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Comparison of Two MR Sequences for the Detection of Multiple Sclerosis Lesions in the Spinal Cord

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PURPOSE: To compare cardiac-triggered dual-echo spin-echo and magnetization transfer–prepared gradient-echo (MT-GE) MR imaging in the detection of multiple sclerosis (MS) lesions in the spinal cord. **METHODS:** The cervical spinal cord in 20 patients with MS and in nine healthy volunteers was examined with spin-echo and MT-GE MR imaging. Sagittal images were scored for number of lesions, certainty about lesions, image quality, and visual hindrance by artifacts in random order by two radiologists separately and in a blinded manner. **RESULTS:** In one healthy volunteer, a lesion was seen on images obtained with both images. Lesion/cord contrast-to-noise ratio was equal on both the MT-GE and T2-weighted spin-echo images. MT-GE images showed better image quality and fewer artifacts than the spin-echo images did. The readers found approximately the same number of lesions. However, the number of definite lesions was higher for the spin-echo sequence than for the MT-GE sequence. One reader found 45 definite lesions with spin-echo and 34 definite lesions with MT-GE. For the other reader, these numbers were 37 (spin-echo) and 31 (MT-GE). On the spin-echo images, 90% of the patients were considered to have definite lesions; on the MT-GE images, the readers found definite lesions in 65% (reader 1) and in 70% (reader 2) of the patients. **CONCLUSION:** Image quality was better with the MT-GE technique than with the spin-echo technique, and lesion/cord contrast-to-noise ratio on the MT-GE images was equal to that of T2-weighted spin-echo images. However, for detecting spinal cord MS lesions in the sagittal plane, the spin-echo images were preferred to the MT-GE images.

Index terms: Magnetic resonance, comparative studies; Magnetic resonance, magnetization transfer; Sclerosis, multiple; Spinal cord, magnetic resonance

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Multiple sclerosis (MS) lesions are well delineated on T2-weighted spin-echo (long repetition time [TR], long echo time [TE]) magnetic resonance (MR) images. The high signal of cerebrospinal fluid (CSF) may cause artifacts as a result of partial volume averaging. In addition, T2-weighted spin-echo images are sensitive to motion (1). These artifacts can be reduced with spatial presaturation, gradient moment nulling, and cardiac triggering (2).

To avoid the disadvantages of long-TR spin-echo imaging, $T2^*$-weighted gradient-echo (GE) sequences were developed. Because of their small flip angle and shorter TR and TE, they are faster and less sensitive to motion. GE images intrinsically have a lower signal-to-noise ratio because of the small flip angle and an increased sensitivity to magnetic field inhomogeneities owing to an absence of a refocusing 180° radio frequency pulse. As with T2-weighted spin-echo images, the high signal intensity (SI) from CSF may cause artifacts on GE images. Although, theoretically, $T2^*$-weighted GE sequences are less sensitive to intrinsic cord lesions than are T2-weighted spin-echo sequences, reports are controversial. An

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equal or greater potential for T2*-weighted GE imaging to depict intrinsic cord disease successfully was reported by Katz et al (3). In contrast, Enzmann et al (4) reported that T2*-weighted GE imaging is less sensitive than T2-weighted spin-echo imaging. The latter study used a very small flip angle and a very short TR, which reduced the signal-to-noise ratio.

Recently, magnetization transfer (MT) imaging has been advocated as a method to increase tissue contrast on MR images. In the spinal cord, the application of an MT presaturation pulse preceding a GE sequence results in a significant increase in the contrast-to-noise ratio between intrinsic cord lesions and normal spinal cord tissue (5).

We compared a routinely used sagittal dual-echo spin-echo sequence with an MT-prepared GE sequence for the detection of MS lesions in the spinal cord.

Subjects and Methods

The spinal cords of nine healthy volunteers (five men, four women; mean age, 32 years; range, 28 to 43 years) and of 20 patients (11 women, nine men; median age, 37 years; range, 21 to 48 years) with clinically definite relapsing-remitting MS were studied. MR imaging was performed at 1.0 T with a quadrature receive coil. MR imaging included a cardiac-triggered sagittal long-TR dual-echo spin-echo sequence (2300/20,80/1 [TR/TE/excitations]) and a nontriggered GE sequence (616/22/4, 20° flip angle) preceded by an MT saturation pulse (MT-GE) sequence. The MT pulse had a gaussian shape, with a bandwidth of 250 Hz and a duration of 7.6 milliseconds. The MT pulse was centered 1500 Hz off-resonance with an amplitude of 500°. MT presaturation of our GE sequence decreased the SI of normal spinal cord tissue by 25%, while the SI of CSF was unaffected, as determined in a healthy volunteer. Section position, section thickness (3 mm), intersection gap (0.3 mm), field of view (150 × 300 mm) and matrix (128 × 256) were identical for both protocols. The acquisition time was approximately 5.5 minutes for the spin-echo sequence and 5.3 minutes for the MT-GE sequence.

