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Sagittal MR of Multiple Sclerosis in the Spinal Cord: Fast versus Conventional Spin-Echo Imaging

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PURPOSE: **We compared conventional spin-echo (CSE) with fast spin-echo (FSE) dual-echo MR images to determine which of these sequences was better able to depict spinal cord abnormalities in patients with multiple sclerosis (MS).**

METHODS: **CSE and FSE dual-echo MR images were obtained in 37 patients with MS and in six healthy control subjects, all of whom were examined on a 1.0-T MR unit with a phased-array coil and cardiac triggering. Two blinded interpreters graded the MR studies, first separately and then by consensus. Images were scored for presence of artifacts, number of focal lesions, and presence of a diffuse increase in signal intensity.**

RESULTS: **No abnormalities were seen in the volunteers. The CSE sequences were significantly less hindered by MR imaging artifacts than were the FSE sequences. Interobserver agreement was slightly higher for the CSE than the FSE sequences. After reaching a consensus, the observers found that both CSE and FSE techniques enabled detection of approximately the same number of focal lesions; however, in three patients, small single lesions seen on the CSE images were missed on the FSE images. Also, depiction of a diffuse increase in signal intensity was better on the CSE images. As a result, more patients had abnormal findings on the CSE sequences than on the FSE sequences (35 versus 31).**

CONCLUSION: **Cardiac-triggered dual-echo FSE sequences are almost as good as CSE sequences for depicting spinal MS lesions. Therefore, in cases of established spinal MS, FSE techniques may be as effective as CSE techniques. Because sensitivity for subtle abnormalities is lower with FSE imaging, CSE remains the preferred technique for patients with suspected MS of the spinal cord.**

For the detection of spinal cord abnormalities in patients with multiple sclerosis (MS), sagittal T2-weighted magnetic resonance (MR) imaging is the technique currently used, and, in most studies, conventional spin-echo (CSE) sequences are performed (1–4). However, owing to the large field of view needed to cover the entire spinal cord sagittally, T2-weighted CSE is time consuming, with an acquisition time of around 10 minutes.

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The rapid acquisition with relaxation enhancement technique, which is now commonly known as turbo or fast spin echo (FSE) (5), has been studied by several investigators for its utility in imaging the brain (6) and spinal cord (1, 7, 8) in patients with MS. Owing to its shorter acquisition time, FSE is now increasingly used to obtain sagittal MR studies of the entire spinal cord to detect MS abnormalities (9–11).

Two studies comparing the potential of FSE and CSE in the detection of spinal MS lesions (1, 12) generated contradictory findings. Sze et al (1) compared the sensitivity of FSE with that of CSE in patients with intradural disease, including 21 cases of MS. These authors concluded that FSE is almost as sensitive as CSE while saving considerable acquisition time. In another study, Hittmair et al (12) concluded that compared with CSE, FSE images missed some MS abnormalities. More specifically, areas of increased signal intensity (SI), which were detected on sequences with a relatively short echo time, were seen less well on heavily T2-weighted FSE images. The

possibility of FSE sequences missing MS lesions was also reported in a recent case report (13). In a study comparing $T2^*$-weighted gradient-echo sequences with dual-echo CSE in patients with MS, it was suggested that the lower sensitivity of the gradient-echo sequences may be attributed to the availability of two echoes in dual-echo imaging (14). An absence of two echoes may also have been the reason for the lower sensitivity of FSE in the above-mentioned studies.

We tested the hypothesis that dual-echo FSE imaging is as sensitive as dual-echo CSE imaging for detecting MS abnormalities in the spinal cord.

Methods

Thirty-seven patients with clinically definite MS and six healthy age- and sex-matched volunteers were imaged sagittally at 1.0 T using a spinal phased-array coil. Of 37 patients, 25 had symptoms suggestive of spinal cord involvement of MS. Both a cardiac-triggered dual-echo CSE sequence (±2200/20,80/1 [repetition time/echo time/excitations]) and a cardiac-triggered dual-echo FSE sequence (±2200/22,90/3) with an echo train length of 5 were performed. The resulting mean repetition time, which was dependent on the subjects' heart rates, did not differ between the two sequences. In 38 subjects, CSE was performed before FSE, while in five patients, FSE was first. Fifteen 3-mm-thick sections with an intersection gap of 0.3 mm were obtained. The field of view was 240 × 480 mm, the matrix was 256 × 512 for both sequences, and acquisition time was approximately 12 minutes for CSE sequences and approximately 6 minutes for FSE sequences, depending on the subjects' heart rate.

