The challenge of extending turboFLASH (FSPGR, TFE) from a 2D to a 3D acquisition is due to the fact that the effect of an inversion pulse applied at the very beginning of the acquisition is lost during the acquisition. This is due to the high number of excitation pulses and the relatively long measurement time associated with 3D acquisitions. This may be overcome by repeating the inversion pulse during the measurement, an approach called magnetization-prepared rapid gradient echo (MP-RAGE). Three-dimensional image acquisition requires a repetition of all phase-encoding steps in the slab (partition) direction for every phase-encoding step within the imaging plane. The inversion pulse is thus placed just prior to the partition-encoding loop (in most cases). Within the partition-encoding loop, the signal is changing due to recovery of the longitudinal magnetization.

There are several advantages to using MP-RAGE for T1-weighted imaging. Unlike multislice 2D imaging, the partition encoding used in 3D acquisitions, such as in MP-RAGE, allows for continuous coverage with thin slices in a reasonable measurement time (5 minutes or less at 3 T). Inversion of the magnetization allows better control over T1-weighting, permitting greater T1 contrast compared with spin echo and 2D gradient echo imaging. Figure 36.1 presents postcontrast axial 3 T T1-weighted 2D GRE (Fig. 36.1A) and MP-RAGE (Fig. 36.1B) images of a 28-year-old, severely disabled woman with a 7-year history of relapsing/remitting multiple sclerosis (MS). There is a large number of MS plaques (many confluent), with abnormal low signal intensity, noted in the periventricular and more peripheral white matter. Note the greater T1 contrast with (B) MP-RAGE, reflected by the superior gray-white matter differentiation (small black arrow) and the improved MS plaque conspicuity (white arrows), the latter relative to normal adjacent white matter. Scan times were 1:52 (2D GRE) and 3:52 (MP-RAGE) min:sec, respectively. The slice thickness for the 2D acquisition was 4 mm, with an in-plane resolution of $0.86 \times 0.86$ mm$^2$. The 3D scan was acquired with a voxel dimension of $1 \times 1 \times 1$ mm$^3$. The axial scan was reformatted using a 1.5-mm slice thickness. The axial MP-RAGE image appears slightly blurred when compared with the 2D scan, principally due to the slightly poorer in-plane resolution. A major advantage of this type of isotropic acquisition is the ability to reformat images in other planes with high resolution, as illustrated in (B) and (C), 1.5-mm coronal and sagittal reformatted images. Thus high-resolution images in all planes are available from a single 3:52 min:sec acquisition, while the 2D GRE scan—obtained in about half the acquisition time—provided only axial images. Note the active MS plaque (large black arrow, B–D), demonstrating abnormal contrast enhancement, which is well visualized in all three planes.

MP-RAGE has been used both at 1.5 and 3 T for high-resolution, structural brain imaging. However, multiple caveats exist in regard to its use. MP-RAGE is a gradient echo technique, and thus the artifact generated due to metal can be greater than with fast spin echo technique. Depending upon the specific choice of pulse parameters, visualization of lesion enhancement (particularly weakly enhancing lesions) may be poor with MP-RAGE when compared with a conventional spin echo pulse sequence. In
routine clinical imaging at 1.5 T, the relatively long scan times have also prevented widespread use in screening brain exams. However, at 3 T, high-quality T1-weighted scans can be generated in a reasonable time with MP-RAGE, leading to broader use in routine exams.

Fig. 36.1