The expression of transporter OATP2/OATP8 decreases in undetectable hepatocellular carcinoma by Gd-EOB-MRI in the explanted cirrhotic liver

A short title: OATP expression in undetected HCC

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Keywords: hepatocellular carcinoma, EOB-MRI, OATP, transporter,

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Abbreviations: hepatocellular carcinoma (HCC), Gadoxetic acid-enhanced magnetic resonance imaging (Gd-EOB-MRI), multi-detector computed tomography (MD-CT), organic anion transporter (OATP), model for end-stage liver disease (MELD), alpha-fetoprotein (AFP), protein induced by Vitamin K absence or antagonists-II (PIVKAII), radio frequency ablation (RFA), trans-arterial chemoembolization (TACE), multidrug-resistant protein (MRP),

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Abstract

**Purpose:** The aim of this study is to evaluate the detectability of hepatocellular carcinoma (HCC) in the explanted cirrhotic liver using Gadoxetic acid-enhanced magnetic resonance imaging (Gd-EOB-MRI) and the degree of organic anion transporter OATP2/OATP8 (OATP1B1/1B3) HCC which couldn’t be preoperatively detected by multi-detector computed tomography (MD-CT) and Gd-EOB-MRI.  

**Methods:** Eleven patients (HBV 3, HCV 7, nonBnonC 1) out of 145 recipients of liver transplantation were analyzed. The detectability by each imaging modality and the expression of OATP2/OATP8 of HCC were analyzed using the whole liver thin sliced histological and immunohistochemical examination retrospectively.  

**Results:** The imaging examination detected 17 lesions of HCC by MDCT and/or Gd-EOB-MRI. Only one lesion detected by Gd-EOB-MRI had well differentiated and minute (7mm) HCC. However, the histological examination revealed newly 11 lesions and one false-positive lesion of HCC in the explanted livers. The median diameter of the preoperatively undetectable HCC by imaging was 8 mm (2-12). The histological characteristic of the preoperatively undetectable HCC was well differentiated HCC (10/11). The accuracy rate in MDCT and Gd-EOB-MRI was 53.6% (15/28) and 57.1% (16/28). The rate of positive predictive value in MDCT and Gd-EOB-MRI was 93.7% (15/16) and 94.2%
HIDAKA et al. (16/17) respectively. The expression of OATP2/OATP8 in the preoperatively undetectable HCC was negative in 9 lesions, was weak positive in 2 lesions.

Conclusions: The detectability of Gd-EOB-MRI is almost equal to MDCT in a cirrhotic liver. Small HCCs were difficult to detect even with Gd-EOB-MRI. The transporter of OATP2/OATP8 was less expressed in the preoperatively undetectable HCCs.

Keywords: hepatocellular carcinoma, EOB-MRI, transporter, OATP
INTRODUCTION

Hepatocellular carcinoma (HCC) is the seventh most common cancer in patients with chronic liver disease particularly with hepatitis B and C virus related hepatic dysfunction such as liver cirrhosis in the world [1]. Early and adequate diagnosis of HCC in the patient underling liver dysfunction by optimal imaging modalities is likely to contribute to select the treatment and management for HCC and affect the mortality after various treatments which are the resection, liver transplantation, radio frequency ablation (RFA) and trans-arterial chemoembolization (TACE) [2-5]. A guideline from the American Association for the Study of Liver diseases has recommended that nodules with 1-2cm in diameter in a cirrhotic liver should be investigated with 2 dynamic studies, including either computed tomography (CT) scan, contrast ultrasound or magnetic resonance imaging (MRI) [4,6]. In recent years, liver specific agent has improved the detection of liver tumors. Gadoxetate-ethoxybenzyl-diethylenetriamine (Gd-EOB-DTPA; Primovist, Bayer Schering Pharma AG, Berlin, Germany) have been used as the liver specific contrast agent for detection of HCC [7]. This agent is initially taken up by hepatocytes and excreted to the biliary system. In a rodent study, the gadoxetic acid was uptaken by organic anion-transporting polypeptide (OATP) 2/8 (OATP1B1/1B3) and the excreted to
the biliary canaliculi through the export transporter, multidrug-resistant protein (MRP) 2
[8, 9]. Several reports indicated that the expression of hepatocyte transporter especially
OATP2/OATP8 in HCC correlated with the enhancement of Gd-EOB-MRI in the
hepatocyte phase [10-12].