MR images were displayed on randomly numbered sheets of film, without any clinical or imaging information. The proton density–weighted image and the corresponding T2-weighted image were printed next to each other. Two readers scored the MR images independently for spinal cord abnormalities, which were classified either as focal lesions or as a diffuse increase in SI. The latter classification was defined as increased SI running throughout the length of the spinal cord, which was best identified on proton density–weighted studies, since the spinal cord is isointense with cerebrospinal fluid on these images and any increase in SI of the spinal cord may readily be detected (15). Severity of artifacts was scored on a scale of 0 to 5, with scores of 3, 4, or 5 indicative of hindering image interpretation. The readers were also asked to judge which sequence they were scoring (FSE or CSE). After the first session, the images were scored again until a consensus was reached between the two observers.

Statistical Analysis

Interobserver agreement was calculated by using Cohen's κ statistic and Spearman's rank correlation coefficient (*r*). Differences between the two MR sequences in the number of abnormalities found and in the degree of hindrance caused by artifacts were subjected to an analysis of variance (ANOVA) test before the consensus reading to correct for interobserver variance.

Results

The type of MR sequence (CSE or FSE) could be distinguished in the majority of cases, mainly by the high SI of fat as found on the T2-weighted FSE images. Still, there was some blinding, as evidenced by misclassification of the type of MR sequence by the two readers in 10 (23%, reader 1) and eight (19%, reader 2) of the 43 subjects, respectively. No abnormalities were found in the healthy control subjects on either sequence, and these examinations were all scored as definitely normal.

Both readers found more FSE than CSE examinations seriously hindered by artifacts (Table 1), which was confirmed by ANOVA testing after correction for interobserver variance ($F = 4{,}72$; $P < .05$). The types of artifacts observed are listed in Table 2.

Interobserver agreement as to the number of focal lesions seen was approximately equal for CSE ($r = .83$) and FSE ($r = .85$) sequences. Agreement as to the presence of a diffuse increase in SI was higher for CSE ($\kappa = .85$) than for FSE ($\kappa = .73$); however, the scores indicated good agreement, and the difference was not statistically significant.

After reaching a consensus, the observers found that CSE and FSE images showed focal lesions in an almost equal percentage of patients (Table 1). Also, the median number of spinal lesions per patient did not differ significantly between CSE and FSE (Table 1) sequences; however, in three patients, a single small lesion was missed on FSE images that was visible on CSE images.

Diffuse increase in SI of the spinal cord was detected more often on the CSE images than the FSE images (Table 1), and depiction of a diffuse increase in SI was better on the CSE images (Fig 1). The three cases in which a diffuse increase in SI was not scored on FSE images included the two studies in which pulsation and/or movement artifacts hindered interpretation. In the remaining case, CSE images showed

TABLE 1: Results of scoring CSE and FSE images

	CSE	FSE
No. (%) of patients with focal lesions	27 (70)	23 (62)
Median no. (range) of focal lesions	1 (0–12)	1 (0–13)
No. (%) of patients with diffuse increase in signal intensity	12 (35)	9 (24)
No. (%) of abnormal examinations	35 (94)	31 (84)
No. (%) of examinations hindered by artifacts	4 (11)	7 (19)
No. (%) of scans not interpretable because of artifacts	...	1 (3)

Note.—CSE indicates conventional dual-echo spin echo; FSE, fast dual-echo spin echo.

TABLE 2: Artifacts hindering image interpretation in CSE and FSE images (n = 43)

	CSE No. (%)	FSE No. (%)
CSF pulsation artifacts	5 (12)	11 (26)
Heart pulsation artifacts (ghosting)	4 (10)	3 (7)
Patient motion	3 (7)	4 (10)
Partial volume averaging	...	1 (2)
Low signal-to-noise ratio	1 (2)	...

Note.—CSE indicates conventional dual-echo spin echo; FSE, fast dual-echo spin echo. Only artifacts that hindered image interpretation are included (ie, those given a score of 3, 4, or 5 on a 5-point scale).

