Evaluation of Shared-View Acquisition Using Repeated Echoes (SHARE): A Dual-Echo Fast Spin-Echo MR Technique

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PURPOSE: To compare the clinical efficacy of a dual-echo fast spin-echo imaging technique, SHARE (shared-view acquisition using repeated echoes), with conventional long-repetition-time spin-echo imaging. **METHODS:** Conventional spin-echo and SHARE fast spin-echo MR images of the brain were acquired in 50 randomized patients and interpreted separately in conjunction with the T1-weighted images. All images were reviewed independently by two neuroradiologists who were blinded to the clinical history and previous interpretations. **RESULTS:** The diagnoses rendered for the spin-echo and SHARE images were concordant in 48 of the 50 subjects (96%) by the first reader and in all 50 cases (100%) by the second reader. SHARE images were acquired in one-fourth of the imaging time yet image contrast, quality, and sensitivity to long T2 lesions were comparable. The SHARE technique was less sensitive to hemorrhagic residua. **CONCLUSIONS:** SHARE is a viable time-saving alternative to the conventional long-repetition-time pulse sequence. Although SHARE images are not as sensitive to magnetic susceptibility effects, the time saved using this technique could be used to perform a gradient-echo sequence when indicated.

Index terms: Magnetic resonance, comparative studies; Magnetic resonance, technique; Brain, magnetic resonance; Efficacy studies

Several variations of the rapid acquisition with relaxation enhancement technique (1, 2) have been investigated as potential time-saving replacements for long repetition time (TR) spin-echo images (3, 4). In this trial, we compared conventional long-TR dual-echo spin-echo imaging with the SHARE technique (shared view acquisition using repeated echoes), a variation of the RARE pulse sequence. SHARE images are generated by using a fast spin-echo train consisting of 6 echoes. The 40- and 80-msec echoes encode the middle of k space to generate two images at these effective echo delay times. In clinical practice this technique results in a 25% improvement in speed over conventional fast spin-echo techniques when the acquisition time is TR limited. SHARE provides two "effective echoes" with intermediate and T2-weighted contrast characteristics, similar to the spin-echo series.

Methods

A prospective comparison between SHARE and long-TR spin-echo imaging was performed on 50 randomized patients. The images were obtained over a 3-month period from November 1991 to January 1992. A prospective blinded comparison of conventional spin-echo and SHARE fast spin-echo imaging was effected by supplementing the conventional spin-echo magnetic resonance (MR) sequences of the brain with a dual-echo SHARE sequence. The conventional spin-echo studies consisted of dual-echo long-TR axial sequences: 2500/30,90/1 (TR/echo time [TE]/excitations) with a 16/4 kHz variable bandwidth, 192 phase-encoding steps, and an acquisition time of 8:30. The studies were performed on 1.5-T GE Signa Advantage MR Systems (General Electric Medical Systems, Milwaukee, Wis).

SHARE Technique

This modification of the RARE technique uses the acquisition of multiple spin echoes after each 90° pulse (Fig 1). With a TR of 2600 msec, spin echoes are formed every 20 msec from 20 to 120 msec. The first echo is formed but not sampled. The SHARE scheme for Fourier space mapping has already been described (E.K. Fram, P.J. Keller, and B.P. Drayer, Rapid Spin Echo Imaging (RARE) Producing Two Effective Echo Times by Sharing Views, presented at the Society of Magnetic Resonance in Medicine, 1991). The center of k space is sampled at both 40 and 80 msec. Because the central views in Fourier space determine image contrast, the resultant SHARE images have effective echo times (TEeff) of 40 and 80 msec, respectively (2600/40,80/1). The higher-order phase-encoding steps (mapped to the periphery of k space) are sampled with echoes at 60, 100, and 120 msec. These views are shared by both (40 and 80 msec TEeff) images, which allows data for the short and long-TE images to be acquired simultaneously. The SHARE method of k space mapping maintains symmetry and provides relatively smooth transitions through k space. Five millimeter-thick axial images are obtained with a 20-cm field of view, 16-kHz bandwidth, 256 × 192 matrix using a single excitation per view. This technique provides 18 axial long-TR images of the brain in a 2:10 acquisition time.