Compared with MD-CT, some investigators indicated that Gd-EOB-MRI had
significantly higher accuracy and sensitivity in the detection of small HCC in patients
with normal liver and liver cirrhosis [13-15].

However we have reported that there are some HCCs in the explanted cirrhotic liver in
the liver transplantation which could not be detected by even current modalities [16]. It
is uncertain about the degree of the expression in an undetectable HCC by the advanced
modalities including GD-EOB-MRI and the real detectability of HCC in the cirrhotic
explanted liver.

This study aims to reveal the real detectability of MD-CT and Gd-EOB-MRI and
the expression of hepatocyte transporter of HCC in the explanted cirrhotic liver which
could not be detected preoperatively even by Gd-EOB-MRI.

17 METHODS

18 Patients
We had 146 cases in liver transplantation (LT) in our university from 1997 to July 2011. Between 2008 and 2010, eleven patients (HBV 3, HCV 7, nonBnonC 1) out of 145 cases of LDLT were analyzed. From 2008 Gd-EOB-MRI had been used for the diagnosis of all patients with HCC before LT. MD-CT and Gd-EOB-MRI was done to evaluate the status of HCC. Our policy of the indication of LDLT for the patients with HCC stick to the Milan Criteria: solitary tumor less than 5 cm, multiple tumor less than 3 nodules and 3 cm (17, 18). The details of these patients were described as follows, Backgrounds of the patients were Child-Pugh score 9 (median, 6-13), MELD score 11.5 (7-16), AFP 9.6 ng/ml (3.2-506), and PIVKA-II 38mAU/ml (10-80) respectively in Table 1.

Imaging and diagnostic methods

Multidetector CT technique

CT was performed with a 64-MDCT scanner (Aquilion 64, Toshiba Medical Systems) with the following scanning parameters: rotation time, 0.5 second; beam collimation, 64 × 0.5 mm; section thickness and interval, 3 mm and 2.4mm; field of view, 32 cm;120 kV; tube current, 250–350 mAs. All helical scans were started from the top of the liver and proceeded in a cephalocaudal direction. In each patient,
unenhanced and three-phase (arterial, portal, and delayed phase) contrast-enhanced helical scans of the whole liver were obtained. Patients were instructed to hold their breath during scanning. A dose of 110 – 135ml of nonionic contrast material (iomeprol; Iomeron, Bracco) was injected into an antecubital vein at a rate of 4- 5 mL/s. An automatic bolus tracking program (Real Prep, Toshiba Medical Systems) was used to time the start of acquisition after contrast injection.

**MR imaging technique**

MR imaging was performed with a 1.5T superconducting system (Signa, GE Medical Systems, Milwaukee, WI, USA), using a body phased array multicoil for signal detection. Unenhanced sequences included breath-hold T2-weighted single-shot FSE sequences with and without fat saturation, and breath-hold T1-weighted GRE dual-echo “in and out of phase”. Contrast-enhanced sequences were acquired after intravenous injection of Gd-EOB-DTPA at a dose of 0.1 ml/kg body weight at a speed of 1.5 ml/sec immediately followed by a 20-mL saline flush, using a dual power injector. Both dynamic and hepatobiliary-phase images were obtained using a fat-suppressed, 3D GRE sequence (Liver Acquisition with Volume Acceleration: LAVA, GE Medical Systems) before and after IV bolus administration of Gd-EOB-DTPA. Imaging delay times were
determined with an automatic bolus tracking program (Smart Prep, GE Medical Systems) after contrast agent administration. Hepatic arterial phase images were obtained 10 s after the arrival of contrast medium in the proximal abdominal aorta, and portal venous and equilibrium phase images were obtained, respectively, 60 and 180 s after the beginning of the injection. Finally, hepatobiliary-phase imaging was obtained 20 min after the beginning of contrast-medium injection.

