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Brain Iron in Patients with Parkinson Disease: MR Visualization Using Gradient Modification

In patients with Parkinson disease, improved visualization of brain iron on a mid-field-strength magnet can be obtained with T2-weighted images and elimination of phase-encoding artifacts. A long echo delay time accentuates the loss of signal from brain iron. However, the long pulse sequence creates phase-encoding artifacts from CSF pulsations at the level of the basal ganglia. These artifacts are eliminated and resolving power increased with additional pulsing in the slice-selective and read gradients. Elimination of motion artifacts enhances visualization of brain iron in three ways: (1) extrapyramidal nuclei containing iron have better definition, (2) abnormalities are better identified, and (3) pseudolesions disappear.

Our findings suggest there is significant improvement in the resolving power of brain iron on MR scans made with a mid-field-strength scanner when gradient modification is used.

For the last year we have been investigating different methods of imaging brain iron on a mid-field-strength magnet using spin-echo (SE) pulse sequences [1]. We were interested in improving visualization of brain iron on SE pulse sequences because SE protocols are the most frequently used sequences, with inversion recovery and gradient echoes providing supplementary information. Visualization of brain iron was improved in patients without atrophy in the sylvian fissure regions with use of a long repetition time (TR) and a long echo time (TE) [1]. Using these T2-weighted images the regions of iron deposition were dark, because of T2 shortening. In patients with atrophy in the sylvian fissure regions the long TR (3000 msec) and long TE (120 msec) sequences created significant phase-encoding artifacts at the basal ganglia [1]. These artifacts obscured the iron in the extrapyramidal nuclei. Phase-encoding artifacts can be eliminated by increasing the pulsing of the slice-selective and read gradients [1, 2].

A study of patients with Parkinson disease was undertaken to validate the improved visualization of iron in the extrapyramidal nuclei using phase-compensating gradients. Parkinson patients were chosen because significant phase-encoding artifacts were created by CSF pulsations in enlarged sylvian cisterns and by the tremor of the disease.

Our findings suggest significant improvement in resolving power of brain iron on a mid-field-strength MR scanner using gradient modification.

Subjects and Methods

Ten patients with the clinical diagnosis of Parkinson disease were studied with MR imaging. The clinical evaluation was performed by two neurologists specializing in extrapyramidal disorders. The patients’ ages ranged from 40 to 81 years, with a mean of 62.8 years. The duration of their symptoms ranged from 1 to 12 years, with a mean of 3.4 years.

The patients were examined on a 0.5 T Vista MR 2055 superconducting magnet. SE pulse sequences were used for all patients.

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All patients were studied with contiguous 5-mm axial T1- and T2-weighted images. The T1-weighted images had a TR/TE = 933/22 pulse sequence. The T2-weighted images used a TR/TE = 3000/120 pulse sequence, with and without the phase-compensating gradients. The phase-compensating gradients have been given the name MAST®, which stands for Motion Artifact Suppression Technique [2].

Two signal averages were obtained for the T1- and T2-weighted images. The acquisition matrix was 128 x 256, which was interpolated to a 512 x 512 matrix. Scanning time was 8.2 min for T1-weighted images and 12.8 min for T2-weighted images. The field of view was 20 x 20 cm. A 128 x 256 acquisition matrix was used.

Fig. 1.—68-year-old Parkinson disease patient.
A, TR/TE = 933/22. Note absence of phase-encoding artifacts and atrophy in areas of sylvian fissures.
B, TR/TE = 3000/120. Without MAST®. Note signal-loss artifact in sylvian fissures (large arrow) and that artifacts from phase-shift images obscure substantia nigra (small arrow).
C, TR/TE = 3000/120. With MAST®. Note elimination of artifacts seen in Fig. 1B and clear visualization of iron in substantia nigra (arrow) and red nuclei.