Image Analysis

All spin-echo and SHARE images were reviewed independently by two of three neuroradiologists (E.K.F., B.P.D., B.L.D.) who were blinded to the clinical history and previous interpretations. The long-TR spin-echo and SHARE images were interpreted separately in conjunction with the spin-echo T1-weighted images and evaluated for the presence and identity of focal signal abnormalities, which were individually marked on each image. A diagnosis was independently derived for each study. After the spin-echo and SHARE images were evaluated separately by each of two readers, the images and interpretations were compared by a third reader (B.A.J.). This comparison included assessment of the number of focal signal abnormalities recognized using each of the techniques via a point-by-point comparison on the SHARE and spin-echo images. The diagnosis assigned to each set of images was also assessed for concordance between the SHARE and spin-echo readings. The relative amount of image degradation caused by motion and flow-induced artifacts was then compared.

Statistical Analysis

The sensitivities demonstrated by each technique for the detection of hyperintense and hypointense foci (< 3 mm) were compared separately as follows. The probabilities that the readers would recognize a focus were estimated for each technique and then compared by a formal hypothesis test. Each estimate was obtained as the proportion of foci recognized with one technique (spin-echo or SHARE) out of the total number recognized with both methods. The test consisted of comparing these two probabilities using the normal approximation to the binomial with a 2-tailed alternative.

Results

A wide cross-section of disease was encountered in our cohort of patients (Table 1). Subjects ranged in age from 2 months to 89 years (mean, 49 years). The geographic and signal characteristics of mass lesions such as neoplasms correlated closely on conventional spin-echo and SHARE fast spin-echo images (Fig 2). Descriptions of all neoplasms were concordant, and side-by-side comparisons of the two techniques revealed no discrepancies.

Focal high-signal white-matter lesions were demonstrated equally well on both techniques; in some cases, these small foci were better depicted on the SHARE images (Fig 3). Statistical analyses of the detection of hyperintense periventricular and subcortical white-matter lesions using the spin-echo and SHARE techniques are presented
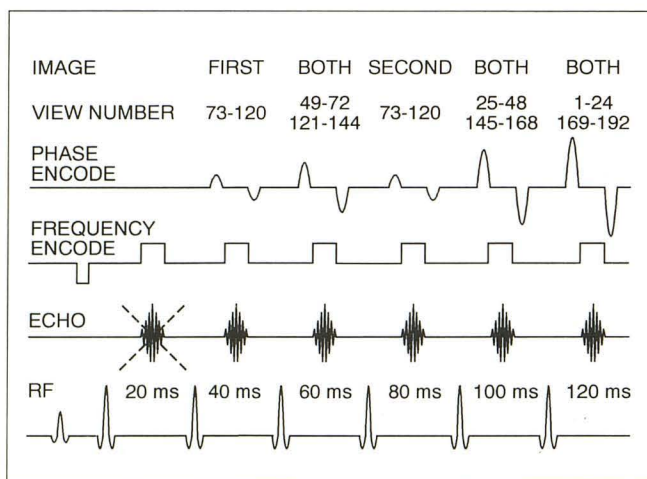

Fig. 1. Pulse sequence timing diagram for SHARE technique. The multiecho train consists of 6 echoes, formed at 20-msec intervals. The first echo is not sampled, but its formation is an important feature of SHARE.