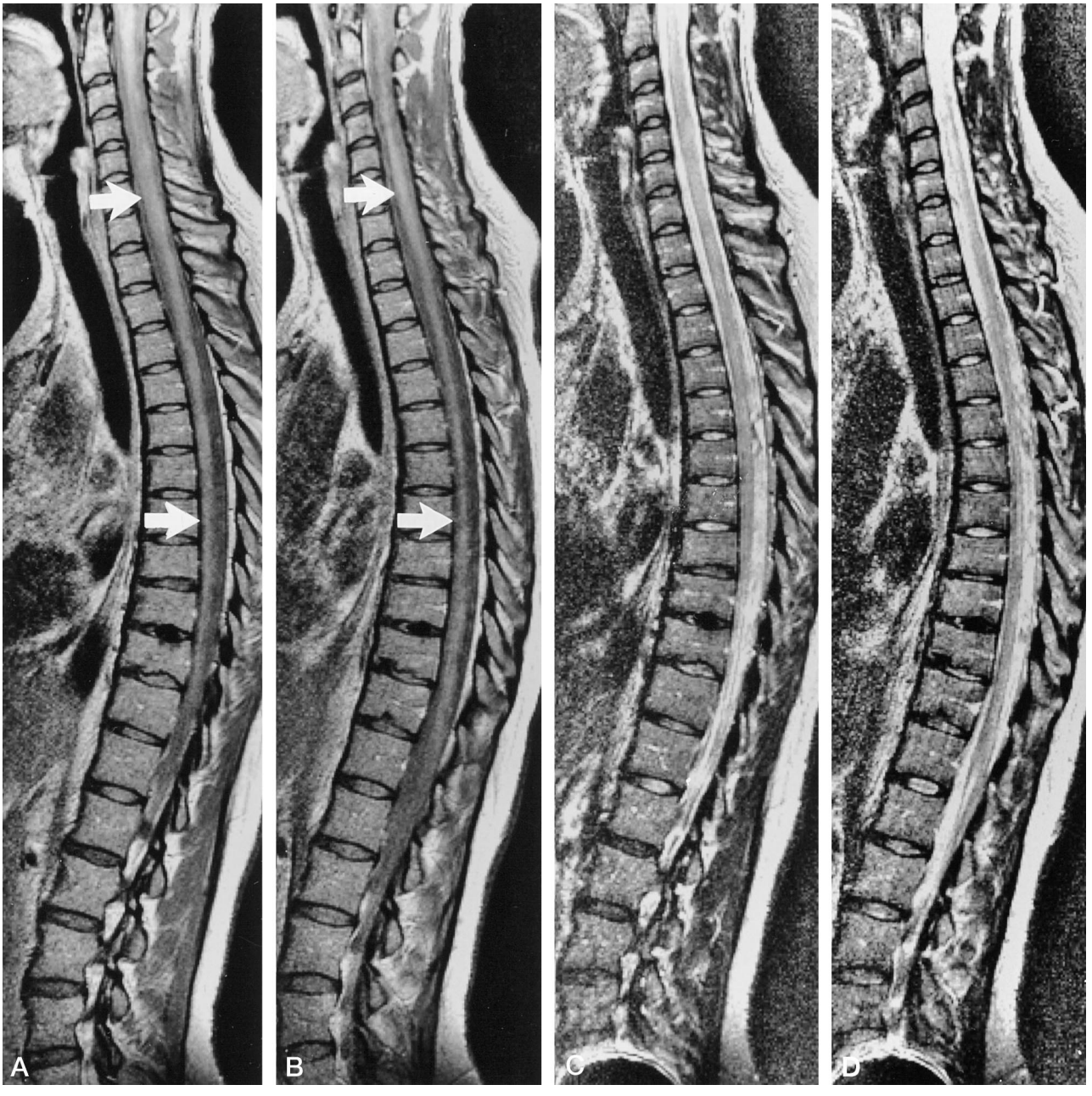

FIG 1. Diffuse changes in the spinal cord in a patient with MS. Proton density– and T2-weighted MR images of the brain (not shown) depicted abnormalities suggestive of MS.

