Contrast Enhancement of Intracranial Lesions: 
Conventional T1-Weighted Spin-Echo versus Fast Spin-Echo MR Imaging Techniques

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BACKGROUND AND PURPOSE: The T1-weighted fast spin-echo (T1-FSE) MR imaging sequence is not used routinely, since the speed advantage is not as dramatic as it is in T2-weighted imaging. We evaluated the T1-FSE sequence to determine whether this technique can replace the conventional T1-weighted spin-echo (T1-SE) sequence for routine contrast-enhanced imaging.

METHODS: Sixty-nine patients with intracranial enhancing lesions underwent both T1-SE and T1-FSE sequences in a random order after administration of contrast agent. Acquisition time was 55 seconds for the T1-FSE sequence and 2 minutes 38 seconds for the SE sequence. The conspicuity of enhancing lesions, peritumoral edema, and gray-to-white matter contrast as well as motion and flow artifacts were analyzed. Signal-to-noise ratios of enhancing lesions, gray matter, and white matter as well as contrast-to-noise ratios (CNRs) of enhancing lesions, with gray matter with white matter as the standard, were calculated.

RESULTS: The conspicuity of enhancing lesions was better on T1-FSE sequences than on T1-SE sequences, although the difference in the CNRs of enhancing lesions did not reach significance. Images obtained with the T1-FSE sequence showed less flow and motion artifacts than did those obtained with the T1-SE sequence. The conspicuity of peritumoral edema and gray-to-white matter contrast was lower on the T1-FSE images than on the T1-SE images.

CONCLUSION: The T1-FSE sequence reduces imaging time and has the potential to replace the conventional T1-SE sequence for the evaluation of enhancing lesions in the brain when time is a consideration.
field disappeared with serial MR examinations. Brain stem gliomas in three patients, dissemination from glioblastoma in one, cavernous hemangioma in one, and multiple sclerosis in two were diagnosed on the basis of typical clinicoradiologic findings. A cerebellar tumor was diagnosed as hemangioblastoma in one patient with von Hippel-Lindau disease. The diagnosis of cerebral lymphoma was obtained in two patients by virtue of a marked decrease in tumor size following steroid therapy. The diagnosis of one meningocerehalitis was obtained by verification of viral infection by CSF analysis.

MR Imaging

MR imaging was performed with a 1.5-T magnet. Parameters for the T1-SE sequence were 690/14/1 (TR/TE/number of excitations); acquisition time, 2 minutes 38 seconds; number of sections, 19. For the T2-weighted sequence, parameters were 3700/96/1 (TR/TE/number of excitations); echo train length, 7; acquisition time, 2 minutes 7 seconds; number of sections, 19. All images were obtained in the axial plane. To shorten the scan time of the long-TR sequences, T2-weighted imaging was performed with the FSE technique in all patients. If more information was needed, T1-SE or T2-weighted sequences were applied in the coronal or sagittal plane. Then, single-dose contrast-enhanced scans were obtained after intravenous administration of 0.1 mmol/kg gadopentetate dimeglumine. Approximately 5 minutes after injection, both T1-SE and T1-FSE sequences were performed. Parameters for these sequences were 690/12/1 (TR/TE/number of excitations); echo train length, 3; acquisition time, 55 seconds. The number of sections in the T1-FSE sequence was 15, because that is the maximum number of sections allowed with a TR of 690. All sequences used a 265 × 196–224 matrix, a 200- to 220-mm rectangular field of view, and 5-mm-thick sections with a 1-mm gap. To minimize the difference in delayed enhancement effects (7), the postcontrast T1-SE and T1-FSE sequences were performed in random order.

Quantitative Analysis

The signal intensities of enhancing lesions, white matter, gray matter, and background were analyzed quantitatively for each sequence. Standard electronic measurements of signal intensity in each region of interest (ROI) were made by one of the researchers. An ROI was selected from the T1-SE images and a corresponding ROI was found on the T1-FSE images. When patients had more than five enhancing lesions, five lesions were randomly selected. Measurements of signal intensity in the gray and white matter were obtained in areas of the frontal lobe adjacent to the anterior horn of the lateral ventricle and the interhemispheric fissure, respectively. All circle-shaped ROIs were 690 ± 22.2 for the T1-SE sequence and 61.4 ± 18.3 for the T1-FSE sequence (P = .14); the SNRs of the gray matter were 39.1 ± 9.8 for the T1-SE sequence and 35.2 ± 7.1 for the T1-FSE sequence (P = .77). There were no statistically significant differences between the two sequences. The SNRs of the white matter were 44.8 ± 11.1 for the T1-SE sequence and 38.3 ± 7.4 for the T1-FSE sequence.
TABLE 1: Conspicuity of enhancing lesion and peritumoral edema in 60 patients with intracranial lesions

<table>
<thead>
<tr>
<th></th>
<th>FSE &gt; SE</th>
<th>FSE = SE</th>
<th>FSE &lt; SE</th>
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<tbody>
<tr>
<td>Lesion (n = 60)</td>
<td>11</td>
<td>47</td>
<td>2</td>
</tr>
<tr>
<td>Peritumoral edema (n = 34)</td>
<td>0</td>
<td>26</td>
<td>8</td>
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Note.—FSE indicates T1-weighted fast spin-echo sequence; SE, T1-weighted spin-echo sequence; FSE > SE, the FSE sequence is superior to the SE sequence; FSE = SE, the two sequences are comparable; FSE < SE, the SE sequence is superior to the FSE sequence.