Both spin-echo and MT-GE images were obtained in all patients and volunteers. The images of all subjects were output to hard copies without any accompanying patient data. The proton density–weighted and T2-weighted spin-echo images were evaluated simultaneously. The MT-GE images were evaluated separately from the spin-echo images. The image sets were scored in random order by two readers separately without knowledge of the patient data. The images were scored as to overall image quality, number of lesions, delineation and certainty of lesions, and presence of imaging artifacts, using a semiquantitative scale of 0 to 5. Lesions with a score of 4 or 5 for certainty were considered definite lesions. For the spin-echo sequences, lesions were considered to be present only if they were seen on both the proton density–weighted and T2-weighted images.

Fifteen definite MS lesions in 15 patients (as determined by both readers) were used for contrast calculations. Using analysis software available on our MR imager, regions of interest were drawn in the MS lesions, the CSF, the normal-appearing spinal cord tissue, and in the surrounding air (noise signal). The contrast-to-noise ratio was defined as the algebraic difference in SI between the MS lesion and spinal cord divided by the noise: contrast-to-noise ratio = $(SI_{lesion} - SI_{cord})/SI_{noise}$. In the same way, contrast-to-noise ratios between lesion and CSF and between CSF and cord were also calculated.

An analysis of variance (ANOVA) was performed on the readers' scores for image quality and for visual hindrance by artifacts, both of which are subjective measures, with high interobserver variability. The ANOVA was used to correct for this subjectivity. Differences in contrast-to-noise ratio between MT-GE and dual-echo spin-echo were tested with Student's *t* test, since the data of the contrast measurements showed a fairly normal distribution. Differences in the median number of lesions per patient detected with the two sequences were tested with Wilcoxon's paired test for ranks because of the abnormal distribution of these data. Correlations between the readers' responses were calculated by using Spearman's rank correlation coefficient (SRCC), because these data were also not distributed normally.

Results

Interreader reliability was high for all lesions found (SRCC = .77, $P < .001$) and for the number of certain lesions found (SRCC = .76, $P < .001$). Interreader reliability was low for image quality and for visual hindrance by artifacts (SRCC < .4, $P > .1$).

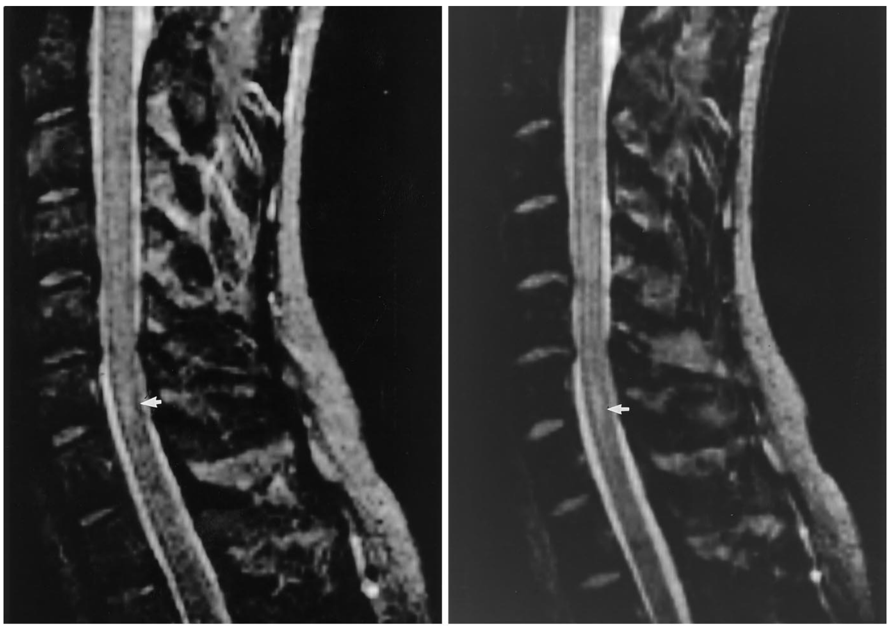
The ANOVA revealed that image quality was judged better for MT-GE studies than for dual-echo spin-echo studies after correction for reader subjectivity ($F = 5.67$; $P < .05$) and that there was less visual hindrance by artifacts on MT-GE images than on dual-echo spin-echo images ($F = 6.75$; $P < .05$).