Diagnosis of HCC by imaging

Images were diagnosed by experienced radiologist before LT. Criteria for the diagnosis of HCC was shown as follows. HCC was diagnosed if two imaging characteristics were met: (a) the nodule was seen to clearly enhance during the hepatic arterial phase in MD-CT, Gd-EOB-MRI or (b) the nodule had washout during portal venous phase in MD-CT, had hypointence to the surrounding liver during the hepatobiliary phase.

Histopathologic analysis

The detectability in each imaging modality was analyzed using the whole liver thin sliced histological examination [16]. Explanted livers were fixed in 10% formalin
for 48 hours. The livers were then sectioned and serial sections were cut from paraffin blocks. Each section carefully was made from the paraffin-embedded blocks and stained with hematoxylin and eosin. Suspicious nodules by gross inspection were examined by an experienced pathologist (co-author S.O. T.H.). The pathological diagnoses and analyses were made according to the third edition of The General Rules for the Clinical and Pathological Study of Primary Liver Cancer, published by the Liver Cancer Study Group of Japan (LCSGJ) and Consensus for small hepatocellular carcinoma [19].

Immunohistochemical examination was performed as follows. Sections were deparafinized by ethanol concentrations and washed in tris-phosphate-buffered saline (TBS). Then, the sections in pH 6.0 citric acid buffer solution were treated with microwave at 125 °C for antigen retrieval for 10 min. After washing, they were treated with 0.1% H₂O₂ at room temperature for 10min. The sections were reacted at room temperature for 60 min with primary monoclonal antibodies against OATP2/OATP8 (OATP1B1/1B3) (1:30) (Cat. No. 651140, Progen Biotechnik, Heidelberg, Germany). Secondary antibody (Envision™; DAKO, Chicago, USA) was used at room temperature for 30 min. The sections were stained with 3, 3-diaminobenzidine tetrahydrochloride (DAB) for visualization. The sections were
counterstained with Mayer’s Hematoxylin.

3 Statistical Analysis

The diagnostic accuracy, sensitivity, and positive predictive value of MD-CT and Gd-EOB-MRI in the diagnosis of HCC were evaluated all lesions. The suspicious lesions were assessed and measured by a radiologist. The macroscopic lesions of HCC were assessed and measured by a pathologist in each section. In this retrospective analysis, the accuracy of diagnosis was calculated as the real number of HCCs in the whole explanted liver examination and number of true negative lesions divided by number of HCCs and false-positive, false-negative lesions and true-negative lesions (16). Sensitivity was calculated as the number of true-positive lesions divided by the total number of HCCs. Positive predictive value was calculated as the number of HCCs divided by the number of HCCs and the number of false-positive lesions. A chi-square test was used in the differences of accuracy, sensitivity and positive predictive value between MD-CT and Gd-EOB-MRI. Significance level was considered statistically significant when the p-values were less than 0.05. Statistical analysis was done by SPSS Version 18.0.
RESULTS

Accuracy, Sensitivity and Positive predictive value

Preoperative evaluation of HCC in the patients with LC detected 17 lesions in 11 patients by MD-CT and/or Gd-EOB-MRI, however, one nodule was only detected by Gd-EOB-MRI before LT. The histological whole liver examination revealed newly 11 lesions of HCC and one false positive lesion in the explanted livers. A total of HCC in the explanted liver was 28 nodules.

