Evaluation between 3.0 T vs 1.5 T MRI in Detection of Brain Metastasis using Double Dose Gd-DTPA

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Purpose: Early detection of small brain metastases is important. The purpose of this study was to compare the detectability of brain metastases according to the size between 1.5 T and 3.0 T MRI.

Materials and Methods: We reviewed 162 patients with primary lung cancer who were examined for TNM staging. After administration of double dose of Gd-DTPA, MR imaging was performed with SPGR by 3.0 T MRI and then with T1 SE sequence by 1.5 T MRI. In each patient, three readers performed qualitative assessment. Sensitivity, positive predictive value, and diagnostic accuracy were calculated in 3.0 T and 1.5 T MRI according to size. Using the signal intensity (SI) measurements between the metastatic nodules and adjacent tissue, nodule-to-adjacent tissue SI ratio was calculated.

Results: Thirty-one of 162 patients had apparent metastatic nodules in the brain at either 1.5 T or 3.0 T MR imaging. 143 nodules were detected in 3.0 T MRI, whereas 137 nodules were detected at 1.5 T MRI. Six nodules, only detected in 3.0 T MRI, were smaller than 3.0 mm in dimension. Sensitivity, positive predictive value, and diagnostic accuracy in 3.0 T MRI were 100 %, 100 %, and 100 % respectively, and in 1.5 T MRI were 95.8 %, 88.3 %, and 85.1 % respectively. SI ratio was significantly higher in the 3.0 T MRI than 1.5 T MRI (p=0.025).

Conclusion: True positive rate of 3.0 T MRI with Gd-DTPA was superior to 1.5 T MRI with Gd-DTPA in detection of metastatic nodules smaller than 3.0 mm.

Index words: Magnetic resonance (MR), high-field-strength imaging Brain neoplasm, metastases Contrast medium
Introduction

Brain metastases present a poor prognosis suggesting a shortened survival time. Early diagnosis of brain involvement and determination of the number of metastases are important not only for quality of life but also for cost effectiveness [1-3]. The decision regarding a conservative versus a surgical approach depends on the number of brain metastases detected by radiologic means [1-3].

A contrast-enhanced MRI has become the method of choice for visualization of brain metastases [1]. High-dose gadolinium-enhanced MR examinations may have advantages over 0.1 mmol/kg examinations in detecting early and/or small metastases (3-7). A delayed study can also increase the contrast [2]. Comparing to the 1.5 T MRI with an axial T1-weighted spin echo sequence (SE), the higher field strength MR systems combined with a sequence of SPGR [spoiled gradient recalled acquisition in the steady state] and administration of a high dose of Gd-DTPA [gadopentetate dimeglumine] may also have advantages in detecting small metastases, although this has not yet been verified by clinical data. The purpose of this study is to compare the detectability of brain metastases classified according to the size of nodules, between thin slice SPGR of 3.0 T and conventional thick slice SE of 1.5 T MRI with the administration of a double dose of Gd-DTPA.

Materials and Methods

Patients

From December 2002 to February 2004, a total of 162 consecutive patients with primary lung cancer participated in our study. The institutional review board approved our study, and informed consent was obtained from all patients regarding the potential risks of both the double dose of contrast medium and two assessments by MRI scanning on a 3.0 T and 1.5 T machine. After the study, 31 patients of this population were diagnosed as having brain metastases. Mean patient age was 61.2 [range, 43 to 80 years].

Protocol

On the 3.0 T MR scanner (GE Signa VH/i; GE medical system, Milwaukee, USA), the images were acquired using a standard head coil and an actively shielded gradient system with a maximum gradient strength of 43 mT/m. On the 1.5 T MR scanner (Magnetom Vision; Siemens Medical Systems, Erlangen, Germany), a standard head coil and a maximum gradient strength of 25 mT/m were used.

All patients were examined after administrating a contrast agent with a double dose of Gd-DTPA (0.2 mmol/kg). First, examinations were performed on a 3.0 T MR scanner and then were subsequently performed on a 1.5 T MR scanner without additional contrast injection. The scan interval between the 3.0 T and 1.5 T MR examination was less than 20 minutes. The contrast agent used was Gd-DTPA (Magnevist; Schering AG, Berlin, Germany). In all patients, the double dose of Gd-DTPA at 0.2 mmol/kg was administered intravenously as a bolus and scanning commenced immediately.

MR imaging included the following sequences on both scanners: At 3.0 T MRI, an axial 3D SPGR, which is usually used at present, was used (TR/TE/TI = 5.7/1.44/400 milliseconds; flip angle 20°; 2 mm slice thickness; FOV of 220 mm; matrix size of 512×512 ZIP; spatial resolution of 0.43×0.43×2 mm; two acquisition) with a scan time of 3 minutes 30 seconds. At 1.5 T MRI, an axial T1-weighted spin echo sequence was used (TR/RE = 600/14 milliseconds; flip angle 90°; 5 mm slice thickness; FOV of 210 mm; matrix size of 174×256; spatial resolution of 1.2×0.82×5 mm; two acquisition) with a scan time of 5 minutes 30 seconds.