The contrast-to-noise ratio between lesion and cord tissue was almost equal for T2*-weighted MT-GE and T2-weighted (TE, 80) spin-echo images (Table 1). The lesion/cord contrast-to-noise ratio was significantly lower on proton density–weighted spin-echo images than on MT-GE images ($P < .01$). However, the contrast-to-noise ratio between lesions and CSF was better for proton density–weighted spin-echo images than for MT-GE images, since le-

TABLE 1: Contrast measurements in patients with MS

Contrast-to-Noise Ratio* (n = 15)	Spin-Echo Proton Density–Weighted Images, Mean (SD)	Spin-Echo T2-Weighted Images, Mean (SD)	Magnetization Transfer–Prepared Gradient-Echo Images, Mean (SD)
Lesion/cord	2.08 (1.55)†	3.35 (1.99)	3.99 (1.65)
Lesion/CSF	3.75 (2.23)†	−4.04 (4.20)‡	−7.19 (4.04)
Cord/CSF	1.78 (2.39)†	−6.15 (4.92)§	−10.69 (3.34)

* Contrast-to-noise ratios were calculated by using the formulas $(SI_{lesion} - SI_{cord})/SI_{noise}$; $(SI_{lesion} - SI_{CSF})/SI_{noise}$ and $(SI_{cord} - SI_{CSF})/SI_{noise}$.
† $P < .01$ Student's *t* test, proton density–weighted spin-echo (SE) versus magnetization transfer–prepared gradient-echo (MT-GE).
‡ $P < .05$ Student's *t* test T2-weighted SE versus MT-GE.
§ $P < .01$ Student's *t* test T2-weighted SE versus MT-GE.



A **B**

Fig 1. False-positive lesion by MR imaging. T2-weighted spin-echo image (*A*) and T2*-weighted MT-GE image (*B*) of cervical spinal cord of healthy volunteer show a low-cervical focus of high signal intensity (*arrow*), interpreted by both readers as a probable MS lesion.

TABLE 2: Number of cervical cord lesions in patients

	Reader 1			Reader 2		
	SE n = 20	MT-GE n = 20	*P*	SE n = 20	MT-GE n = 20	*P*
Median number of lesions (range)	2 (1–4)	2 (0–6)	NS	2 (0–5)	2 (0–5)	NS
Median number of definite lesions (range)	2 (0–4)	1.5 (0–5)	0.036	2 (0–5)	1 (0–5)	NS

Note.—SE indicates spin echo, MT-GE, magnetization transfer–prepared gradient echo. Statistical examination was made with Wilcoxon's rank sum test for pairs; $P < .05$ was considered statistically significant; NS indicates not significant.

sions had higher SI than CSF on proton density–weighted spin-echo images. On T2-weighted spin-echo images and on T2*-weighted MT-GE images, the SI of CSF was much higher than the SI of lesions, resulting in strongly negative contrast-to-noise ratios (Table 1). Contrast-to-noise ratio between cord and CSF was better with the MT-GE technique than with both spin-echo techniques ($P < .01$). This difference was caused mainly by the much lower noise level on the MT-GE images.

In one volunteer, a focus of high SI was identified by both readers on both the spin-echo and MT-GE images. These images were scored as abnormal by both readers (Fig 1). All other volunteer studies were scored as normal.

With both sequences, approximately equal numbers of lesions were found in the patients. One reader found 51 lesions on the dual-echo spin-echo images and 47 lesions on the MT-GE images. The other reader found 41 (spin-echo) and 40 (MT-GE) lesions. However, on the dual-echo spin-echo images, the proportion of definite lesions was higher than on the MT-GE images (Table 2). One reader found 45 definite lesions on spin-echo images and only 34 definite lesions on MT-GE images. The other reader found 37 definite lesions on spin-echo images compared with 31 definite lesions on the MT-GE images.

Both readers detected definite lesions in 18 of 20 patients on the dual-echo spin-echo images (90%). The patients in whom no definite lesions were found on spin-echo images were the same for both readers. However, on the MT-GE images, definite lesions were detected in 65% of the patients by the first reader and in 70% of the patients by the second reader (Table 3). The patients in whom no definite lesions were found on MT-GE images but in whom definite lesions were found on dual-echo spin-echo images, were the same for both readers. Further analysis showed that in small peripheral lesions and in cases of diffuse high SI of the spinal cord, certainty about lesions was higher with the spin-echo technique than with the MT-GE technique (Figs 2 and 3).