TABLE 1: Categories of disease

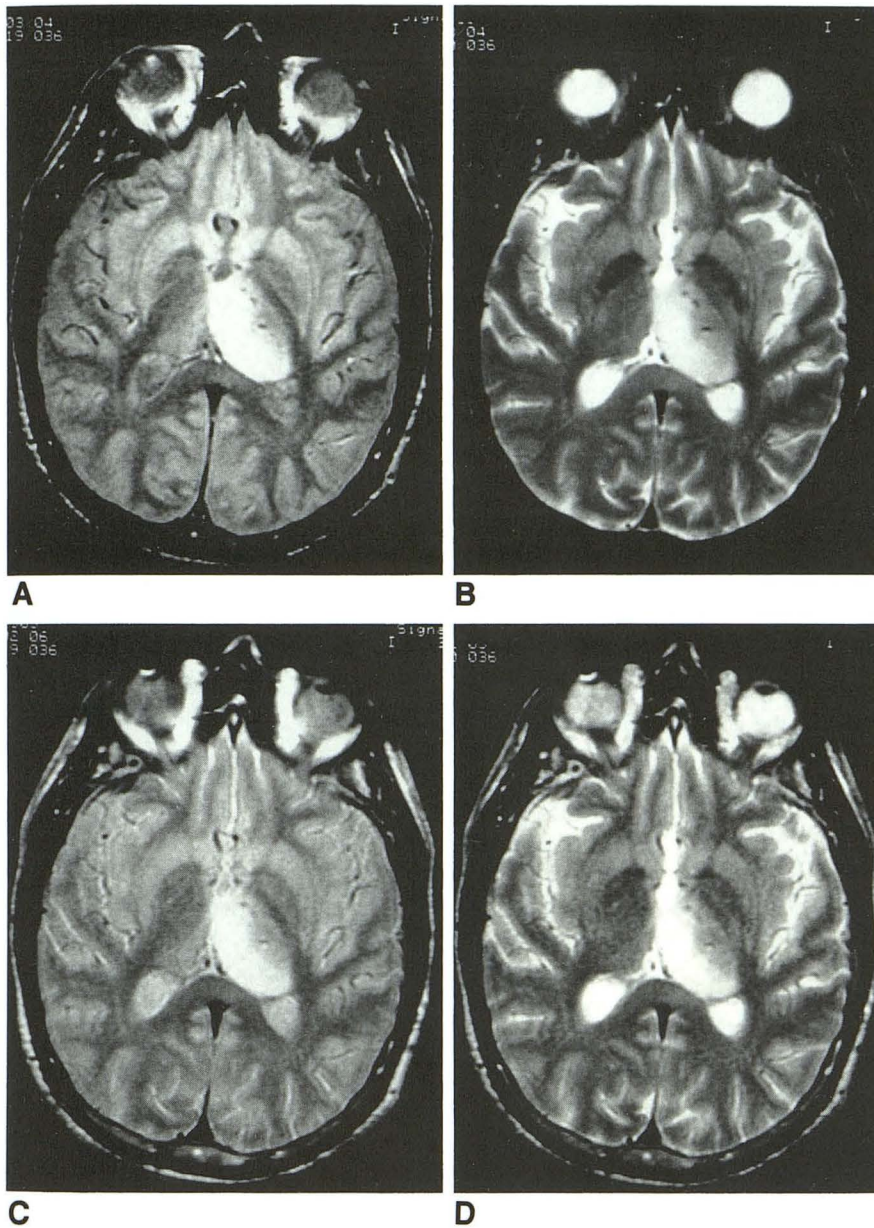| No. of patients	Diagnosis
12	Normal
12	Small vessel ischemic disease
7	Cerebral infarction
5	Tumor
4	Cavernous malformations
4	Miscellaneous
2	Multiple sclerosis
2	Encephalomalacia
2	Infection

Fig. 2. A 69-year-old man with a left thalamic glioma. *A*, axial spin-echo 2500/30 and *B*, 2500/90 images show a hyperintense left thalamic mass partially effacing the third ventricle. The geographic and contrast characteristics of the lesion correlate closely on the SHARE images, *C*, 2600/40; *D*, 2600/80.

in Table 2. These data show that the sensitivities for the detection of hyperintense white-matter foci for the two methods were equal by the first observer, but SHARE was slightly more sensitive than spin-echo according to the second observer's results (Table 2). In one patient with multiple sclerosis, optic nerve lesions were identified prospectively only on the SHARE images (Fig 4).

The signal characteristics of hemorrhage were similar on the two techniques, although the hypointense components were not as conspicuous on the SHARE images. Thus, SHARE was less sensitive to small deposits of hemosiderin, which manifest as subtle hypointense foci (Fig 5). Although hemorrhagic foci and blood degradation

products greater than 3 to 4 mm in diameter were detected with equal accuracy, conventional spin-echo allowed recognition of a greater number of smaller lesions (Table 2). However, because there were multiple foci in most patients with hemorrhagic lesions, this only affected the final impression in one patient by one of the observers (see below).