Proton density–weighted (*A* and *B*) and T2-weighted (*C* and *D*) CSE (±2200/20,80/1) images. Diffuse increase in SI of the spinal cord, compared with SI of cerebrospinal fluid, is visible running continuously throughout the cord, and is seen at both the cervical and thoracic levels (*arrows*). This feature is best seen on the proton density–weighted images. Note that in healthy subjects, the spinal cord should appear isointense with CSF on proton density–weighted images (15). *Figure continues.*

diffuse SI increase and focal lesions, while FSE images showed only focal lesions.

In total, four patients who were determined to have abnormal findings on CSE images were considered to have normal results on FSE images (Table 1). In three cases, this discrepancy was the result of the interpreters having missed a single focal lesion (Fig 2). In the remaining patient, a diffuse increase in SI was seen on the CSE images, which could not be seen on the FSE images because of artifacts.

Discussion

When choosing a sequence for assessing spinal MS abnormalities, a balance needs to be found between image quality, sensitivity, and acquisition time. We studied whether shortening acquisition time by applying an echo train to a dual-echo spin-echo sequence causes loss of image quality and sensitivity for depicting spinal MS abnormalities.

The results suggest an almost equal potential for

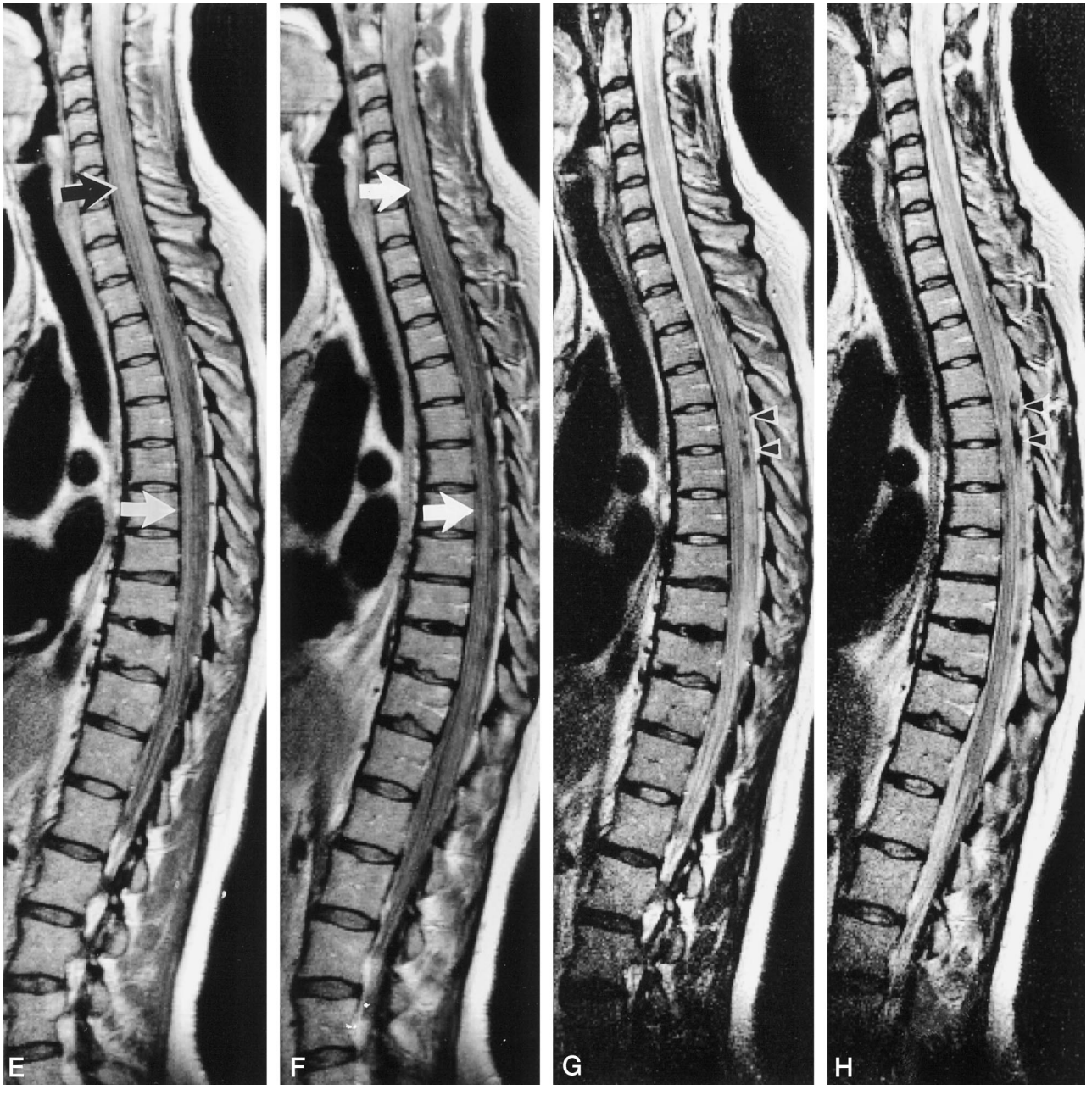

FIG 1, *continued.*