In comparison of the diagnostic accuracy, sensitivity and positive predictive value of HCC in MDCT and Gd-EOB-MRI, all parameters were greater with Gd-EOB-MRI than MDCT (Accuracy Gd-EOB-MRI vs. MDCT: 57.1% (16/28) vs. 53.5% (15/28), Sensitivity: 59.2% (16/27) vs. 55.5% (15/27) and Positive predictive value: 94.1% (16/17) vs. 88.2% (15/17)), respectively in Table 1. The HCC only detected by Gd-EOB-MRI was hypervascular nodule at arterial phase, iso-intence nodule at hepatobiliary phase, 8 mm in a diameter and well differentiated tumor in the pathological finding.

Pathological comparison of preoperatively detected and undetected HCC

A total of 17 lesions were detected by Gd-EOB-MRI and/or MDCT. Eleven
hypervascular nodules and 8 hypovascular nodules were detected by MDCT. Thirteen
hypervascular nodules and 11 hypointence nodules at the hepatocyte phase were
detected by Gd-EOB-MRI.

The mean tumor diameter of preoperatively undetectable HCC was
significantly smaller than detected HCC (undetectable HCC: mean diameter 0.8 cm,
range 0.2 – 1.1 cm vs. detectable HCC: 1.85 cm, range 0.7 – 4.2 cm, p < 0.001).
However, the differentiation of these tumors was similar (undetectable HCC: 13 well, 3
moderate vs. detectable HCC: 9 well, 2 moderate, p=0.97) in Table 2.

The expression of OATP2/OATP8 in the undetectable HCCs by Gd-EOB-MRI
The characteristics and expression of OATP2/OATP8 in the undetectable HCC
by Gd-EOB-MRI was shown in the Table 2. The no expression of OATP2/OATP8 in
HCC and the expression of OATP2/OATP8 in liver parenchyma with liver cirrhosis are
shown in Fig 1. The negative and weak expression of OATP2/OATP8 in the
undetectable HCC was shown in Fig 2. Nine lesions of the undetectable HCC had the
negative of the expression of OATP2/OATP8, weak expression was shown in 2 lesions.

DISCUSSION
Some reports indicated that the detectability of HCC was significantly higher in
the Gd-EOB- MRI than MD-CT in the normal liver and even though in cirrhotic liver
[13-15]. The results of this study revealed that there were HCCs in the cirrhotic liver
which can not be detected preoperatively by even Gd-EOB-MRI although the accuracy
of Gd-EOB-MRI was superior to MD-CT. These data was based on the weakness of
contrast in the hepatic phase by Gd-EOB-MRI as the uptake of the contrast agent in the
cirrhotic liver was decreased [19, 20]. Usually the border between HCC lesion and
normal liver was identified clearly in the hepatic phase however the image contrast in
the cirrhotic liver was not clear in the border between the malignant lesion and the
normal liver. Di Martino et al reported that the detectability of HCC less than 2 cm by
Gd-EOB-MRI was significantly higher than MDCT [15]. Mita et al indicated that there
was no difference between Gd-EOB-MRI, Sonazoid contrast-enhanced ultrasonography
and CT arteriportal angiography for diagnosing HCC in nodules smaller than 2 cm.
[21]. Tajima et al reported that the degree of liver enhancement was significantly lower
in the chronic liver dysfunction than the normal liver function group. The cirrhotic liver
has the potential of multi-centric carcinogenesis and the minute HCC which we had
reported before [16]. The characteristic of undetectable HCC was minute nodule smaller
than 1 cm (median diameter: 8 mm) in our results. These finding might be associated
that the contrast enhancement between HCC and the cirrhotic liver was not clear in the hepatobiliary phase. Even though the modalities of the image have been progressed, it was difficult to detect the minute HCC in the cirrhotic liver by even Gd-EOB-MRI because our patient was the end staged liver with high Child-Pugh score and MELD score.