Independent evaluation of the conventional spin-echo and SHARE fast spin-echo exams produced disparities in 2 of 50 final interpretations by one of the readers. In one otherwise normal scan, a small ischemic focus in the pons was diagnosed on the SHARE study. The spin-echo exam was read as normal. In a second patient, a
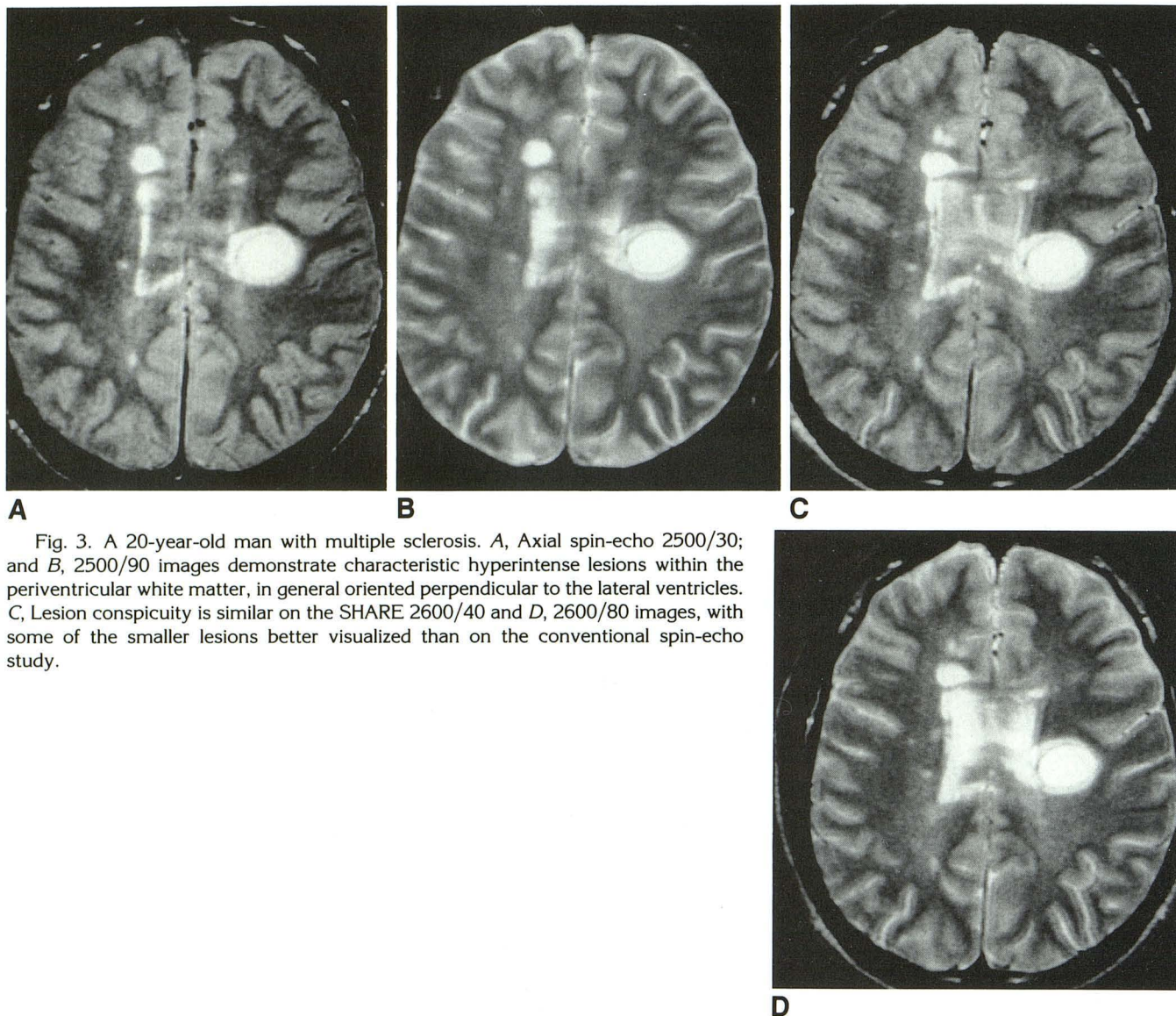
A   B   C