Three radiologists performed randomized, independent blinded review. The three readers were merely informed that all of the patients had lung malignancies. The postcontrast MR examinations of the brain on all of the patients were evaluated. The readers did not have access to other image sets within each study.

The presence, size, and number of metastatic nodules were assessed. The postcontrast images were divided into the following two groups: 3.0 T MRI with a double dose of Gd-DTPA and 1.5 T MRI with a double dose of Gd-DTPA. The readers were asked to document the number of nodules. Each nodule in each study was numbered and classified according to its largest diameter measurement: ≤3 mm, 3 mm to 5 mm, or >5 mm.
Subsequently, if there was any debate about nodule classification, a final interpretation using imaging studies was done until consensus among the readers was accomplished. If disagreements persisted, 3-6 months of follow-up MR scans were obtained for further validation. For the patients who had follow-up MR scans, these scans were considered positive for metastases if there was a response to the treatment or if there was a growth of nodules identified during the follow-up period.

In addition, the sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of the 3.0 T and 1.5 T MRI were calculated using the results from the final interpretation according to size.

A quantitative image assessment was performed next. The same lesions on scans of the two different MRI systems were determined by comparing peripheral structures. Signal intensities of adjacent tissue and nodule were assessed by region of interest (ROI) measurements placed identically on both series of images using the same sized circular ROI from the software available on both scanners. Nodule-to-adjacent tissue contrast (SI ratio) is defined by

$$\text{SI ratio} = \frac{S_{\text{tissue}1} - S_{\text{tissue}2}}{S_{\text{tissue}2}} \times 100$$

$S_{\text{tissue}1}$ taken as the signal intensity of an ROI assessed over a nodule and $S_{\text{tissue}2}$ taken as the signal intensity assessed over the contralateral white matter. The signal intensity of a nodule was measured within an enhanced area. In inhomogeneously enhanced nodules, the area of maximum uptake was chosen for measurement.

**Statistical Analysis**

The paired Wilcoxon’s signed ranks test was used to compare qualitative scores, and the matched-pair t test was used to compare nodule SI ratios between the 3.0 T and 1.5 T MRI with a double dose of Gd-DTPA. For all tests, significance was set at $p < 0.05$, and SPSS software (SPSS Inc. Chicago, US) was used for statistical analyses.

**Results**

In the final review made by consensus of three radiologists (Table 1), a total of 143 metastatic nodules were detected by the 3.0 T MRI with a double dose of Gd-DTPA. Of these nodules, 49 nodules were $\leq 3$ mm in diameter, 37 nodules were 3 mm to 5 mm, and 57 nodules were $>5$ mm. A total of 137 metastatic nodules were detected by the 1.5 T MRI with a double dose of Gd-DTPA in the final interpretation. Of these nodules, 43 nodules were $\leq 3$ mm in diameter. The 3.0 T MRI with a double dose of Gd-DTPA was significantly more effective at detecting nodules smaller than 3 mm ($p = 0.014$) than the 1.5 T MRI. However, we found no significant difference in the detection of nodules larger than 3 mm ($p > 0.05$) (Table 1).

In 6 of the 31 cases, six nodules, which were only detected by the 3.0 T MRI with a double dose of Gd-DTPA, and missed by the 1.5 T MRI with a double dose of Gd-DTPA, were unanimously agreed upon by all participants in the final interpretation. In three of the six nodules, a growing nodule was detected during a follow-up MR scan which confirmed the presence of metastases (Fig. 1). Three of the 6 nodules missed were unable to be detected using the 1.5 T MRI with a double dose of Gd-DTPA due to artifact (Fig. 2). Finally the 3.0 T MRI with a double dose of Gd-DTPA was

**Table 1. Total Number of Brain Metastases Classified by Size and Detected at the Final Interpretation**

<table>
<thead>
<tr>
<th>Size</th>
<th>3.0 T MRI with Gd-DTPA</th>
<th>1.5 T MRI with Gd-DTPA</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 3$ mm</td>
<td>49</td>
<td>43</td>
<td>0.014</td>
</tr>
<tr>
<td>3 mm $&lt;\cdot\cdot\cdot $5 mm</td>
<td>37</td>
<td>37</td>
<td>$&gt;0.05$</td>
</tr>
<tr>
<td>5 mm $&lt;\cdot\cdot\cdot $</td>
<td>57</td>
<td>57</td>
<td>$&gt;0.05$</td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
<td>137</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Note: Data are the number of nodules

**Table 2. The Values of Currently Used Statistical Measures for the 3.0 T and 1.5 T MRIs with Gd-DTPA According to Nodule Size**

<table>
<thead>
<tr>
<th>Metastatic nodules</th>
<th>Present</th>
<th>Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 3$ mm</td>
<td>143</td>
<td>0</td>
</tr>
</tbody>
</table>

*Pseudolesions that were detected as nodules by the 1.5 T MRI were detected as vascular structures by the 3.0 T MRI.
useful for confirming the presence of these nodules.