On corresponding proton density–weighted (*E* and *F*) and T2-weighted (*G* and *H*) FSE (±2200/22,90/3) images, the presence of a diffuse increase in SI is less obvious, partly because the FSE images are somewhat degraded by cerebrospinal fluid pulsation artifacts (*arrowheads*).

FSE and CSE in detecting focal MS lesions in the spinal cord; however, in three patients, small focal lesions that were seen on CSE images were not seen on the FSE images. As a result, the CSE findings in these patients were scored as abnormal, while the FSE findings were considered normal. Visibility of diffuse increases in SI was also better on the CSE images. Most patients with a diffuse increase in SI also had focal lesions, so missing diffuse SI changes on FSE images had no bearing on whether the examination was considered abnormal. In one patient, however, a diffuse increase in SI was the only abnormality seen on the CSE images, and this abnormality was not seen on the FSE images owing to artifacts.

Apart from differences in detecting subtle spinal cord abnormalities in some patients, the two sequences performed almost equally well, in keeping with findings from a previous study (1), which also used dual-echo sequences. The lower sensitivity of FSE reported in two other studies (12, 13) may have been associated with several factors that possibly decrease the sensitivity of FSE sequences for detecting subtle abnormalities. First, the FSE sequence in these studies used only one long echo time, causing heavy

