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Gated Gradient-Motion-Refocused (GMR) Images with Spin-Echo Sequences

Motion artifact presents one of the most important difficulties in obtaining quality MR images. Patient cooperation and sedation techniques often help in eliminating ghosting during cranial MR imaging. Recently, a gradient-motion-refocusing (GMR) sequence was developed in order to augment other motion-suppression techniques. We studied 200 patients undergoing cranial MR imaging, in 50% of these patients, we used GMR motion suppression.

Materials and Methods

All MR images were obtained on a 1.0-T system.* Spin-echo (rather than gradient-echo) sequences were chosen. A circular head coil (30 cm in diameter) was used in all patients.

Technique for the 100 GMR patients included gated 2400–3800/multiecho 24, 90 (TR/TE); one acquisition; 256 × 256 matrix; 42% gap; 5-mm sagittal gradient slice thickness; 7-mm axial gradient slice thickness; 25-cm field of view; and zoom factor of 1.3. All sequences were gated with an average time delay of 40 msec from the R-wave peak. The average scan time per sequence ranged between 7 and 11 min, depending on the gated TR.

Technique for the 100 non-GMR patients included gated 2100–2400; nongated 1900/multiecho 35, 90; one acquisition; 256 × 256 matrix; 42% gap; 7-mm gradient slice thickness (sagittal and axial); 25-cm field of view; and zoom factor of 1.3. In 50 patients, sequences were gated, with a time delay of 40 msec from the R-wave peak. The average scan time per sequence ranged between 7.5 and 10.5 min, depending on the gated TR.

Results

The gated GMR images showed all structures with better detail and clarity than did the gated non-GMR images.

The contrast of the corpus callosum, cerebellar folia, and subarachnoid space was excellent in the gated, GMR, sagittal images. The contrast between the gray and white matter on the axial, gated, GMR images also was excellent. Poorer contrast was noted on all non-GMR images.

Figures 1A and 1B exemplify the observations made on the sagittal images. Although these examples are striking, we thought the observations made were consistent with our analysis of all 100 cases.

Figures 2A and 2B exemplify our observations on the axial images in these 100 random cases. Once again, a marked difference can be seen in the clarity and contrast of the structures in the GMR and the non-GMR images.

Discussion

Motion of spins during an imaging sequence can give rise to ghosting artifacts that may obscure anatomic or pathologic detail in the reconstructed image. This source of error adds to the error caused by motion between sequences (such as respiratory motion or cardiac motion). The artifacts arise from phase errors incurred as the mobile spins move through the applied magnetic field gradients. This artifact is more severe in T2-weighted sequences with long TE times because of the longer time available for the phase of the moving spins to become misregistered [1]. Averaging data to reduce the problem in the T2-weighted sequences is impractical because of the long TRs used. If the motion is regular, compensating gradients may be designed to eliminate the in-sequence phase errors of the moving spins [2–4].

The standard double-echo sequence was modified to incorporate flow rephasing at the time of the second echo [5]. The modification involves the use of bipolar gradients in the readout direction to provide phase coherence of the spins moving with constant velocity at the time of the second echo. The first echo is not compensated for motion effects. Thus the proton-density images are not affected by GMR motion suppression. This pulse sequence is shown in Figure 3.

This modified sequence has replaced the standard double-echo sequence for imaging the brain. The sequences are run in the gated mode; artifacts due to the pulsating CSF are eliminated, and the CSF/dura interfaces are clearly defined in the second-echo images. Another advantage is that the sequence still uses 180° RF pulses. Consequently, the sequence is no more susceptible to image degradation caused by chemical-shift artifacts or static-magnetic-field inhomogeneities than is the standard double-echo sequence (in contrast to gradient-echo sequences).

We chose to integrate the existing spin-echo sequences with GMR rather than to use gradient-echo imaging techniques. Enzmann and Rubin [6, 7] recently published their results using a gradient-refocused pulse sequence with a partial-flip-angle (gradient-echo) protocol. They chose this approach because the gradient-echo protocol has a faster average acquisition time per sequence than their slower spin-echo protocols. They admit however that their GRASS images (partial-flip-angle images) were inferior in lesion detectability to the CSF-gated spin-echo images because of poorer contrast and lower signal-to-noise ratio.

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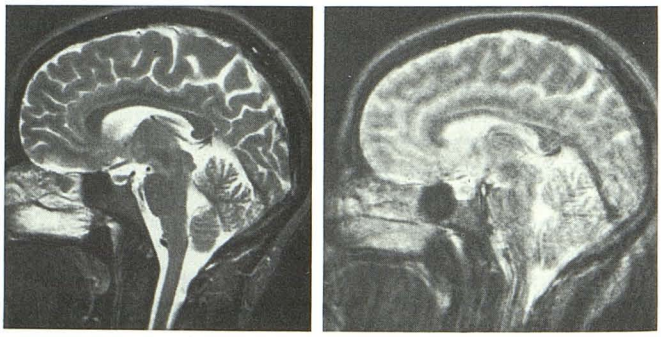
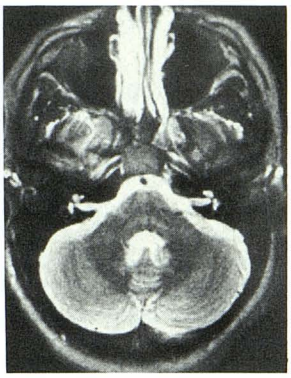


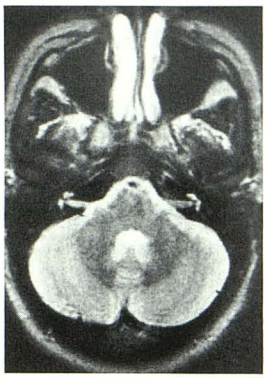
Fig. 1.—*A* and *B*, Sagittal, gated, T2, gradient-motion-refocused (GMR) sequence (*A*) is compared with gated, T2, non-GMR sequence (*B*). Contrast and image clarity with better resolution of intracranial structures are noted in the GMR image.

* Magnetom, Siemens Corp., Iselin, NJ.

Fig. 2.—*A* and *B*, Axial, gated, T2, gradient-motion-refocused (GMR) sequence (*A*) is compared with gated, T2, non-GMR sequence (*B*). The cerebellopontine-angle structures are sharper in detail with the GMR imaging technique.

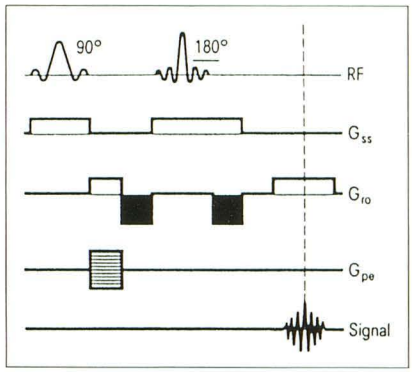


2A



2B

Fig. 3.—Gradient-motion-refocused MR pulse sequence. G_{ss} = slice-selection gradient; G_{ro} = readout gradient; G_{pe} = phase-encoding gradient.



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