3D DIR: 3D Double Inversion Recovery in Multiple Sclerosis

P. Polak[1], R. Zivadinov[1,2], and G. Poloni[1]
[1]Buffalo Neuroimaging Analysis Center, Department of Neurology, University at Buffalo, State University of New York, Buffalo, NY, United States, [2]The Jacobs Neurological Institute, Department of Neurology, University at Buffalo, State University of New York, Buffalo, NY, United States

OBJECTIVE: To implement an improved 3-dimensional (3D) Double Inversion Recovery (DIR) sequence to enhance lesion detection in MS patients in white (WM) and grey matter (GM).

BACKGROUND: Diagnosis and prognosis of multiple sclerosis (MS) is currently strongly based on magnetic resonance imaging (MRI) outcomes, which conventionally includes T_2-weighted (T_2W), and pre- and post-contrast T_1-weighted (T_1W) imaging. (Zivadinov and Cox, 2007) Double Inversion Recovery (DIR) sequences have been proven to enhance lesion detectability in both WM and GM. (Geurts et al., 2005; Redpath and Smith, 1994) With the introduction of long echo-train (ET) lengths with single-slab prescriptions (Mugler et al., 2000) and the consequent reduced acquisition time demands, 3D sequences are clinically viable. DIR commonly aims to suppress CSF and WM while leaving signal from lesions and GM, with low signal-to-noise ratio (SNR) an inherent issue; however, the increased contrast-to-noise ratio (CNR) between the lesions and the background tissue can outweigh this problem. 3D DIR sequences display superior sensitivity to clinically significant lesions in both the GM and WM, thereby helping resolve the clinical/radiological paradox in MS. (Zivadinov et al., 2008)

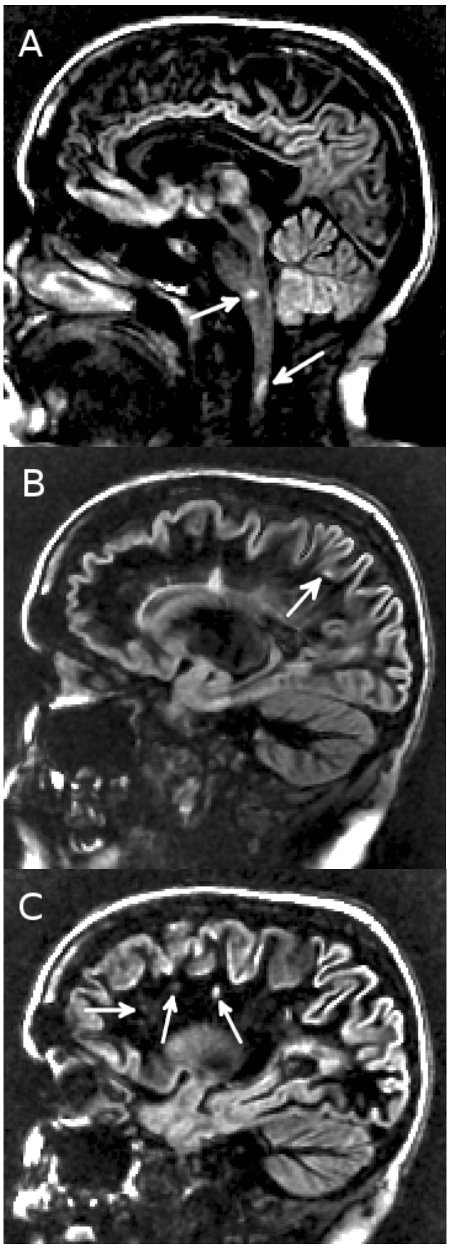

Figure 1: 3D DIR slices acquired sagittally on an MS patient highlighting lesions in the spinal cord (1A) in the deep WM and potentially in GM (1B). A fat suppression pulse was applied immediately before the imaging portion of the inversion sequence.

METHODS: 3D DIR was developed on a 3T GE scanner (General Electric, Milwaukee, WI) using an experimental approach based on theoretical double inversion recovery dynamics and T_2 relaxation principles. Series of sequences with varying imaging parameters (TE_{eff}, TR, TI_1, TI_2) were run on a clinically-definite MS volunteer. ROI analyses were conducted in the areas of CSF, WM, GM and lesions, and the signal intensities were graphically plotted in order to determine a “best guess” of the optimum sequence parameters. A further set of sequence parameters, centered on the previous estimates were then imaged and analyzed in a similar fashion on another volunteer to produce a better estimate. This experimental approach was iterated over a set of ten MS volunteers in order to produce the optimum set of sequence parameters.

RESULTS: The following parameters were established for optimum lesion detection: TR=7000ms, TE_{eff}=190ms, TI_1=2300ms, TI_2=480ms, FOV=280mm, acquisition matrix=256x256, slice thickness=2mm, echo train length=256, averages=2, acquisition time=10min for full brain coverage. Lesion visibility is highlighted in three main areas: spinal cord region (Figure 1A), periventricular and possibly deep GM (Figure 1B), and small lesions in deep WM (Figure 1C). While these DIR parameters are optimal for 3T and a particular ET variable flip angle algorithm, this method can easily be extended for any magnet strength and ET signal intensities in order to produce an optimal set of sequence parameters.

CONCLUSIONS: The optimized DIR sequence described has an improved lesion detection power, being able to highlight smaller lesions in the WM due to the WM signal attenuation. Lesions in the GM and in the spinal cord are also detectable, and are potentially more clinically significant than the WM signal alterations. 3D DIR can contribute to a better understanding of the “clinical/radiological paradox” and may be soon introduced as part of the conventional MRI protocol for the diagnosis and prognosis of MS.

REFERENCES

Geurts JJ, Pouwels PJ, Uitdehaag BM, Polman CH, Barkhof F, Castelijns JA. Intracortical lesions in multiple sclerosis: improved detection with 3D double inversion-recovery MR imaging. Radiology 2005; 236: 254-60.

Mugler JP, 3rd, Bao S, Mulkern RV, Guttmann CR, Robertson RL, Jolesz FA, et al. Optimized single-slab three-dimensional spin-echo MR imaging of the brain. Radiology 2000; 216: 891-9.

Redpath TW, Smith FW. Technical note: use of a double inversion recovery pulse sequence to image selectively grey or white brain matter. Br J Radiol 1994; 67: 1258-63.

Zivadinov R, Cox JL. Neuroimaging in multiple sclerosis. Int Rev Neurobiol 2007; 79: 449-74.

Zivadinov R, Stosic M, Cox JL, Ramasamy DP, Dwyer MG. The place of conventional MRI and newly emerging MRI techniques in monitoring different aspects of treatment outcome. J Neurol 2008; 255 Suppl 1: 61-74.