In Vivo Application of Quantitative Mapping of Myelin Water Fraction Using T2* Decay

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Introduction: Quantitative mapping of myelin water fraction (MWF) can provide insight into the development and degeneration of the brain or the pathology of white matter diseases. A single-slice technique based on the CPMG data acquisition has been successfully developed to study the pathology related to demyelination in patients with multiple-sclerosis [1]. We have developed a new multi-slice technique to estimate MWF using T_2* relaxation, which makes the acquisition much faster (8.7 minutes for up to 12 slices) with finer temporal resolution (128-echo measurements with the first echo at 2.1 ms and 1.1 ms interval) than the previous approaches with T_2 relaxation. Applications to fixed brains were successful and high quality MWF maps were obtained [2]. In this abstract, we present the preliminary results of *in vivo* applications. T_2* relaxation of living brains is different from those of fixed ones, and the measurements of T_2* decay are more affected by the susceptibility-induced local field gradients, movements, and physiological fluctuations, etc. We used the three-pool model analysis [3] for T_2* decay measurements with an incorporation of the local gradient compensation [4].

Method: Brains of healthy subjects were scanned with a 128-echo multi-gradient-echo sequence on a GE 3T scanner to record the T_2* decay curve. 8 slices were acquired (up to 18 slices are possible) with a matrix of 128 x 128, a slice thickness of 3 mm, and a FOV of 20 cm. TR was 2 s, flip angle was 90 degrees, the first echo was 2.124 ms, and echo spacing was 0.776 ms. We used the three-pool model [3] for multi-exponential fitting to estimate MWF from the decay measurements. The three-pool model consists of a myelin water pool (T_2* < τ_1), a myelinated axon water pool (τ_1 < T_2* < τ_2), and a mixed water pool (τ_2 < T_2*). Optimal set of (τ_1, τ_2) was selected from the T_2* distributions over the regions of interest in white matter (Figure 1). Since T_2* decay measurements for some of tissues are affected by the susceptibility-induced local gradients, we have incorporated the compensation method using a *sinc* function [4] into the multi-exponential fitting procedure.

Results: Figure 1 shows the histogram of T_2* over the regions of interest in white matter. It has three distinct peaks which correspond to the myelin water pool (3~22 ms), the myelinated axon water pool (22~50 ms), and the mixed water pool (50~132 ms), respectively. Based on these T_2* ranges, the upper 4 slices of the brain were analyzed and their MWF maps were estimated as shown in Figure 2. The rightmost column of Figure 2 explains the effect of the susceptibility-induced local gradients on MWF mapping. The bottom image (B) is the MWF map estimated without the local field compensation. MWF at the orbitofrontal region was significantly reduced. In contrast, the map estimated with compensation (A) shows the recovered MWF on that region. Figure 3 shows MWF maps for another living brain. Only high MWF (>0.15) are shown, overlaid on anatomical images.

Discussion: This study shows the preliminary results of MWF mapping using T_2* relaxation applied to living brains. We have expected that T_2* ranges of living brains would be longer than those of fixed ones (3~16, 16~34, 34~45 ms for each of three pools) considering the T_2 shortening effect due to the tissue fixation. As expected, T_2* ranges for living brains were estimated to be 3~22 ms, 22~50 ms, and 50~100 ms for the myelin, myelinated axon, and mixed pools, respectively. We used the compensation method using a *sinc* function to reduce the effect of the susceptibility-induced local gradients. The *sinc* function approach assumes that the local gradient is linear in z-direction. More sophisticated high-order compensation would improve our fitting results. These preliminary results have demonstrated the feasibility of myelin mapping using T_2* relaxation with fast acquisition and multi-slice coverage of the brain. We have encountered severe artifacts on FID measurements for lower parts of brain, resulting in erroneous myelin maps. Further studies are needed to reduce other artifacts caused by patient motion and physiological fluctuations.

References: [1] MacKay A, et al. MRM 1994; 31:673-7. [2] Du YP, et al. ISMRM 2006, p.2104. [3] Lancaster JL, et al. JMRI 2003; 17:1-10. [4] Fernandez-Seara, et al. MRM 2000; 44:358-66.

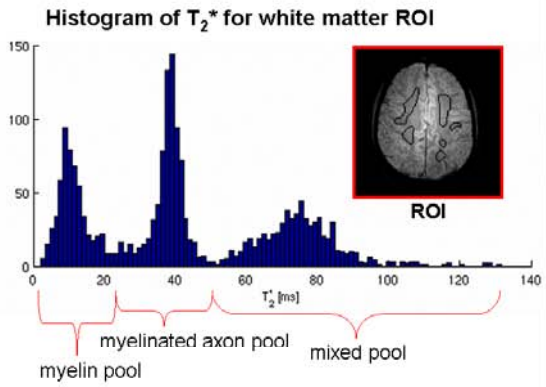

Figure 1. Histogram of T_2* distribution

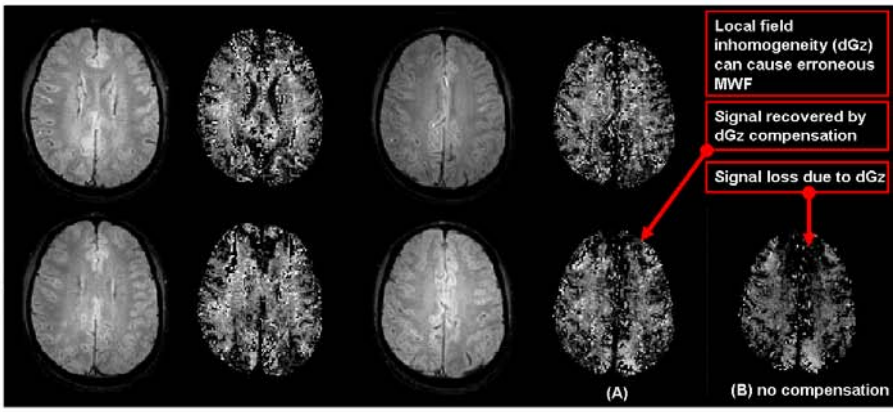

Figure 2. Myelin water fraction (MWF) map

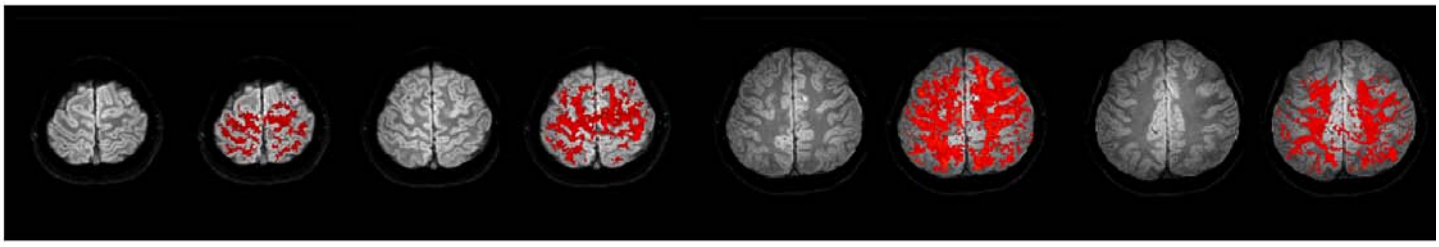

Figure 3. MWF(>0.15) overlaid images