Fig. 2.—46-year-old Parkinson disease patient.
A, TR/TE = 933/22. Note absence of phase-encoding artifacts and atrophy in areas of sylvian fissures.
B, TR/TE = 3000/120. Without MAST®. Note signal-loss artifacts in sylvian fissures (short arrow) and that artifacts from phase-shift images obscure globus pallidus (long arrow).
C, TR/TE = 3000/120. With MAST®. Note elimination of artifacts seen in Fig. 2B. Presumed small microvascular infarcts can now be seen in right globus pallidus (arrow). There is better demonstration of brain iron in globus pallidus than was seen in Fig. 2B.
view was 30 cm for both T1- and T2-weighted images. MAST® required a 30-cm field of view, so all images were acquired with a 30-cm field of view to aid comparison.

Results

Phase-encoding artifacts were not seen with T1-weighted images in the 10 patients studied (Figs. 1A and 2A). Artifacts from CSF pulsatile motion (such as signal loss and phase-shift images) were seen only on T2-weighted images without MAST® (Figs. 1B and 2B). These artifacts were eliminated by MAST® (Figs. 1C and 2C). MAST® also eliminated motion artifacts from involuntary tremors in the Parkinson patients.

The elimination of phase-encoding artifacts improved visualization of brain iron in three ways. First, iron in the extrapyramidal nuclei had better definition (Figs. 1C and 2C); second, abnormalities previously hidden by artifacts were now seen (Fig. 2C); and third, pseudolesions caused by phase-shift images were eliminated (Fig. 2C).

The enhanced visualization of brain iron can be described as improvement in the resolving power, or in the ability to distinguish subtle findings [3]. The improved resolving power is related to the increase in signal-to-noise ratio (S/N) and the image contrast [3].

Discussion

Improved visualization of brain iron in the extrapyramidal nuclei on a mid-field-strength magnet requires a long TR and a long TE [1]. A long TR (3000 msec) provides an adequate signal in the brain tissue; a long TE (120 msec) allows adequate loss of phase coherence of water protons adjacent to paramagnetic molecules in the extrapyramidal nuclei [1].

Unfortunately, the long TR and long TE allow phase-encoding artifacts to occur in the area of the basal ganglia. The phase-encoding artifacts are caused by misregistration of signal from motion. Researchers at Stanford University [4–7] have shown that CSF pulsatile motion causes significant artifacts at the basal ganglia, which can be seen as signal loss and phase-shift images. The signal-loss artifact is loss of signal intensity in CSF from pulsatile motion. The phase-shift image is displacement of signal on the phase-encoding gradient, causing areas of abnormally increased or decreased signal, again related to pulsatile CSF. Both artifacts were accentuated in Parkinson disease patients who have atrophy in the sylvian fissures (Figs. 1B and 2B). Pulsating CSF is not the only type of motion that can cause phase-encoding artifacts. Eye motion (Figs. 1B and 2B) and involuntary tremors in Parkinson patients are two other causes of motion artifacts.

The effect of the phase-encoding artifacts is to degrade resolving power, or the ability to discriminate subtle disease [3]. The resolving power (T) is a function of S/N ratio and the image contrast (C): T=<(S/N)^2>C^2.

Identification and separation of an object from background can be improved by increasing the S/N ratio and/or the subject contrast [3]. Eliminating the phase-shift images increases both the S/N ratio and the object contrast. First, elimination of the phase-shift images decreases noise, thereby improving the S/N ratio. Second, object contrast (C) is defined as C = (I−lo)/lo, where I is object intensity and lo is background intensity. Background intensity (lo) can be decreased by eliminating phase-shift artifacts, which cause “ghost” images to be projected over the object (I).

The phase-encoding artifacts from CSF pulsations degrade resolving power of the basal ganglia in three ways. First, the phase-shift images obscure the extrapyramidal nuclei, which contain iron (Figs. 1B and 2B). Second, abnormalities can be hidden; for example, small microvascular insults in the right globus pallidus (Figs. 2B and 2C). Third, pseudolesions are created, such as pseudovascular insult in the left globus pallidus (Figs. 2B and 2C).