Recent studies investigated whether the transporter of Gd-EOB-MRI was expressed in the HCC with various types. There was some HCC which had high intensity of hepatocyte phase in Gd-EOB-MRI even with the expression of OATP transporter [10]. These lesions were so called green hepatoma. They indicated the degree of contrast in the hepatic phase has been increased as the OATP1B3 has been more expressed in the HCC lesion. Out study revealed that the minute HCC in the explanted liver which has not been detected even by Gd-EOB-MRI had no and less expression of OATP2/OATP8. These findings might indicate the loss of membrane transporter in the normal hepatocyte during the process of the carcinogenesis of HCC. The transporter of the membrane of hepatocyte in the dysplastic nodule has been maintained, thereafter has been lost the function of the membrane during the carcinogenesis. However, in some cases the expression of OATP2/OATP8 in the moderate HCC has acquired the expression of transporter in such as the green hepatoma.
It might be associated between the excretion of the transporter such as the multi resistance drug protein which has the excretion part of the Gd-EOB-MRI into the bile duct and bile canal. As the tumor has increased gradually to the moderate differentiation, the failure and compression of the bile duct in HCC has done. The early HCC may have lost the expression of the OATP2/OATP8 function on the membrane of carcinogenic hepatocyte at first with the multi step carcinogenesis. Kitao et al reported that the expression of OATP8 significantly decreases during multistep hepatocarcinogenesis [23]. The less expression of OATP2/OATP8 has the potential biomarker of early HCC such as Glypican 3 and Heat shock protein (HSP) 70 [24, 25].

**CONCLUSION**

The detectability of HCC by Gd-EOB-MRI is almost equal to MDCT in a cirrhotic liver. Small HCCs were difficult to detect even with Gd-EOB-MRI. The transporter of OATP2/OATP8 was less expressed in the preoperatively undetectable HCCs.


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1 Figure Legends

2 Figure 1. The expression of OATP2/OATP8 in liver parenchyma and HCC

3 Figure 2. Undetectable HCC in dysplastic nodule, well differentiated, 8mm

4 Figure 3. No expression of OATP is shown in A, B. Weak expression is shown in C, D
Table 1. Accuracy, Sensitivity and Positive predictive value of MD-CT, Gd-EOB-MRI

<table>
<thead>
<tr>
<th></th>
<th>MD-CT</th>
<th>Gd-EOB-MRI</th>
<th>p-value</th>
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<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>53.5% (15/28)</td>
<td>57.1% (16/28)</td>
<td>N.S.</td>
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<tr>
<td><strong>Sensitivity</strong></td>
<td>55.5% (15/27)</td>
<td>59.2% (16/27)</td>
<td>N.S.</td>
</tr>
<tr>
<td><strong>Positive predictive rate</strong></td>
<td>88.2% (15/17)</td>
<td>94.1% (16/17)</td>
<td>N.S.</td>
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Table 2. The characteristics of detectable and undetectable HCC in the explanted liver

<table>
<thead>
<tr>
<th></th>
<th>detectable HCC (n=16)</th>
<th>undetectable HCC (n=11)</th>
<th>p-value</th>
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<tbody>
<tr>
<td><strong>MD-CT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hypervascular</td>
<td>86.7% (13/15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wash out</td>
<td>33.3% (5/15)</td>
<td></td>
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<tr>
<td><strong>Gd-EOB-MRI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hypervascular</td>
<td>81.3% (13/16)</td>
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<tr>
<td>hypointense</td>
<td>68.8% (11/16)</td>
<td></td>
<td></td>
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<tr>
<td>(hepatobiliary phase)</td>
<td></td>
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<tr>
<td>diameter (cm)</td>
<td>1.85 (0.7 - 4.2)</td>
<td>0.8 (0.2 - 1.1)</td>
<td>&lt;0.001</td>
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<tr>
<td><strong>Differentiation</strong></td>
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<tr>
<td>Well</td>
<td>13</td>
<td>9</td>
<td>0.97</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
<td>2</td>
<td></td>
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</tbody>
</table>
Figure 1. The expression of OATP2/OATP8 in liver parenchyma and HCC
Figure 2. An undetectable HCC by Gd-EOB-MRI, well differentiated, 8 mm in a dysplastic nodule
Figure 3. The lack of expression of OATP in undetectable HCC by Od-EOB-MRI in A and B. Weak expression is shown in C and D.