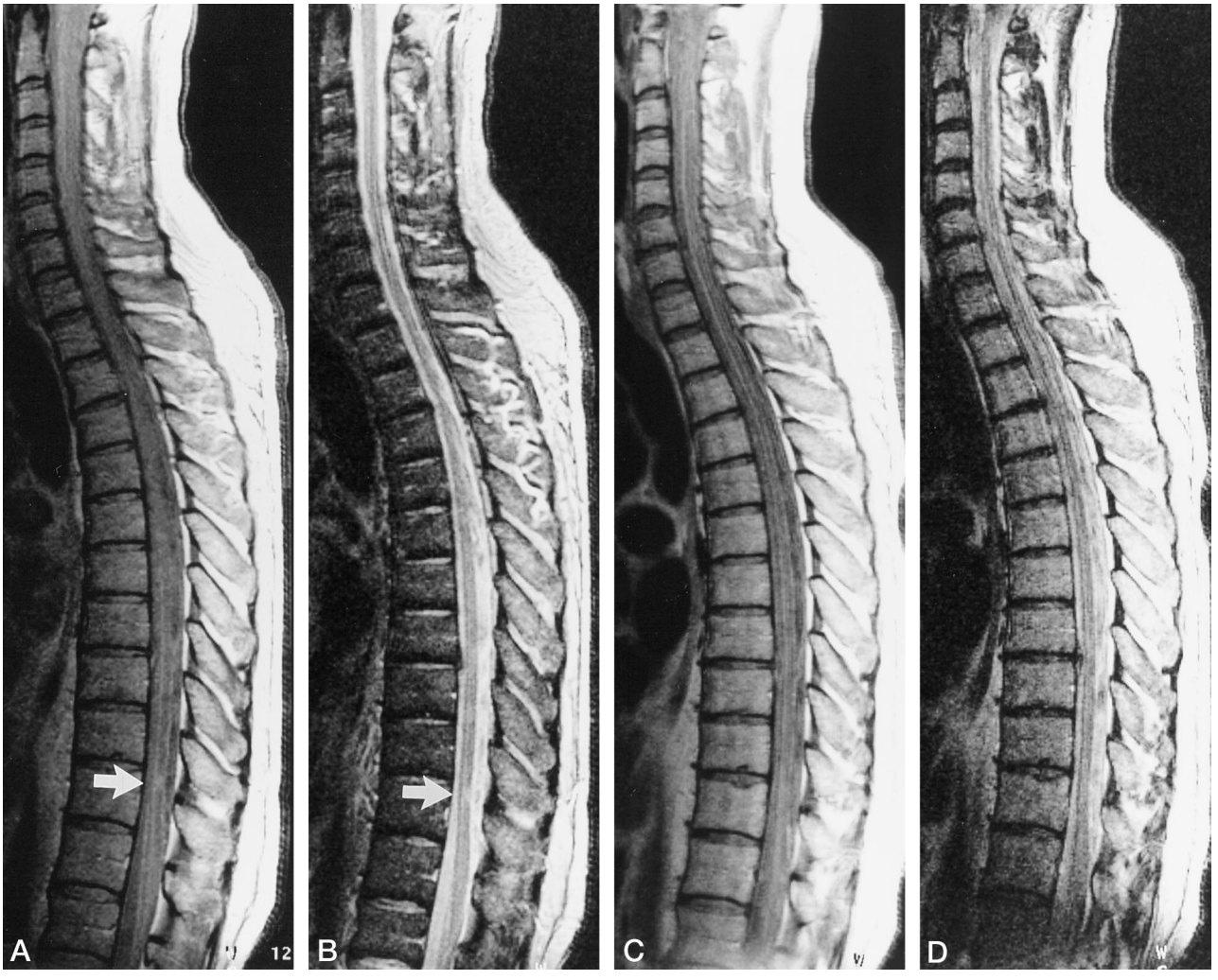

FIG 2. CSE images in a patient with MS show a single small focal lesion, which was missed on FSE images. Proton density– and T2-weighted CSE images of the brain (not shown) depicted abnormalities that were suggestive of MS.

Proton density–weighted (*A*) and T2-weighted (*B*) CSE images (±2200/20,80/1) show a small focal lesion (*arrows*) at T10–11. This lesion was not seen on the corresponding FSE images (±2200/22,90/3) (*C* and *D*).

T2 weighting. In spinal MS lesions, T2 may be relatively short, and therefore too heavy T2 weighting may decrease sensitivity. This was suggested as a reason for the disappointing results produced by fluid-attenuated inversion recovery sequences in spinal cord studies (16). An FSE sequence combined with short-tau inversion recovery was recently reported to perform well in a study of spinal MS, which may be partly explained by the relatively short echo time (12). In our study, we avoided the disadvantage of too-heavy T2 weighting by using both a short and a long echo time for both sequences. Availability of two echo times was also associated with better performance of CSE as compared with a (single-echo) $T2^*$-weighted gradient-echo sequence (14). Another reason for the lower sensitivity of FSE sequences reported previously may have to do with applying too long an echo train, which may negatively influence image contrast (7). Our FSE sequence had a relatively short echo train of 5.

We performed the CSE sequences before the FSE sequences in all but five cases. This may have led to bias if patients were more restless during the last examination. However, the time difference was only 10 minutes, and artifacts caused by patient motion (swallowing, body movements) did not occur much in either sequence, and only slightly more often in the FSE sequences. In only one patient was the FSE image uninterpretable because of artifacts associated with patient motion.

Conclusion

Dual-echo FSE is almost comparable to dual-echo CSE in detecting spinal MS lesions, adding the benefit of short acquisition time. Nevertheless, the shorter acquisition time of FSE imaging came at the price of a slightly lower sensitivity for small and subtle abnormalities and of more artifacts causing degradation of image quality. Therefore, in cases of suspected spinal MS, CSE remains the sequence of choice because of higher sensitivity for depicting subtle abnormalities. In established MS, FSE may be used to confirm the presence of spinal abnormalities, with the

benefit of saving time. The results support the findings of previous studies, which suggest that availability of a short echo time may be an important factor influencing sensitivity for spinal MS lesions. When choosing a sequence to replace CSE, this should be kept in mind.

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