Can T1-Differentiation in a Magnetization Prepared Turbo Field Echo Sequence at 7T Predict "Persistent Black Hole" White Matter Lesions in Multiple Sclerosis?

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Introduction

Multiple sclerosis is a neurological disorder most commonly starting in young adulthood. Although white matter lesions (WML) are not indicative of the cognitive impairment of the patient, the pathological cause of the lesions is still being actively studied [1]. In this study, a T1 weighted sequence is used to separate these lesions into two groups with different T1.

Materials and Methods

Bluestein, et al. [2], noted that the T1 distribution of white matter lesions was bimodal, with one peak around 2200 ms and the other roughly 4300 ms (Fig 1). Using the T1 and PD values $T1_{NAWM}$ = 1350 ms, $T1_{WML-low}$ = 2200 ms, $T1_{WML-high}$ = 4300 ms, PD_{NAWM} = 0.63, $PD_{WML-low}$ = 0.88, and $PD_{WML-high}$ = 0.95, we simulated the signal response of normal appearing white matter (NAWM), short T1 white matter lesions, and long T1 white matter lesions (Fig 2). That simulation showed that setting TS = 4500 ms and TI ranging from 880-980 ms, results in images with the long T1 WMLs brighter and short T1 WMLs darker than surrounding NAWM. Four MS patients (2 RRMS, 2 SPMS) were scanned with IRB approval using Philips' 3T and 7T Achieva scanners to test the new sequence. The patients underwent 3T FLAIR (TR = 11000 ms, TI = 2800 ms, TE = 125 ms, TSE factor = 31), and three 7T MPRAGE sequences (Conventional T1: TS/TI = 4550/1800 ms, white matter attenuated (WHAT) TS/TI = 4550/500 ms, and WML T1-differentiating TS/TI = 4500/925ms. Other parameters for the MPRAGE sequences were: TR/TE = 4.1/1.6 ms, flip angle = 8°, and TFE factor = 360. The images were then compared to one another and the appearance of white matter lesions were noted with each sequence.

Results

The T1-differentiating sequence could indeed separate WM lesions: one being brighter and the other darker than the surrounding white matter tissue. The two WML contrasts were observed in an MS patient (see Fig 3D). A clinically standard 3T FLAIR sequence showed all WMLs evenly hyperintense (Fig 3A). The 7T WHAT scan also showed all WMLs evenly hyperintense, with some slightly brighter (Fig 3B). The 7T T1-W sequence showed all lesions, but some were black and some were gray compared to adjacent NAWM (Fig 3C). Our preliminary results indicate that bright, "long T1" WML in the T1-differentiating sequence are more prevalent in progressive patients rather than those who were recently diagnosed.

Discussion

Demyelination and axonal loss are considered to be the two leading causes of white matter lesion contrast differences in MRI [3]. An IR-TFE sequence with TS/TI = 4500 ms/925 ms demonstrates that white matter lesions can be separated into at least two groups depending on the severity of the focal tissue damage. More established lesions with greater demyelination and axonal loss will have longer T1, whereas lesions with less severe damage have shorter T1s. This may be observable at lower field strength, however T1s are longer and thus better differentiated at 7T. T2 weighted sequences cannot differentiate white matter lesions in this manner. The new T1-differentiating sequence could be used to prospectively identify persistent black holes, though a larger longitudinal study would need to be conducted to test that hypothesis.

Conclusion

Using a T1-weigthed sequence with an intermediate TI can show differentiation in white matter lesions, and could be used for characterization of those lesions, including their propensity to become persistent black holes, indicating permanent tissue damage.

References: [1] Barkhof, 2002, [2] Bluestein, 2011, [3] Van Walderveen, 1998
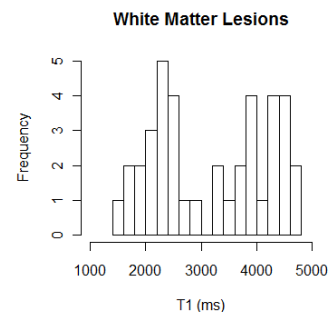
White Matter Lesions

Figure 1: Measured T1s in white matter lesions show a broad distribution with two main peaks occurring around 2200 ms and 4300 ms.
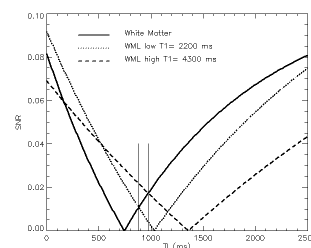

Figure 2: Simulation showing that the range of TI for separating white matter lesions lies between 880 and 980 ms.
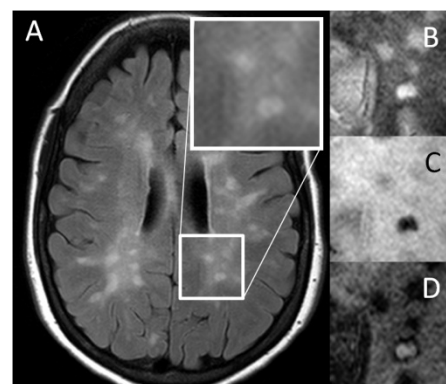

Figure 3: (A) 3T FLAIR, (B) 7T WHAT, (C) 7T T1w-MPRAGE, and (D) 7T MIX sequences showing that white matter lesion T1 contrast is variable. A persistent black hole (bottom) and a less severe lesion (top) are highlighted.