Two techniques have been developed to eliminate the phase-encoding artifacts and thereby to improve resolving power: CSF gating and gradient modification. The Stanford group [4–7] uses peripheral CSF gating to eliminate the CSF pulsatile motion. CSF gating has limitations. It can only remove temporal motion (i.e., CSF pulsatile flow), it cannot remove spatial motion (i.e., laminar and turbulent flow). Acquisition can be prolonged with arrhythmias. There is a setup time. Peripheral vascular disease could theoretically cause dampened pulses, thereby preventing gating.

Gradient modification can also eliminate phase-encoding artifacts. In static material the slice selective (Z) and read (Y) gradients are designed to bring all magnetization into phase at the center of the “echo” signal. Only the phase-encoding (X) gradient is supposed to alter the phase of the signal. Any motion occurring between RF excitation and the end of the echo signal can interact with the gradients to introduce phase errors, and hence artifact production. Clearly, the later the echo, the greater the opportunity for motion to cause phase errors. If, however, extra gradient pulsing is introduced into the slice and read gradients, it is possible to tailor these pulses such that material moving with constant velocity will be rephased [2] (Fig. 3). With more complex gradient waveforms, the approach may be extended so that it also rephases material moving at constant acceleration, or constant pulsatility, and so on to more complex motion.

While it may seem unlikely that the observed tissues would maintain constant velocity (or acceleration, etc.) between RF excitation and echo, it can be shown that any motion can be accurately described (via the Taylor series expansion) [2] as a sum of components of constant velocity, constant acceleration, and so on. The more components considered, the more accurate the description of the motion, but the simplest terms contribute most to the accuracy. Thus, the gradient shaping approach to phase nulling, using increased gradient pulsing, can compensate for any motion. The more terms in the equation, the greater compensation for different kinds of motion and the better the artifact reduction. The gradient modification MAST® compensates for acceleration, velocity, and pulsatility, and thereby eliminates phase-encoding artifacts. A comparison of the normal and motion-desensitized sequences is shown in Figure 3. Gradient modification can be applied to all field strengths.

There are limitations to gradient modification. A minimum TE is needed to allow the extra gradient pulses to be applied. For gradient echoes the minimum TE is 18 msec; for spin echoes it is 40 msec. At the present time the smallest field of
Time

RF

SS

PHASE

READ

ACQUISITION

A

**Fig. 3.**—Gradient modification pulse sequence (RF = radiofrequency, SS = slice-select gradient, PHASE = phase-encoding gradient, READ = readout gradient, ACQUISITION = signal measurement). (From Norfray et al. [1].)

A, Standard TE (120 msec). Two pulses are obtained in slice-select and readout gradients. Interval between slice and readout pulses and phase-encoding pulse allows dephasing to occur.

B, Motion-desensitized TE (120 msec). Additional pulses in slice-select and readout gradients prevent dephasing in phase-encoding gradient.

view is 30 cm, again related to the power requirement on the gradients. Gradient modification causes increased signal in blood vessels, which should not be interpreted as thrombosis. Increased signal will also be seen in the cerebral aqueduct.

The technique used to improve the resolving power of brain iron on the mid-field-strength magnet allowed us to study the iron in our 10 Parkinson disease patients. In eight patients there was a narrowing of signal from the pars compacta of the substantia nigra [8]. In one patient there was normal brain iron; however, microvascular infarcts were seen in both putamina. The 10th patient had increased brain iron in the putamen as compared with the globus pallidus. These findings will be the subject of a separate report.

In conclusion, we have undertaken to show improved visualization of brain iron in Parkinson disease patients on a mid-field-strength magnet by using a long SE pulse sequence combined with gradient modification. The long TR provides adequate signal in the brain, while the long TE allows adequate loss of signal in the extrapyramidal nuclei. The gradient modification (MAST®) technique eliminates the phase-encoding artifacts, thereby improving the resolving power for brain iron. Owing to these techniques, mid-field-strength MR scanners can now be used to study diseases having modified brain iron in the extrapyramidal nuclei.

REFERENCES

1. Norfray JF, Couch JR, Elble RJ, Good DC, Manyam BV, Patrick JL. Visualization of brain iron by mid-field MR. *AJNR* 1988;9:77–82