TABLE 3: No. (%) of patients with definite cervical spinal MS lesions

	Spin-Echo Images (n = 20)	Magnetization Transfer–Prepared Gradient-Echo Images (n = 20)
Reader 1	18 (90)	13 (65)
Reader 2	18 (90)	14 (70)

Discussion

Our results confirm the good image quality of GE imaging with little visual hindrance from motion. With MT presaturation, the contrast-to-noise ratio between lesions and spinal cord tissue equals that of T2-weighted spin-echo images. However, dual-echo spin-echo images were more helpful in delineating MS lesions of the spinal cord in the sagittal plane. Interpretation of small peripherally located plaques and areas of diffuse high SI may be difficult with MT-GE imaging, owing to partial volume artifacts. In these cases, the proton density–weighted spin-echo technique is helpful, as it has better contrast-to-noise ratio for lesion/CSF than does the T2-weighted technique, making

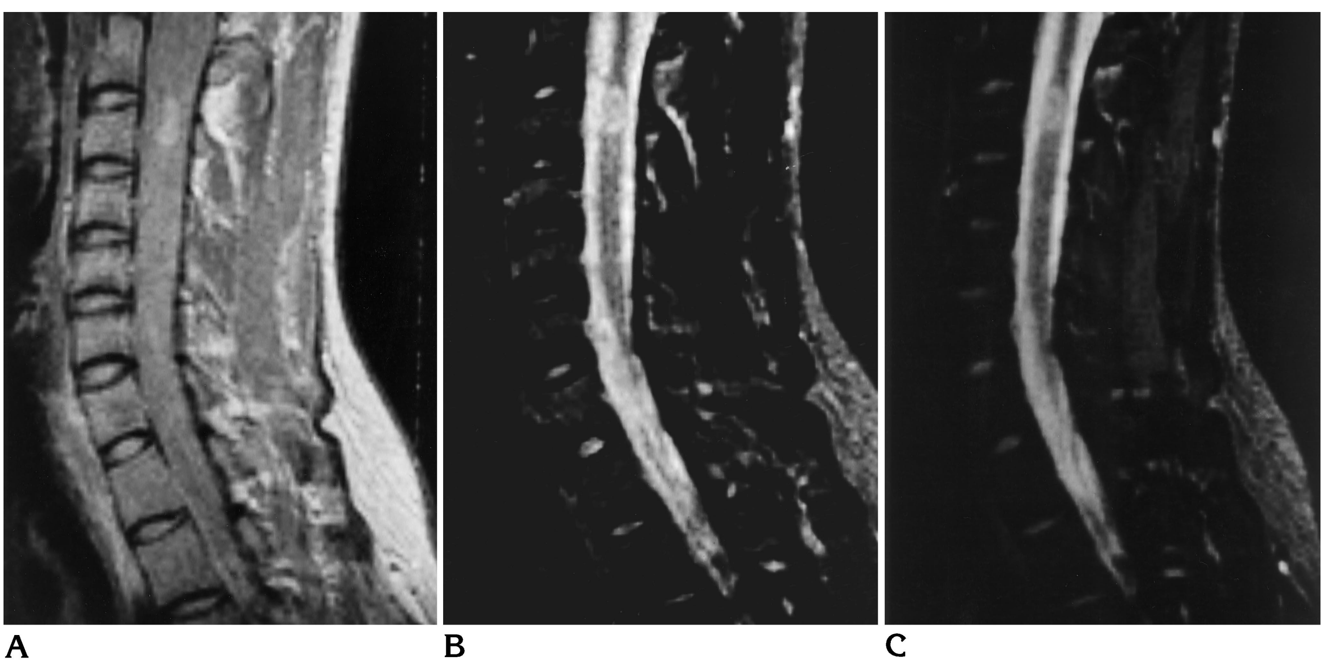


Fig 2. Proton density–weighted spin-echo image (*A*) of patient with MS shows a large MS lesion in the cervical spinal cord. The T2-weighted spin-echo image (*B*) depicts the lesion as well as the $T2^*$-weighted MT-GE image (*C*) does, although delineation was considered to be better on both spin-echo images.