Nodules observed by the 3.0 T MRI with a double
dose of Gd-DTPA were brighter or better delineation
than by the 1.5 T MRI with a double dose of Gd-DTPA.
Out of 137 nodules, 65 were brighter (Fig. 3) and out of
137 nodules, 63 were better delineated (Fig. 4). Forty-
five of 137 nodules were satisfactory in both conditions.

By consensus, the final review stated, nodules
detected by the 3.0 T and 1.5 T MRI were considered
positive for metastases (Table 2). Additionally, there
were 18 pseudolesions which were detected as nodules
by the 1.5 T MRI, but as vascular structures by the 3.0
T MRI (Fig. 5). The sensitivity, positive predictive
values, and diagnostic accuracy of the 1.5 T MRI with
a double dose of Gd-DTPA were 95.8%, 88.3%, and
85.1% respectively. The sensitivity, positive predictive
value, and diagnostic accuracy of the 3.0 T MRI with
a double dose of Gd-DTPA were 100%, 100%, and

Fig. 1. A 65-year-old male with single brain metastasis. (a) The 3.0 T MR image with a double dose of Gd-DTPA shows a small metastatic nodule (arrow). (b) The 1.5 T MR image with a double dose of Gd-DTPA cannot show the nodule. In (c), a growing nodule was detected during the follow-up MRI with a double dose of Gd-DTPA which confirmed the presence of metastasis (arrow).

Fig. 2. A 73-year-old male with multiple brain metastases. Metastatic nodule (a) by a 3.0 T MR image with a double dose of Gd-DTPA show a metastatic nodule (arrow). But (b) the 1.5 T MR image with a double dose of Gd-DTPA cannot show the metastatic nodule by artifact.
100% respectively. For metastatic nodules smaller than 3 mm, the sensitivity, positive predictive value, and diagnostic accuracy of the 1.5 T MRI with a double dose of Gd-DTPA were 87.8%, 70.5%, and 64.2% respectively. The sensitivity, positive predictive value, and diagnostic accuracy of 3.0 T MRI with a double dose of Gd-DTPA were 100%, 100%, and 100% respectively (Table 3).

For quantitative image assessment, the SI ratio in the post contrast sequences (Table 4) was significantly higher in the 3.0 T MRI with a double dose of Gd-DTPA than in the 1.5 T MRI with a double dose of Gd-DTPA (p = 0.025).

### Table 3. Estimation of the Values of Currently Used Statistical Measures for the 3.0 T and 1.5 T MRI with Gd-DTPA According to Nodule Size

<table>
<thead>
<tr>
<th>Metastatic nodules</th>
<th>Total</th>
<th>≤ 3 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.0 T</td>
<td>1.5 T</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>100</td>
<td>95.8</td>
</tr>
<tr>
<td>Specificity</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>100</td>
<td>88.3</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Diagnostic accuracy</td>
<td>100</td>
<td>85.1</td>
</tr>
</tbody>
</table>

### Table 4. Results of a quantitative assessment of nodules that were detected by the 3.0 T and 1.5 T MRIs with Gd-DTPA (n=137)

<table>
<thead>
<tr>
<th>Nodules-to-adjacent tissue: SI ratio</th>
<th>3.0 T</th>
<th>1.5 T</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>94.59</td>
<td>63.86</td>
<td>0.025</td>
</tr>
</tbody>
</table>

### Discussion

Detection of metastatic nodules is dependent on both their size and contrast ratio (2). As methods to increase the contrast, a higher dose of Gd-DTPA, a higher field strength, and delayed study can all be used to aid detection (2-5, 8-17). Nodules larger than 10 mm are easily detected because vasogenic edema is customarily associated with larger metastases (2). So, when a higher dose of Gd-DTPA is used, the detection rate of larger nodules is not influenced. However, a higher dose is helpful for detecting small nodules because it increases nodule enhancement, yet this method has the disadvantages of increasing the false positive rate and promoting side effects (2-5, 8-14). A delayed study can also increase the contrast (2). It has been recommended that image acquisition be delayed from 5 to 35 minutes after the administration of contrast material at a dose of 0.1 mmol/kg to ensure optimal detection (2, 15).

