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Is 3D MPRAGE better than the combination DIR/PSIR for cortical lesion detection at 3 T MRI?

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Abstract
Background and objectives: Based on the application of newer magnetic resonance imaging (MRI) acquisition sequences, the detection of cortical lesions (CL) in multiple sclerosis (MS) has significantly improved. Double inversion recovery (DIR) at 3 T has increased the detection sensitivity and classification specificity when combined with phase sensitive inversion recovery (PSIR). Previous findings with 3D magnetization prepared rapid acquisition with gradient echo (MPRAGE) sequences, showed improved classification specificity of purely intracortical (IC) and mixed (MX) lesions, compared to the classification based on DIR/PSIR. Direct comparison between the detection of CL by 3D MPRAGE and by DIR/PSIR at 3 T has not been evaluated.
Methods: Eleven subjects were imaged on a 3 T magnet. DIR/PSIR and 3D MPRAGE images were reviewed independently. Each image set was reviewed twice; only lesions detected on both sessions were scored. Review time per scan was ~5 min for DIR/PSIR and ~15 min for 3D MPRAGE.
Results: We identified 141 CL (62 IC+79 MX) based on DIR/PSIR images vs. 93 (38 IC+55 MX) based on MPRAGE from all eleven patients. MPRAGE under-detected the number of CL in seven cases and over-detected the number of CL in three, only one case had the same number of CL on both sets of images.
Conclusions: Combination DIR/PSIR at 3 T is superior to 3D MPRAGE for detection of cortical gray matter lesions in MS. The contrast-to-noise ratio of CL appears to be inferior on the MPRAGE images relative to DIR/PSIR

1. Introduction

Cortical lesions (CL) are common in multiple sclerosis (MS) (Kidd et al., 1999; Bo et al., 2006) and found to contribute to cognitive impairment (Nelson et al., 2011). However,

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accurate identification of CL on conventional MRI remains challenging, due to their small size and the poor contrast between lesions and surrounding gray matter. Various magnetic resonance imaging (MRI) sequences have been implemented at different field strengths to improve the visualization of CL (Geurts et al., 2005; Bagnato et al., 2006; Cohen-Adad et al., 2012; Tallantyre et al., 2010). Currently, double inversion recovery (DIR) is the sequence most widely used for visualizing CL.

Originally introduced by Redpath et al. in 1994, based on conventional spin echo sequence, DIR selectively suppresses either gray or white matter, and cerebrospinal fluid (Redpath and Smith,1994). However, conventional spin echo based DIR involves a very long acquisition time (25.6 min). Bedell and Narayana introduced DIR based on fast spin echo sequence which produced increased conspicuity of MS lesions. Also, its acquisition time of 7.5 min makes it more applicable in clinical settings (Bedell and Narayana, 1998). Turetschek et al. also reported a comparison between DIR and fluid attenuation by inversion recovery (FLAIR), but provided no description of their DIR sequence implementation (Turetscheck et al., 1998). In 2001 DIR was the first sequence reported to identify cortical changes consistent with MS pathology; these findings were confirmed by MR spectroscopy (Sharma et al., 2001). Since then DIR has been used by many investigators and has advanced the field of CL imaging. In 2011 consensus recommendations for MS cortical lesion scoring using DIR MRI were proposed (Geurts et al., 2011), these were based on the results of a study in which the inter-rater agreement on CL detection was low. This could be related to the fact that DIR suffers from inherently low signal-to-noise ratio (SNR) also, the small size of some CL and partial-volume averaging effects may prevent clear delineation of lesion boundaries with respect to the cortical/subcortical junction; these issues are exacerbated at field strengths below 3 T.

The DIR sequence is also prone to image artifacts such as flow, which may affect the visualization of subtle intracortical lesions and has regional variations in GM signal intensity, which may lead to false-positive lesion detections. In addition, DIR provides poor delineation of lesion borders and the low SNR, further obscures details of small structures. Some limitations of DIR can be overcome by using an inversion recovery sequence with phase-sensitive reconstruction (PSIR) (Nelson et al., 2007). The interpretation based on combined PSIR and DIR images improves confidence in the detection of intracortical lesions. The PSIR sequence does not create significant artifacts and complements DIR by allowing clearer delineation of lesion and tissue boundaries. The reliability of CL classification with combined DIR/PSIR can be further improved by using high resolution three-dimensional (3D) magnetization-prepared rapid acquisition with gradient echo (MPRAGE) imaging for better delineation of lesion borders (Nelson et al., 2008). Specifically, the MPRAGE images allowed a better classification of purely intracortical (IC), mixed (MX) and juxtacortical (JX) lesions (Nelson et al., 2007). Bagnato et al. (2009) compared MPRAGE with proton density-weighted and dual echo T2 weighted imaging in the detection of neocortical lesions post-mortem. MPRAGE allowed clearer visualization of CL compared to the other sequences. Tallantyre et al. (2010) compared 7 T MPRAGE with 3 T DIR; 3 T DIR was shown to be more sensitive than 7 T MPRAGE in detecting purely intracortical lesions although some of those were later found to correspond with signal arising from extracortical blood vessels. Although there is some agreement on the superior detection capabilities of MPRAGE compared to other conventional and non-conventional sequences, its capability to provide better CL detection than DIR/PSIR in a direct comparison with 3D MPRAGE at 3 T has not been reported. Convincing demonstration that CL can be better identified without DIR/PSIR has practical clinical importance as redundant sequences might be eliminated from protocols, decreasing overall scan times. In addition, MPRAGE images are more commonly acquired in routine clinical evaluations of MS patients.

The study was designed to compare the cortical lesion detection sensitivity of the 3D MPRAGE sequence to combination DIR/PSIR on a 3 T scanner with parallel imaging. We hypothesized that 3D MPRAGE would prove superior to 2D DIR/PSIR.

2. Materials and methods

2.1. Patients

Eleven MS patients (9 female; median age at the time of MR acquisition 55 years, EDSS 0–6.5 mean 2.8) were included in this study. Written informed consent was obtained from each subject following institutional review and approval of the research protocol.

2.2. Imaging protocol

Patients were scanned on a Philips 3T Intera scanner with Quasar Plus gradient systems (maximum gradient amplitude 80 mT/m, slew rate 200 mT/m/s) and a six channel head coil. The scan protocol included axial DIR and PSIR imaging, each with 0.94 mm x 0.94 mm in-plane resolution (256 $\times$ 256 matrix and 24 cm FOV) and 44 contiguous slices of 3.0 mm thickness. Coronal 3D MPRAGE images were also acquired with an isotropic voxel size of 0.94 mm $\times$ 0.94 mm $\times$ 0.94 mm (inversion time (TI)=1123 ms, pulse flip angle=6°) and were reformatted in the axial plane. SENSE encoding was employed along the A/P direction for DIR and PSIR with a SENSE factor of 2.0. Two-dimensional SENSE encoding was applied along R/L (R=2) and A/P (R=2.5) for the MPRAGE sequence. Scan times were 7.5 min for DIR, 4.2 min for PSIR, and 6.4 min for MPRAGE. The MRI protocol is summarized in Table 1.

2.3. Cortical lesion identification

CL were identified on DIR and validated on PSIR as described elsewhere (Nelson et al., 2007) by two raters (FN, AP) by consensus. CL were classified as IC (total confinement within the cortical ribbon) or MX (originating in the cortex but with some subcortical extension). MPRAGE images were examined independently from DIR/PSIR images and CL were identified and classified based on MPRAGE images alone, in two separate sessions by the same two raters. Lesions not agreed upon by consensus of both reviewers were excluded