

High Resolution White Matter T1 Mapping in Multiple Sclerosis at 7T

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Introduction: Multiple Sclerosis (MS) is a condition that affects young adults typically aged 20-40 years, and involves inflammation and demyelination of neural axons in the brain and nervous system. Although there are different types of MS lesion, most appear as areas of demyelination in the brains white matter (WM). MRI has played an important role in the diagnosis of MS and has also been used as a marker of drug efficacy in treatment trials. The increased signal to noise ratio (SNR) and spatial resolution available at ultra high field should improve specificity as well as sensitivity to MS lesions. Previous work¹ has shown that the longitudinal relaxation time (T1) of MS lesions is longer than that of healthy WM, this is thought to be related to the loss of myelin. In this study, we repeat similar measurements at 7T showing that T1 can be measured with high spatial resolution. Previous work² has also shown that the T1 distribution of healthy appearing white matter in the brains of MS patients is shifted relative to that of healthy control subjects. This is particularly true close to MS lesions. Here, we measure the distribution of T1 values at 7T, comparing WM in healthy controls with normal appearing WM in MS patients. We also characterise the spatial distribution of the high T1 values in the brain.

Methods: Five MS patients were recruited from Nottingham University Hospital. Five age and sex matched healthy volunteers were also recruited, and both groups were consented according to local ethics. 7T images were produced using a Philips Achieva system equipped with a whole body gradient set, a head only volume RF transmit coil and a 16 element dome shaped receive coil capable of parallel imaging. The scan protocol at 7T included a 3D MPRAGE sequence (0.6 mm isotropic resolution; 192 x 163 x 96 mm³ FOV; TE=5.9 ms; TR=13 ms; TFE shots=149;160 slices; TI=1051 ms; SENSE factor = 2; total scan time = 7:26 min) and a 2D multi-slice FLAIR sequence (0.6 mm isotropic resolution;192 x 163 x 72 mm³ FOV; TE= 100 ms; TR=1500 ms; 36 slices; TI= 2800; total scan time 5 min). T1 maps were derived using data acquired with a modified version of the MPRAGE sequence. The imaging parameters were modified to give a 200x170x73 mm³ FOV using a 1.25 mm isotropic voxel size. (Additionally we used TE=3.2 ms; TR=6.9 ms; TFE shots=16;58 slices; SENSE factor = 2). 7 separate T1's were used with values 150, 300, 500, 800, 1200, 1800, 2500 ms. The total scan time per T1 was 2 minutes.

Initially, the T1 values of lesions was measured by simulation of the MPRAGE sequence³ and compared to values measured in healthy appearing white matter. T1 values were then obtained on a voxel by voxel basis using a java plugin written for ImageJ⁴ and a T1 map constructed. The high contrast MPRAGE image was used to segment the grey and white matter using SPM5⁵. The segmented white matter was displayed as a probability map which was then converted to a mask image. This mask was used to define areas of healthy appearing white matter in the T1 maps. As far as possible we ensured that these WM areas did not include WM MS lesions. The histogram of T1 values in the healthy appearing WM was normalised (by the total number of pixels in the segmented WM T1 map) and plotted. Finally, the spatial distribution of high T1 values in the WM was assessed by highlighting areas of high T1 (>1500ms) on the segmented T1 map.

Results: Figure 1 shows results derived from a representative MS patient. Fig.1A shows the MPRAGE image used for segmentation, Fig.1B shows a typical T1 map and Fig.1C shows the segmented region containing only healthy appearing WM. Fig.1D and Fig.1E show typical T1 fits to data acquired within (E) and outside (D) a WM MS lesion. Notice the substantial increase in the T1 value measured inside relative to outside a WM lesion. Figure 2 shows the results of T1 measurements in the normal appearing white matter. Fig.2A shows a histogram of T1 values in normal volunteers (blue) and MS patients (red). Notice here that although the peak T1 value is approximately the same, the full width at half maximum (FWHM) of the histogram for the MS patients appears larger. This is confirmed by Fig.2B and Fig.2C which show peak T1 (average \pm std across subjects) and FWHM (average \pm std across subjects) respectively. The spatial distribution of the high T1 values in a MS patient and a healthy volunteer is shown in Figure 3. Notice for the MS patient that areas of high T1 appear as a 'halo' around the location of the MS lesion. (In these images the MS lesion itself appears black since they were not included in the WM mask. Also notice that high T1 is apparent close to the ventricles.