Fig. 3. A 20-year-old man with multiple sclerosis. *A*, Axial spin-echo 2500/30; and *B*, 2500/90 images demonstrate characteristic hyperintense lesions within the periventricular white matter, in general oriented perpendicular to the lateral ventricles. *C*, Lesion conspicuity is similar on the SHARE 2600/40 and *D*, 2600/80 images, with some of the smaller lesions better visualized than on the conventional spin-echo study.

D

subtle focus of residual hemosiderin subjacent to a craniotomy site was not detected on the SHARE images; the history of craniotomy was not available to the readers in this blinded study. Although the final impressions on the SHARE and spin-echo studies were not identical for these two cases, clinical management would not have been affected by these discrepancies. There was concordance of the final impressions in all 50 cases in the second readers who were blind to the first set of interpretations.

Side-by-side comparison of SHARE and spin-echo images for the relative degree of flow-related artifacts revealed no difference in 19 cases (38%). SHARE was superior to spin-echo in 19 (38%) and the SHARE images showed more image degradation caused by blood or cerebrospinal fluid motion than the spin-echo images in 12 cases

(24%). Artifacts caused by patient motion were less conspicuous on the SHARE images in 7 (14%) patients and more conspicuous in 7 (14%) patients. There was no appreciable difference in 36 (72%).

Discussion

SHARE images provide similar contrast characteristics to conventional spin-echo long-TR images and are obtained in one-fourth of the acquisition time. The interpretations rendered for the two techniques were identical in 98 of 100 blinded readings.

SHARE also compared favorably with spin-echo images with respect to conspicuity of small hyperintense lesions. Results from the first readings showed no difference in sensitivity to hyper-

TABLE 2: Statistical analysis: probabilities of detecting hyper- or hypointense foci using spin-echo (SE) or SHARE (FSE) techniques

	Estimates		P
	p (SE)	p (FSE)	
Hyperintense foci			
Reader 1	.77	.76	.82
Reader 2	.72	.77	.01
Hypointense foci [heme]			
Reader 1	.90	.66	.0001
Reader 2	.89	.73	.001

intense white matter foci. The second readings showed a statistically significant difference, although the difference may not be clinically significant. Possible explanations for the higher sensitivity demonstrated by the SHARE images include a more heavily T2-weighted first echo image in this sequence (TE = 40 msec vs 30 msec for the spin-echo sequence). In addition, edge-enhancement effects, demonstrated by multiple-echo acquisition long-TE images (5), may contribute to improved detection of small, high-signal lesions. The inclusion of higher-order echo samples (at 100 and 120 msec) may also contribute to the sensitivity of the SHARE technique to small hyperintense foci because of the heavier T2 weighting of the long-TE data. Although all of these factors might also contribute to the hyperintense appearance of perivascular spaces on intermediate-weighted images, Virchow-Robin spaces were rarely mistaken for punctate white matter lesions in this trial. The location and configuration of the spaces and the use of the T1-weighted images likely played a role in preventing such mistakes. In addition, the intermediate-weighted SHARE images were not compromised by blurring, as reported with other techniques (4, 6).

Our results show that SHARE is less sensitive than spin-echo imaging to magnetic susceptibility effects (Table 2), a characteristic demonstrated by other fast spin-echo techniques (4, 6). One consequence is decreased sensitivity for the detection of small hemorrhagic foci. This is clearly disadvantageous in certain cases. Conversely, the lower sensitivity to focal field inhomogeneities can be exploited for imaging postoperative patients with indwelling metallic hardware or other sources of ferromagnetic artifacts (5). In our experience, SHARE images are less severely compromised by magnetic susceptibility artifacts in patients with surgical hardware and other metallic devices because of the decreased sensitivity to field inhomogeneity.