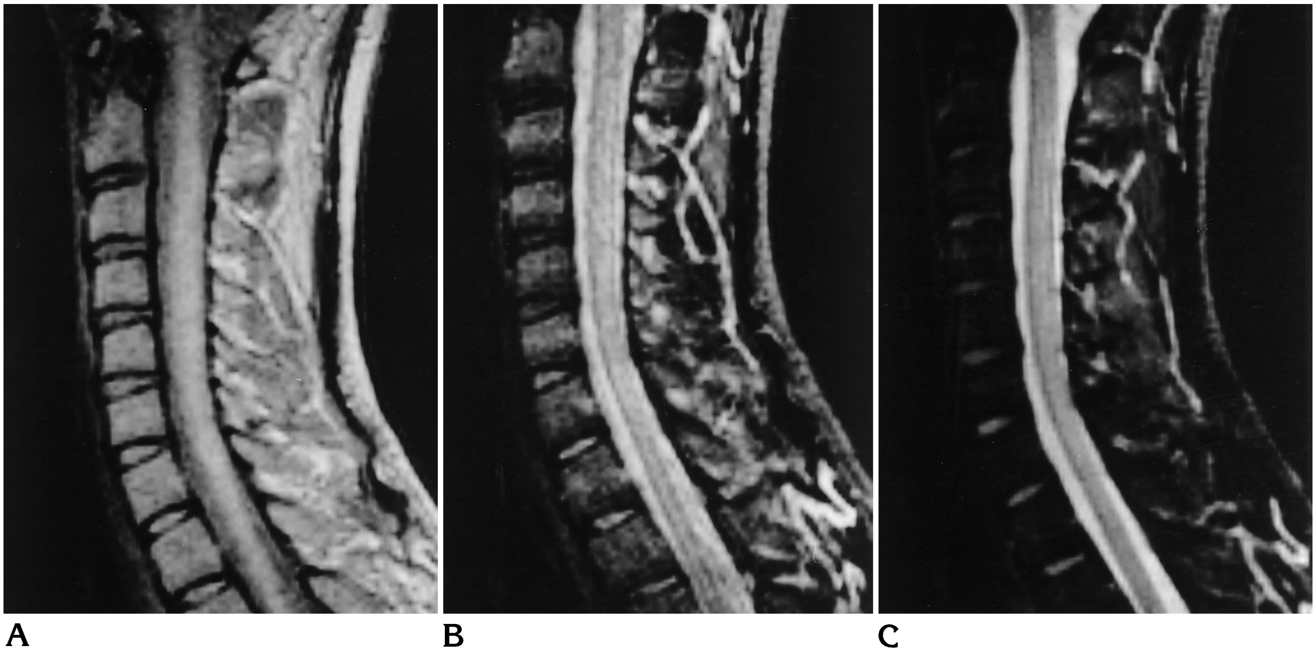


Fig 3. Superiority of T2-weighted spin-echo over MT-GE. The cervical spinal cord shows diffuse signal hyperintensity on both the proton density–weighted (*A*) and the T2-weighted spin-echo (*B*) images. On the MT-GE image (*C*), the high SI can be attributed to partial volume averaging, making the presence of the lesion less certain.

dual-echo spin-echo imaging superior to T2*-weighted MT-GE imaging. Our results differ from those of Finelli et al (5), who suggested that MT-GE may replace spin-echo in routine sagittal imaging of intramedullary lesions. We do agree that axial GE imaging is useful for MS lesions, because of their lower sensitivity to flow artifacts (6).

A disadvantage of cardiac-triggered spin-echo imaging is the relatively long examination time. Although this can be reduced with fast spin-echo imaging (7), a disadvantage of fast spin-echo is that many factors contribute to the signal, including echo train length and echo spacing (8). One study that compared fast and conventional spin-echo imaging reported an equal potential for both sequences in the detection of spinal cord lesions (9).

Another disadvantage of dual-echo T2-weighted spin-echo imaging is the high SI of CSF, which affects image quality because of the partial volume and flow artifacts. Techniques that suppress CSF signal without affecting contrast between MS lesions and cord tissue, like fluid-attenuated inversion recovery, may solve this problem (10).

Our finding of 90% sensitivity for spin-echo in the detection of MS lesions of the cervical spinal cord is higher than that of recent studies, which reported sensitivities of 74% (11) and 82% (12). In the latter study, patients were selected for spinal cord symptoms, which in itself results in increased sensitivity. The high sensitivity of MR imaging in our study without preselection of patients for spinal symptoms stresses the importance of spinal imaging in MS.

In summary, sagittal dual-echo T2-weighted spin-echo imaging is more sensitive than MT-GE imaging for the detection of MS lesions of the spinal cord. Although MT preparation results in good contrast between lesions and spinal cord, T2-weighted dual-echo spin-echo imaging is superior to the MT-GE technique.

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