Three of the 6 nodules missed were unable to be detected using the 1.5 T MRI with a double dose of Gd-DTPA due to partial volume artifact. Eighteen lesions were detected in the 1.5 T MRI with a double dose of Gd-DTPA, which proved to be vascular structures in 3.0 T MRI with a double dose of Gd-DTPA. The true nature of these lesions was revealed because of the greater morphologic detail visualized by the high field.
strength MR image, thus allowing differentiation between true enhancing lesions and sulcal vessels.

In our study, each nodule was classified according to its largest diameter as being ≤ 3 mm, 3 mm to 5 mm, and >5 mm because the slice thickness of the 3.0 T MRI was 2.0 mm and 5 mm for the 1.5 T MRI. Therefore this study classified small metastatic nodules as being smaller than 3 mm.

Although our study supports the use of a higher field strength MRI with a double dose of Gd-DTPA for increased metastatic nodule detection and for improved nodule enhancement and delineation, the results should be interpreted with caution. The reason for this is that for patients with two or more brain metastases, additional metastases found with the 3.0 T MRI seem to be of limited clinical importance. The presence of two or more small nodules generally will not change the way the patient is managed. Therefore, it is of utmost importance to identify the difference between none, one, and more than one metastatic nodule. Patients with a single metastatic nodule located in a respectable region can be treated surgically, and the tumor staged as M1, not M0. However, patients with two or more metastatic nodules are usually

Fig. 4. A 64-year-old male with multiple brain metastases. (a) The 3.0 T MRI with a double dose of Gd-DTPA shows a metastatic nodule with ring enhancement (arrow). (b) The 1.5 T MRI with Gd-DTPA show a metastatic nodule with ring enhancement (arrow). Nodules observed by the 3.0 T MRI with a double dose of Gd-DTPA were better delineated than when observed by the 1.5 T MRI with a double dose of Gd-DTPA.

Fig. 5. A 67-year-old female with multiple brain metastases. (a) The 3.0 T MRI with a double dose of Gd-DTPA shows vascular structure (arrow). (b) The 1.5 T MRI with Gd-DTPA shows a nodular lesion (arrow). A pseudolesion that was detected as a nodule by the 1.5 T MRI with a double dose of Gd-DTPA but as a vascular structure by the 3.0 T MRI with a double dose of Gd-DTPA is showed in this figure.
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treated with radiation therapy and/or systemic chemotherapy [3, 18-22]. On the other hand, the use of a higher strength field MRI was found to be helpful in confirming the appearance of an equivocal metastatic nodule. The 3.0 T MRI with a double dose of Gd-DTPA was also useful for the detection of additional metastases in patients with a known lesion detected by the 1.5 T MRI with a double dose of Gd-DTPA. Because this also has influence on the sensitivity, positive predictive value, and diagnostic accuracy the 3.0 T MRI with a double dose of Gd-DTPA was found to have better results than the 1.5 T MRI with a double dose of Gd-DTPA in our study. Therefore we recommend the use of the 3.0 T MRI with a double dose of Gd-DTPA in only three circumstances: when the findings by the 1.5 T MRI with Gd-DTPA are equivocal, when one potentially surgically respectable nodule is identified, or for detecting early and/or small metastases.

There were two limitations in this study. The first limitation was a difference in protocol sequence. The T1 weighted spin-echo protocol was used for the 1.5 T MRI and SPGR technique protocol for the 3.0 T MRI. Detectability of metastatic nodules is more effective with 3.0 T MRI with T1 SE than with a 1.5 T MRI with SE [2]. SPGR with thin slice thickness is superior to the T1 spin echo sequence with thick slice thickness due to a partial volume effect. Additionally, SE is not optimum for a 3.0 T due to longer T1- and shorter T2- relaxation times of water protons, which decrease the contrast ratio in the 3.0 T images.17 The purpose of this study was to detect early small brain metastases, so using the SPGR sequence with a 3.0 T MRI, which is usually used at present, has advantages for detecting early small brain metastases. The second limitation was that the scan interval between the 1.5 T and 3.0 T MRI was less than 20 minutes. However, a delayed study increases contrast as mentioned above. The current study found that the SI ratio was significantly higher in the 3.0T images than in the 1.5 T images. Considering the delayed study by the 1.5 T MRI, this limitation emphasizes the better detection rate of the 3.0 T MRI with a double dose of Gd-DTPA. And due to these confounding variables, blinded reviews were performed by three readers.

The detectability of metastatic nodules smaller than 3mm was better using a 3.0 T MRI with SPGR than a 1.5 T MRI with T1 SE. Therefore we recommend a 3.0 T MRI with SPGR and a double dose of Gd-DTPA for detecting early and/or small metastatic nodules, furthermore influencing treatment.

References

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