Many "fast spin-echo" techniques have been evaluated in the recent literature (3, 4, 7–9). Conclusions regarding these techniques are not universal by virtue of a common label, as variations of the multiple sequence parameters significantly affect image characteristics. Interecho delay (between successive echoes) and echo train length affect such image qualities as sharpness, contrast, and sensitivity to magnetic susceptibility effects (7–10). Thus the specific pulse sequence used to obtain the data in a fast spin-echo technique will have a significant impact on image characteristics. The phase-encoding order is another parameter that varies with technique (8) and has a significant impact on image contrast characteristics. Not all authors are in agreement regarding the contrast mechanisms in fast spin-echo imaging (9, 11). However, the following factors probably contribute to the contrast characteristics: 1) decreased J modulation of spin echoes, 2) stimulated echoes, 3) magnetization transfer effects, and 4) lack of diffusion-induced losses across susceptibility gradients.

Other workers have reported greater image degradation caused by flow or motion artifacts on fast spin-echo images than on spin-echo imaging (6, 8). We did not encounter these difficulties and, in some cases, the SHARE images showed less degradation caused by motion and flow artifacts than the corresponding velocity-compensated spin-echo images, despite the fact that no flow compensation gradients were used in the SHARE technique. Instead, SHARE is aided by even-echo rephasing because of the unsampled first echo at 20 msec, which renders the echoes at 40 and 80 msec even echoes. The 40- and 80-msec views are thus inherently flow compensated, and SHARE images (with 40- and 80-msec effective TE) are comparable to flow-compensated spin-echo images. This apparent insensitivity to motion occurs regardless of the fact that stimulated echo components of the 40- and 80-msec signals do not benefit from even-echo rephasing.

Clinical Application

The decrease in acquisition time provided by SHARE may be used to augment image resolution or signal-to-noise ratio via an increase in matrix size or number of signal averages, respectively. Alternatively, an additional sequence may be obtained without exceeding the imaging time required for a conventional spin-echo sequence.

