Quantitative Multi-Slice Mapping of the Myelin Water Fraction Using Multi-Compartment Analysis of T2* Relaxation at 3T

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Introduction: Demyelination of white matter in the central nervous system is considered the primary pathology of multiple sclerosis (MS). Quantitative mapping of the myelin water fraction (MWF) can provide valuable insights into the focal pathology and the pathology of the normal appearing white matter. MR imaging of the myelin water fraction is challenging due to its short T2 relaxation time (~17ms). MacKay et al. [1] acquired the MR signal of white matter using a 32-echo Carr-Purcell-Meiboom-Gill (CPMG) sequence and used a nonnegative least squares (NNLS) algorithm to estimate MWF from the T2 decay measurement. By this method, a single slice (256x128) is acquired in each scan with an imaging time on the order of 25 minutes. In this abstract, we present the preliminary results of mapping the MWF using a fast *multi-slice* imaging technique. A multi-slice echo-planar spectroscopy imaging (EPSI) sequence was used to record the T2* relaxation in each voxel with a scan time less than 10 minutes. Multi-exponential analysis using a 3-pool model [2] was used to quantitatively map the MWF in post mortem human brains.

Methods: Two post mortem MS brains were scanned with a 128-echo gradient-echo EPSI sequence on a GE 3T scanner. Multiple images were acquired with a matrix of 256x256, a slice thickness of 5 mm, and a FOV of 20cm in 8.5 minutes. The first echo time and echo-spacing were approximately 2.13ms and 1.17ms, respectively. The TR was 2s and flip angle was 90 degrees. The echoes were acquired on both the flat-top and ramps of the readout gradients to reduce echo-spacing. Only 5 slices were acquired in each scan to avoid over-heating the gradient system, although in theory as many as 12 slices could possibly be acquired with a TR of 2s. Multi-exponential analysis was applied to the T2* decay at each voxel using a 3-pool model, which consists a myelin water pool (T2*<16ms), a myelinated axon water pool (16ms<T2*<36ms), and a mixed water pool (36ms<T2*<160ms). The optimal fitting of these three exponentials with 7 variables (i.e., 3 amplitudes, 3 T2* values, and a baseline amplitude) to a measured T2* decay was implemented using a modified version of the quasi-Newton algorithm.

Results: Representative MWF maps are shown for a post mortem MS brain in the top row in Fig. 1, while the T2 FLAIR images at the same slice locations are shown at the bottom row for comparison. The signal from myelin water was reliably detected in regions of normal appearing white matter in all these slices. The MWF was substantially reduced, or nearly undetectable at the locations of focal MS lesions, as indicated by arrows. Several small lesions shown in the T2 FLAIR images were well depicted in the MWF maps (e.g., the lesions indicated by the arrows at the 4th slice). The MWF in the normal appearing white matter is in a range below 18%, consistent with previously reported measurements [2]. Expected differences in myelin content of normal regions of gray and white matter are also apparent in these MWF maps.

Discussion: These preliminary results demonstrate the feasibility of mapping myelin based on MWF in human brain with good brain volume coverage. The EPSI approach differs from the conventional CPMG methodology in its access to very short echo times and multi-slice volume coverage, and its basis in T2*. Preliminary results suggest that this alternative approach may have advantages in allowing multi-slice characterization of MWF in normal and abnormal brain in reasonable scan times.

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References: 1) MacKay A, et al. MRM 1994; 31:673-7. 2) Lancaster JL, et al. JMRI 2003;17:1-10. 3) Andrews T, et al, MRM 2005;54:449-54.

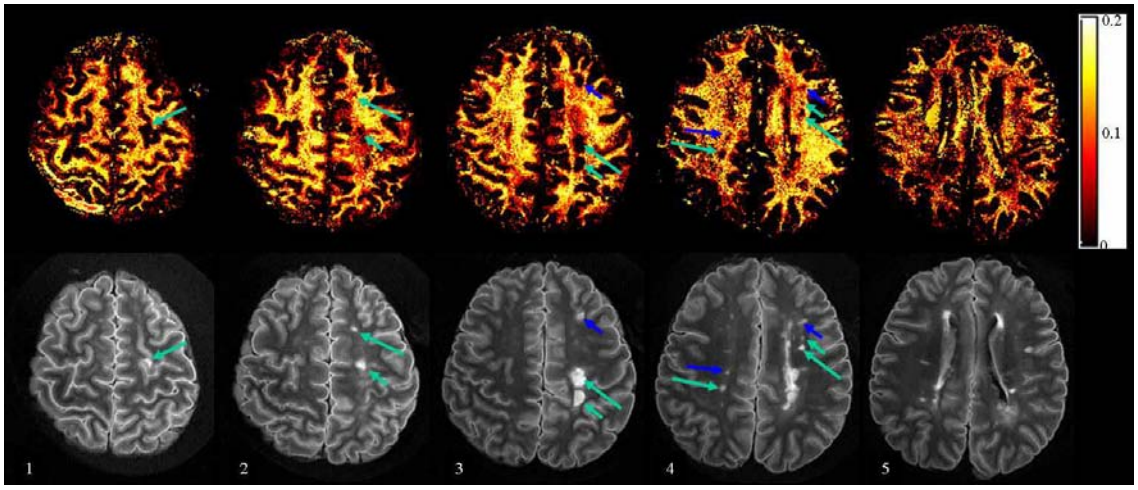

Fig. 1