

# 3D FLAIR-ED: 3D Fluid Attenuated Inversion Recovery for Enhanced Detection of Lesions in Multiple Sclerosis

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**OBJECTIVE:** To implement an optimized 3-dimensional (3D) Fluid Attenuated Inversion Recovery (FLAIR) sequence to enhance lesion detection in MS patients.

**BACKGROUND:** Diagnosis and monitoring of multiple sclerosis (MS) is predominantly based on magnetic resonance imaging (MRI), which has traditionally included T<sub>2</sub>-weighted (T<sub>2</sub>W), and pre- and post-contrast T<sub>1</sub>-weighted (T<sub>1</sub>W) imaging. (Zivadinov and Cox, 2007) In particular, T<sub>2</sub>W FLAIR sequences suppress the hyper-intense signal from cerebrospinal fluid (CSF), improving the contrast and delineation of white matter (WM) lesions, particularly in periventricular regions. 2-dimensional (2D) FLAIR sequences are typically acquired clinically, despite the advantages offered by 3D sequences with respect to image resolution, orthogonal reslicing and improved lesion detection, (Bink et al., 2006) at the price of the increased imaging time. The introduction of long echo-train (ET) lengths with single-slab 3D imaging (Mugler et al., 2000) has reduced the acquisition

time demands such that these sequences are clinically viable, while also altering the T<sub>2</sub> signal expected from longer echo times. (Busse et al., 2006) Through its enhanced lesion detection capabilities, 3D FLAIR sequences may help in resolving the clinical/radiological paradox (Zivadinov et al., 2008) by improving the sensitivity of MRI sequences to otherwise undetected signal alterations.

**METHODS:** 3D Fluid Attenuated Inversion Recovery for Enhanced Detection (FLAIR-ED) was developed on a 3T GE scanner (General Electric, Milwaukee, WI) using an experimental approach based on theoretical inversion recovery dynamics and T<sub>2</sub> relaxation principles. Series of sequences with various imaging parameters (TE, TR, TI) were run on a clinically-definite MS volunteer. ROI analyses were conducted in the areas of CSF, WM, and WM lesions, and the signal intensities were graphically plotted to determine a best estimate for the optimum sequence. A subsequent series of parameters were imaged, centered on the previous determination in a finer mesh, and analyzed in the same manner. In total, scans were run on ten volunteers. This "Newton's Method" approach resulted in an optimum parameter set for lesion contrast with surrounding tissue.

**RESULTS:** The following parameters were determined for optimum lesion detection: TR=7000ms, TE<sub>eff</sub>=600ms, TI=2170ms, FOV=256mm, acquisition matrix=256x192, slice thickness=1.3mm, reconstruction matrix=512x512 (zero-filling interpolation), acquisition time=10min for full brain coverage. Figure 1 provides a comparison between conventional 2D FLAIR and 3D FLAIR-ED. 2D FLAIR parameters: TR=8000ms, TE=146ms, TI=2000ms, FOV=240mm, acquisition matrix=352x224, slice thickness=3mm, reconstruction matrix=512x512. Notice the increased lesion detectability, and in particular the visibility of the subcortical and cerebellar lesions, which are lost in the 2D FLAIR. While these parameters are optimal for this magnet strength and ET variable flip angle algorithm, a similar experimental approach can be conducted on any scanner and algorithm to produce an optimum sequence.

**CONCLUSIONS:** Superior lesion detection power is proven with the 3D FLAIR-ED compared to a 2D clinical FLAIR sequence. Lesion contrast is improved, as is lesion border delineation. Fuzzy, blurred or "dirty white matter" is virtually eliminated and resolved as either healthy tissue or focal lesion in the 3D sequence. 3D FLAIR-ED provides a clinically viable and superior alternative to 2D FLAIR sequences.

## REFERENCES

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