Characterization of hepatic lesions by perfusion-weighted MR imaging with an echo-planar sequence.

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INTRODUCTION
Gadolinium-enhanced dynamic MR imaging often increases the diagnostic value in the detection and characterization of hepatic tumors. Recently, single-shot echo-planar imaging (EPI) compatible with a standard MR system was introduced for clinical application in the upper abdomen. Because of its excellent temporal resolution EPI provides a whole-liver image series within several seconds. Therefore, EPI allows the mapping of many more points along the enhancement profile curves than conventional SE or GRE techniques, and thus an opportunity for more specific characterization of each hepatic lesion. A perfusion-weighted imaging (PWI) can be performed by means of obtaining dynamic first-pass images after intravenous bolus administration of gadolinium in the liver (1) as well as in other tissues, such as the brain (2), kidney (3), or myocardium (4, 5). On PWI with EPI (which are T2*-weighted images), gadolinium serves as a negative contrast agent, with enhancing lesions becoming lower signal intensity with increase in accumulation of contrast due to the T2 shortening. The purpose of this study was to quantitatively and qualitatively analyze the usefulness of perfusion-weighted MR imaging using single-shot gradient echo planar sequence in characterizing hepatic tumors.

MATERIALS AND METHODS
Sixty-one consecutive patients (43 men and 18 women, mean age, 56 years) with 91 focal liver lesions (14 hemangiomas, 19 metastases, and 58 hepatocellular carcinomas (HCC)) underwent PWI. All MR examinations were using a commercially available 1.5-T MR unit (Magnetom Vision; Siemens, Erlangen, Germany) with a phased-array coil. The sequence design of EPI was single-shot gradient-echo type (GRE-EPI). The principle of the gradient echo planar sequence we used is the modulus blipped echo-planar single-pulse technique variation of the original echo planar technique. In the technique described here, 128 gradient echoes are created for the duration of 76.8 msec (at echo-spacing time of 0.6 msec), and then an image with matrix of 128 x 128 is obtained. The GRE-EPI employed the following parameters: TE=32 msec, band-width=2080 Hz/pixel, a matrix of 128 x 128, acquired section numbers of 10-15, section thickness of 5 mm, acquisition time of 1.7-1.76 sec/10-15 sections. The starting time of the acquisition of PWI was synchronized with the start of intravenous bolus administration (2.3 ml/sec) of 0.1 mmol/kg of gadolinium. Acquisition of PWI was repeated every 2 sec for 88 sec after administration of gadolinium. In this study, we defined a period during which the first pass of injected gadolinium might occur in the tumor as "perfusion phase". The enhancement ratio of each hepatic tumor was defined according to the following equation: enhancement ratio = (contrast-enhanced SI - unenhanced SI) x 100% (SI=signal intensity). Differences for mean maximum SI decrease in the perfusion phase and SI recovery between the three tumor types was evaluated. Enhancement patterns were also evaluated qualitatively.

RESULTS
The changes of enhancement ratio with each type of hepatic tumor are illustrated in Figure 1. In HCC and hemangiomas, SI decrease was observed at the perfusion phase. The SI decrease in HCC was faster, while that in hemangiomas was so much less transient than in HCC. In all metastases, in contrast, the SI decrease in the perfusion phase was minimal relative to those in HCC and hemangiomas. The maximum SI decrease was 43.4% in HCC, 53.3% in hemangioma, and 11.7% in metastasis. The mean maximum SI decrease in both HCC and hemangioma was significantly larger than that in metastasis (P<.05). In HCC, the SI recovered rapidly after the perfusion phase, while in hemangioma it recovered only partially and later than that in HCC. SI was recovered finally to 85.2% in HCC, 90.4% in metastasis, and 63.5% in hemangioma relative to the unenhanced signal intensity of the tumors. The mean SI recovery at the end of the examination in both HCC and metastasis was significantly larger than that in hemangioma (P<.05).

For the transient SI decrease in the perfusion phase and SI recovery after the perfusion phase, six combined patterns were observed (Table 1). Majority of HCC showed Pattern 1 (47/58, 81.0%) or Pattern 2 (9/58, 15.5%). All hemangiomas except one showed peripheral nodular signal intensity decrease in the perfusion phase (Patterns 4 and 5). Majority of metastases (15/19, 78.9%) showed Pattern 6.

CONCLUSION
The characteristic signal intensity changes of these three types of hepatic tumors on perfusion-weighted images acquired with gradient echo planar sequence are distinctly different. In addition, the tumor vascularity could be evaluated, because the enhancement effect during the perfusion phase chiefly reflects gadolinium within the intravascular space. Therefore, perfusion-weighted imaging with gradient echo planar sequence is useful in the characterization of hepatic tumors.

REFERENCES

Fig. 1. Time-intensity change for each hepatic tumor throughout perfusion-weighted imaging.

Table 1. Patterns of signal-intensity (SI) changes for each hepatic lesion throughout perfusion-weighted MR imaging.

<table>
<thead>
<tr>
<th>Enhancement patterns</th>
<th>HCC (n=58)</th>
<th>Hemangioma (n=14)</th>
<th>Metastasis (n=19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern 1 (47/58, 81.6%): complete SI decrease and rapid SI recovery</td>
<td>47</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pattern 2 (9/58, 15.5%): partial SI decrease and rapid SI recovery</td>
<td>9</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Pattern 3 (3/19, 11.1%): complete SI decrease and late SI recovery</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pattern 4 (11/19, 12.1%): peripheral nodular centripetal SI decrease extending throughout the whole tumor and late SI recovery</td>
<td>0</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Pattern 5 (2/19, 2.2%): peripheral nodular SI decrease without extension to center of the tumor and rapid SI recovery</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Pattern 6 (17/19, 87.8%): minimal or no SI decrease</td>
<td>2</td>
<td>0</td>
<td>15</td>
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</tbody>
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