Discussion: The results presented show that, as expected, the T1 of MS lesions is longer than that of white matter at 7T. The data acquired show that accurate T1 maps can be acquired with high spatial resolution. Our masking procedure eliminated grey matter, CSF and lesions so that T1 histograms comprising the healthy appearing white matter could be formed. Our results agree with previous studies² at lower field strength and suggest that there is a difference in the T1 distribution between healthy appearing WM in MS patients and normal volunteers. Further, in agreement with previous literature² we have shown that the areas of highest T1 appear close to the site of MS lesions. Future study of this effect may result in T1, and spatial distribution of high T1 values becoming a marker of disease progression in MS.

References: 1) Srinivasan et al, American journal of neuroradiology, 24, 58-67, 2003. 2) Vrenken et al, American journal of neuroradiology, 27, 2005-2011, 2006. 3) P. J. Wright et al, Magnetic Resonance Materials in Physics, Biology and Medicine, 21, 121-130, 2008. 4) (<http://rsb.info.nih.gov/ij/>). 5) (<http://www.fil.ion.ucl.ac.uk/spm/software/spm5/>).

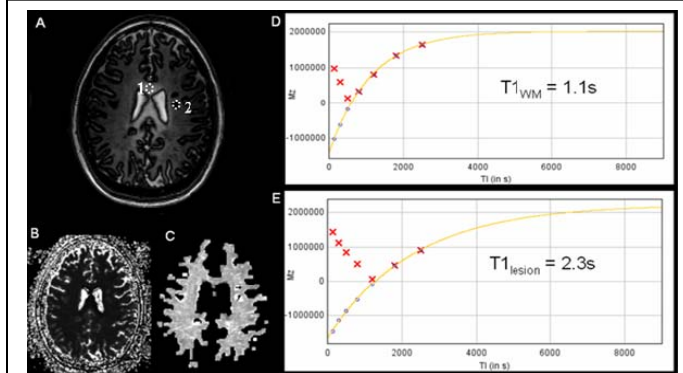


Figure 1: T1 values of normal appearing white matter and MS lesion.

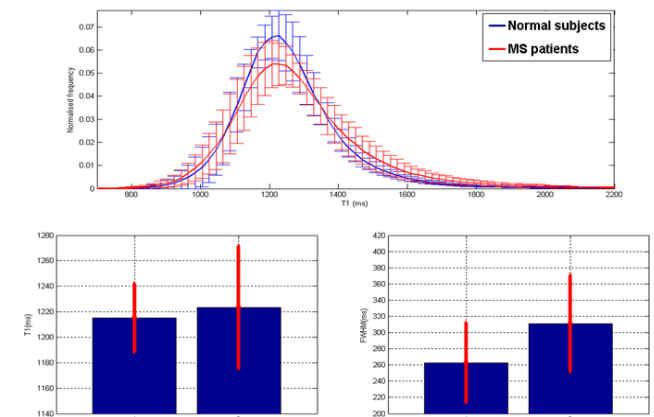


Figure 2: Histograms of healthy appearing white matter in MS patients

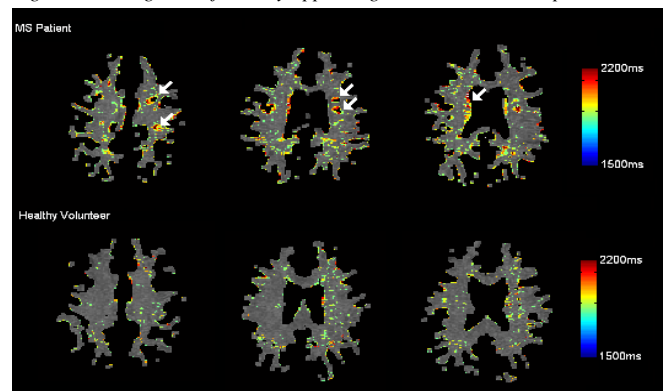


Figure 3: Spatial distribution of high T1 values