Fig. 4. A 28-year-old woman with multiple sclerosis. A, Axial spin-echo 2500/30 and B, 2500/90 images do not show the hyperintense optic nerve lesions as well as the SHARE fast spin-echo technique seen on C, 2600/40 and D, 2600/80 (arrows). The lesions were noted prospectively on the SHARE study only. The right cerebral peduncle lesion is also better visualized on the SHARE images (curved arrows). Patient had subclinical optic neuritis with abnormal visual evoked potentials bilaterally.
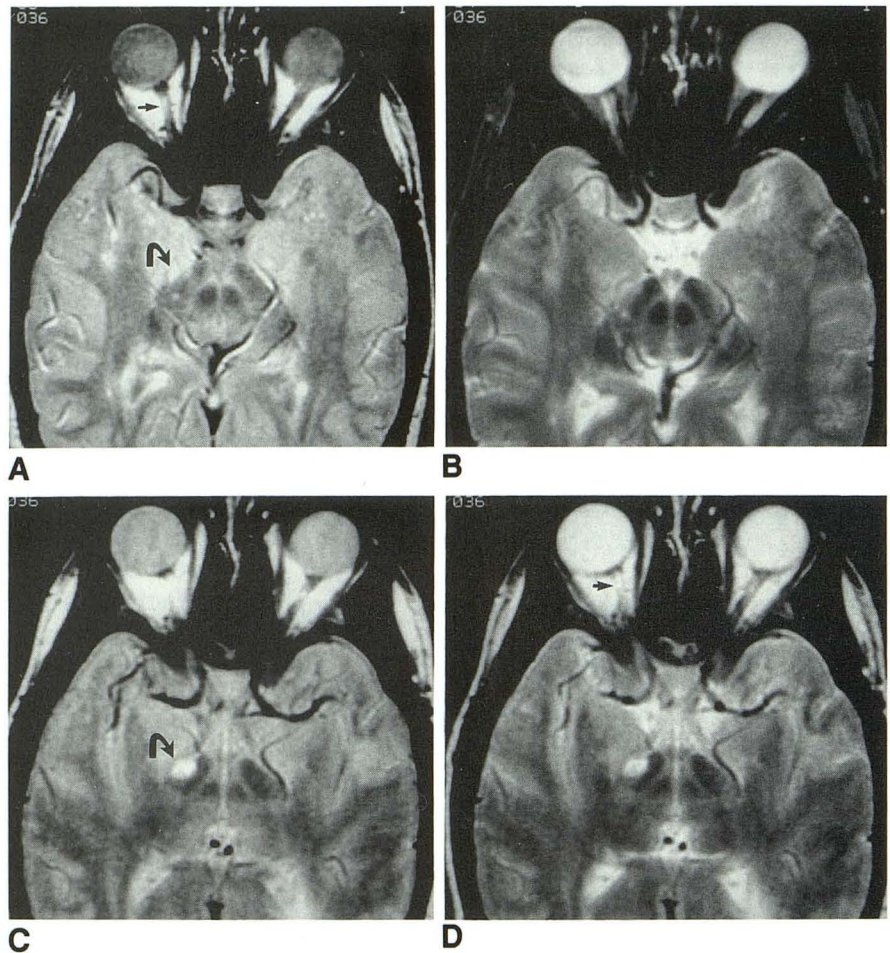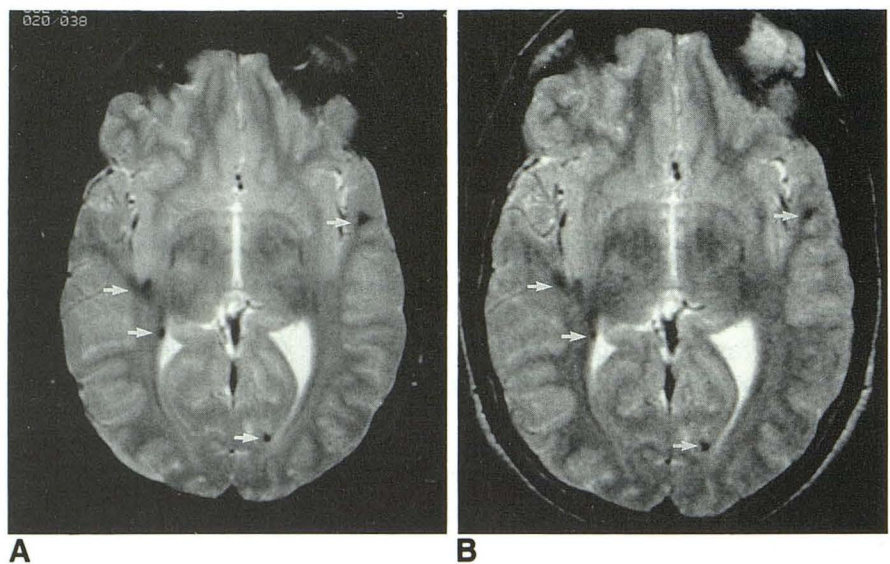

Fig. 5. A 16-year-old boy with multiple cavernous malformations. A, 2500/90 image demonstrates multiple punctate hypointense foci consistent with hemosiderin deposition. B, The SHARE axial 2600/80 image does not demonstrate the same degree of hypointensity at these locations, resulting in less contrast with the adjacent normal brain.

For example, to screen for small hemorrhagic foci, as in closed head injury patients, or to rule out multiple vascular malformations, a gradient-echo sequence can be performed in addition to the SHARE sequence. These two sequences can be accomplished in less time than a long-TR spin-echo sequence, and the combination provides more information than the spin-echo images. The

gradient-echo exam is more sensitive for the detection of small hemorrhagic foci than spin-echo, and the SHARE images provide comparable sensitivity to high-signal lesions. In other patients, T1-weighted spin-echo sagittal and SHARE axial sequences could be performed for a screening MR exam of the brain which can be accomplished in less than 5 minutes. In many clinical situations, the SHARE technique saves significant time without significantly sacrificing image quality or accuracy and thus should be considered as a replacement for long-TR spin-echo images.

Acknowledgment

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