Discussion

Acquisition of T1-weighted images with the T1-FSE sequence was only 55 seconds, about one third the time required with the T1-SE sequence. Reduction of imaging time with no sacrifice in the conspicuity of enhancing lesions allows greater patient throughput and may be critical in routine clinical practice, especially for pediatric or uncooperative patients. Additionally, the speed of the T1-FSE sequence can be traded for increased spatial resolution by using larger image matrices while still maintaining short imaging times. Alternatively, one may acquire additional planes without prolonging the total examination time.

The T1-FSE sequence amplifies MT effects because, by increasing the number of 180° RF pulses, the interval between 180° RF pulses is shortened and more gaussian RF pulses, which include some off-resonance frequencies, are applied (5, 9, 10). One report has also documented that MT effects were amplified by increasing the echo train length, which suppressed white and gray matter (11). This MT effect causes relative signal suppression of normal brain tissue, especially white matter, whereas increased signal intensity due to T1 shortening, caused by contrast administration, does not depend on macromolecular interaction and is not appreciably suppressed by MT pulses (5, 10). This technique is considered to be especially useful for detecting enhancing lesions, such as brain metastases or MS plaques (5, 12–15).

Many previous studies have demonstrated the utility of T1-weighted imaging with the MT technique and administration of high-dose contrast ma-
FIG 2. 60-year-old man with anaplastic ganglioglioma. The T1-FSE sequence was performed before the T1-SE sequence.
A. Peritumoral edema is present on the T1-SE image (arrow).
B. Peritumoral edema is inconspicuous on the T1-FSE image (arrow).

TABLE 2: Qualitative results of gray-white matter contrast

<table>
<thead>
<tr>
<th></th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Excellent</th>
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<tbody>
<tr>
<td>Gray-to-white matter contrast</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Spin-echo</td>
<td>10</td>
<td>34</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Fast spin-echo*</td>
<td>48</td>
<td>12</td>
<td>0</td>
<td>0</td>
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* P < .01.

TABLE 3: Qualitative results of image artifacts

<table>
<thead>
<tr>
<th></th>
<th>Severe</th>
<th>Moderate</th>
<th>Mild</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow artifacts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spin-echo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast spin-echo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P = .54</td>
<td>0</td>
<td>2</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>Motion artifacts</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Spin-echo</td>
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<tr>
<td>Fast spin-echo</td>
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<td></td>
</tr>
<tr>
<td>P = .38</td>
<td>2</td>
<td>22</td>
<td>30</td>
<td>6</td>
</tr>
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</table>

FIG 3. 45-year-old man with glioblastoma. The T1-FSE sequence was performed after the T1-SE sequence.
A and B. The T1-SE image (A) has more severe motion artifacts than does the T1-FSE image (B).
The MT technique is generally considered to be useful for characterizing MS plaques (5, 12–15, 18). A previous study illustrated that MS plaques can be distinguished from ischemic lesions and edema by measuring MT ratios (19). Other researchers showed that complicated histopathologic conditions can be predicted by calculating the MT ratios (20). Recently, van Waesberghe et al (21) investigated the natural history of enhancing MS plaques and found different patterns of changes in MT ratios, which might predict the evolution of MS plaques. In this study, we encountered a patient with multiple sclerosis in whom the peripheral rim of hyperintensity was inconspicuous on the SE sequence but was easily identified on the FSE sequence (Fig 5). Since we did not obtain a noncontrast T1-FSE sequence, it could not be determined whether the hyperintensity showed enhancement or not. However, this case suggests that the T1-FSE sequence may play a potential role in the characterization of MS plaques.

Recently, rapid pulse sequences using multiple 180° RF pulses, such as half-Fourier single-shot turbo spin-echo (HASTE), have been introduced in the evaluation of brain diseases (8). However, the use of many 180° RF pulses requires a longer TR, which makes it impossible to use those sequences for T1-weighted imaging. Another study showed that the contrast of enhancing lesions was improved.
with a combination of FSE and inversion recovery (IR) techniques (17). However, the IR technique also requires a longer imaging time and the relatively longer TR has the risk of reducing T1 enhancement.

One major disadvantage of this technique is the poor contrast of gray-to-white matter and peritumoral edema, which is caused by the differences in suppression of signal intensity by the MT effect (7% for gray matter and 15% for white matter) (5). The placement of early echoes in the center of the k-space to achieve a short effective TE may also lead to poor conspicuity, because image artifacts, such as ringing and image blurring, are produced (22). However, the aim of contrast-enhanced T1-weighted imaging is not to investigate gray-to-white matter contrast or peritumoral edema but to detect enhancing lesions. The T2-weighted images are better than conventional T1-weighted images for evaluation of peritumoral edema.

Another limitation of the T1-FSE sequence is that the maximum number of sections is restricted. The use of a short TR (690 milliseconds) and the multisection technique limited the number of sections to 15. However, 15 sections can almost cover the whole brain. With further development of MR techniques, the above limitations could be overcome in the near future.

Conclusion

The T1-FSE sequence is a fast imaging technique with a potential for replacing the conventional T1-SE sequence in routine MR imaging of enhancing lesions in the brain. A reduction in imaging time allows greater patient throughput, which may be critical in routine clinical practice.

References