

Myelin Imaging in the Brain of MS Patients via Linear Combination

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Introduction: Magnetic Resonance Imaging is the most sensitive imaging modality to detect lesions in Multiple Sclerosis (MS) [1]. White matter has a multi-exponential T_2 decay with a short T_2 component ($T_2 \sim 10$ ms), which has been associated with myelin [2]. By using linear combination (LC) myelin filtering [3,4] we find low signal intensity of short T_2 components in MS lesions visible on a Fluid Attenuated Inversion Recovery (FLAIR) images.

Theory: A T_2 filtered image is made using linear combination of spin echo images with different echo times. The weights of the linear combination along with the echo times are designed using convex optimization to maximize the myelin signal to noise ratio (SNR). The optimization algorithm is required to suppress extracellular white matter T_2 species (T_2 between 70 ms and 90 ms). In addition Cerebral Spinal Fluid (CSF) suppression (T_2 between 200 ms and 5 s) is imposed [2,6]. Thus short T_2 species ($T_2 < 20$ ms) pass through the filter while long T_2 species ($T_2 > 70$ ms) are blocked. TR is varied between acquisitions to keep T_1 weighting the same in all the spin echo source images. A uniform T_2 profile filter is also designed using the same echo times as the short T_2 filter (Fig.1) [3,4].

Methods: A GE Signa LX 1.5T scanner was used to scan 5 healthy subjects and 2 patients with known MS. For each subject 3 spin echo scans were acquired, TE=8/35.2/110 ms, TR = 698/725.2/800 ms. 24 cm FOV, $N_x=256$, $N_y=128$, 15 kHz bandwidth. The short T_2 filter uses the weights 2.3/-3.8/1.5 and the uniform T_2 weighting filter uses the weights 0.9/0.3/-0.2. LC fractional myelin maps were generated. For comparison a regular clinical FLAIR image TR=8s, TE =110 ms, TI = 2.2 s was also acquired. A short T_2 fraction map was formed by dividing the short T_2 filtered image by the uniform T_2 filtered image. For each subject the fractional T_2 signal was integrated over a region of interest (ROI) within MS lesions for patients and in the genu of corpus callosum in normals.

Results: Figure 2 shows the MRI images along with the fractional myelin maps. For the first patient (Fig. 2(a) and (b)), the ROI around the solid arrow had 0 to 5% short T_2 signal percentage. The dashed arrow ROI had 0 to 6% short T_2 signal component percentage. For the second patient (Fig. 2(c) and (d)), the solid arrow ROI had 0 to 4% short T_2 signal, and the dashed arrow had 0 to 5% short T_2 signal. For healthy volunteers 10% to 13% short T_2 signal was measured in the genu of the corpus callosum.

Discussion: From the literature the short T_2 components contribute about 10-12% of the total T_2 spectrum amplitude in healthy volunteers [2,3]. On both patients the lesion low T_2 percentage is far below 10%. This suggests abnormalities that may indicate demyelination. The significance of this finding needs further investigation to determine normal short T_2 signal variations both in MS patients and the normal population.

References:

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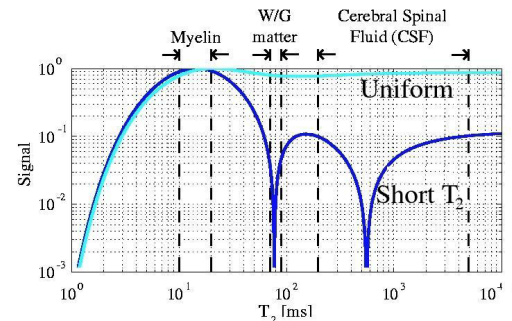


Figure 1: The T_2 response of the short T_2 LC filter used for myelin detection, along with a uniform T_2 filter. The uniform filter uses the same echoes and is used to generate a fractional short T_2 map [4,5,6].

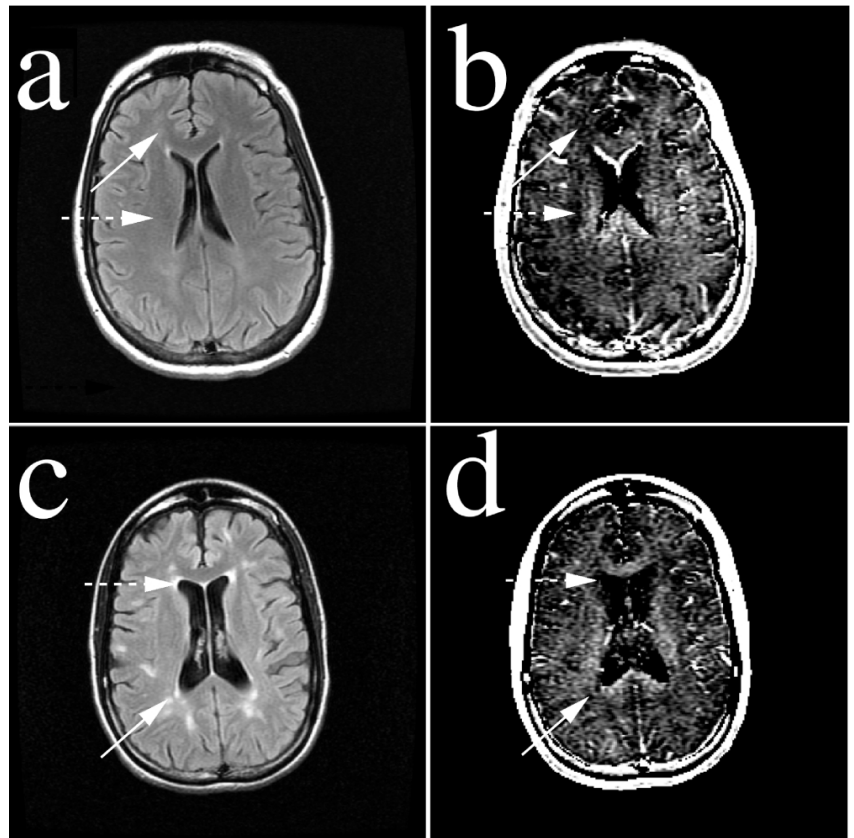


Figure 2: MRI images of MS patients (a,c) FLAIR images. (b,d) Fractional myelin maps using the LC method. Arrows show lesions shown both on the FLAIR image and the fractional myelin image. The fractional short T_2 images were windowed to show the range from 0 to 30% short T_2 amplitude percentage.