotran-enhanced MRI in the detection of hepatocellular carcinomas was performed in patients with advanced liver cirrhosis, rather than patients whose liver function was relatively good and able to endure surgery. In advanced or end-stage liver cirrhosis, the detection of hepatic tumors, particularly hepatocellular carcinoma, is difficult, because the cirrhotic liver parenchyma contains fibrosis, regenerative nodules, fatty infiltration and parenchymal necrosis, as well as a variety of hemodynamic changes, such as collateral flow due to portal hypertension and a transient attenuation difference, including an arterioporal shunt. Several investigators reported that the detection rates of hepatocellular carcinomas for explanted livers with advanced or end-stage liver cirrhosis were 50-80% for contrast-enhanced CT and MRI (27-29). Our results for each imaging modality for the detection of hepatocellular carcinoma in advanced stages liver cirrhosis were consistent with these reports.

Kim et al. reported that the preoperative detection of hepatocellular carcinoma revealed a mean Az value for the triple-phase MDCT (0.949), which was slightly higher than the observed Az value in the ferucarbotran-enhanced MRI (0.947); however, the difference was not statistically significant (30). Conversely, our study demonstrated that the diagnostic performance of the triple-phase MDCT (mean Az, 0.766) was significantly greater than the observed ferucarbotran-enhanced MRI (mean Az, 0.675). This conflicting finding may be due to our study population being skewed for patients with advanced liver cirrhosis, whereas the Kim et al. study was primarily performed on patients with the ability to endure hepatic resection surgery.

In this study, both imaging modalities showed low sensitivities (7% for MRI, 32% for MDCT) for the detection of hepatocellular carcinoma, equal to or less than 1 cm. Furthermore, the overall sensitivity of ferucarbotran-enhanced MRI (43.1%) was lower than that of triple-phase MDCT (60.3%). Several factors may contribute to the low sensitivity of ferucarbotran-enhanced MRI for detecting hepatocellular carcinoma. First, a well-differentiated hepatocellular carcinoma may result in the active uptake of ferucarbotran particles, which results in iso- or hypointensity on ferucarbotran-enhanced images. Previous studies (16, 19) have pointed out that a variety of hepatic tumors, such as focal nodular hyperplasia, regenerative nodule, hepatic adenoma, dysplastic nodule, and well-differentiated hepatocellular carcinomas can display a variable uptake of SPIO, since these tumors contain a variable number of Kupffer’s cells. Therefore, it may be difficult to distinguish well-differentiated hepatocellular carcinoma from other benign hepatic tumors. Second, advanced cirrhotic livers show poor liver enhancement due to decreased activity of Kupffer’s cells, which in turn affects the uptake SPIO particles. Furthermore, the poor liver enhancement is intensified by portal hypertension, which leads to SPIO redistribution to the spleen through increased uptake activity (31). Tang et al. reported a decrease in lesion detectability for ferumoxide-enhanced MRI images for Child-Pugh class C patients with severe portal hypertension (25). Third, the reticular fibrosis and combined ascites of advanced liver cirrhosis shows a high signal intensity, which can obscure small hepatocellular carcinomas in certain situations.

Several factors may cause false-positive results. Namely, it is possible that small hepatocellular carcinomas could be difficult to differentiate from the presence of overlaying portal or hepatic veins in ferucarbotran-enhanced MRI images and the arterioporal shunt in triple-phase MDCT images. The high signal intensity of the overlaying vascular structures was the most fre-
quent cause of false-positive results for the ferucarbotran-enhanced MRI relative to the signal intensity of the liver parenchyma. On the other hand, MDCT images could distinguish peripheral hepatic vessels from small hepatocellular carcinomas because of a lower slice thickness and a higher MDCT resolution.

Small arterioportal shunts were commonly detected in MDCT images; however, were seldom observed in ferucarbotran-enhanced MRI. Small arterioportal shunts hardly influenced the change in the signal intensity for the ferucarbotran-enhanced MRI because they have little influence on the number of and activity level of Kupffer’s cells. Some nodules, such as regenerative or dysplastic nodules, as well as possibly hepatic adenoma may show a predominant hypoahtenuation during portal venous or delayed phases for the contrast-enhanced CT images [6, 16], which may not be distinguished from hypovascular hepatocellular carcinoma.

Ferucarbotran can be used to perform a dynamic study with a rapid IV bolus injection, which cannot be performed with ferumoxides. Reimer et al. reported that the ferucarbotran-enhanced dynamic study improved the differentiation of benign and malignant focal liver lesions [19]. In this study, the ferucarbotran-enhanced dynamic study usually did not improve the detection of hepatocellular carcinoma itself, because of the low contrast between the tumor and the surrounding cirrhotic liver. In addition, the different enhancement patterns of hepatocellular carcinomas for the cirrhosis of ferucarbotran-enhanced dynamic T1-weighted images were compared to those observed on gadolinium-enhanced dynamic imaging [32]. The benign lesions, such as hemangiomas or cysts can be diagnosed via dynamic studies. Therefore, the ferucarbotran-enhanced dynamic study may be effective for the differentiation and characterization of benign and malignant hepatic tumors, rather than the detection of hepatocellular carcinomas in advanced cirrhosis patients.

Despite the results of this study, several limitations should be taken into consideration. First, the sample size was relatively small. Second, a retrospective pathologic correlation analyzed on a lesion-by-lesion analysis could not be performed because only the largest lesions were documented in detail for the pathologic reports of patients with four or more lesions. Nonetheless, an objective assessment may be performed by determining the presence or absence of hepatocellular carcinomas via MDCT images or MRI without any information on the pathologic findings of the explanted livers and by correlating on a one-to-one basis for each nodule for the MDCT or MR images with pathologic findings. Third, we selected 56 days as the longest time interval between the imaging study and transplantation because in screening the radiologic tests, including CT images or sonography, which were performed every 3 months at our institution. With this relatively long interval, could result in an underestimation of sensitivity due to incorrect false-negative diagnoses of hepatocellular carcinomas, because the shortest volume doubling time of a tumor is estimated to range between 27-41 days [33].

In summary, the triple-phase MDCT provided a better diagnostic performance and higher sensitivity than the ferucarbotran-enhanced MRI in the detection of HCC of patients with advanced liver cirrhosis. However, many false positive lesions resulting from nonspecific enhancements, such as arterioportal shunts, could be the major cause for the detection of hepatocellular carcinomas from triple-phase MDCT images.

Acknowledgements

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Ferucarbotran  MDCT  MRI

 목적: 1.5T ferucarbotran MRI  MDCT  MDCT ROC  ROC  p< 0.001.

 재료 및 방법: 20명 (Child B:C=8:12)의 유아을 대상으로 ferucarbotran MDCT  MRI  MDCT  MDCT  ROC  ROC  60.3% 43.1% (p< 0.001).

 결론: MDCT  ferucarbotran MRI  ROC  ROC  p< 0.001.