Myelin Water Fraction Measurement using Free Induction Decay and Refocused Gradient Echoes

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Introduction: Myelin water fraction (MWF) in white matter (WM) is of great interest in many pathological conditions, most notably multiple sclerosis[1]. Current approaches utilize multicomponent T2 or T2* analysis[2,3], which decompose multi-echo spin echo (SE) or gradient echo (GRE) signal curves into discrete components characterizing tissue compartments including myelin water (short T2) and intra- and extra-cellular water (long T2). In this study, we propose a novel MWF measurement technique using the free induction decay (FID) and refocused GRE portions of SE signal decay curve acquired by the GESFIDE[4] sequence (Fig. 1).

Material and Methods: With IRB approval, five normal subjects (ages 22-30) were scanned at 3T (MR750, GE Healthcare) using an 8-channel head coil with our implementation of 2D GESFIDE (res 1.6×1.6×1.5mm^3, 12 interleaved slices at 1mm spacing, TE_{SE}/TR 100/2000ms, 40 echoes with TE 5-130m, and total acquisition time 4.3min). We also acquired data with TE_{SE} 91, 82, 73 and 64ms and readouts at the same TEs. Segmentation of gray matter (GM) and WM in GESFIDE images was performed using a custom algorithm. In our analysis, we fit the FID echoes (assumed to display bi-exponential decay) for the mono-exponential decay rate $R2^*_A$, and the refocused gradient echoes (assumed to display mono-exponential decay with only the long-T2 component) for the mono-exponential decay rate $R2^*_C$. Additionally assuming that $\Delta R2^* = R2^*_A - R2^*_C = R2_A - R2_C$ and characteristic decay rates $R2_m$ and $R2_w$ for myelin water and non-myelin water, we arrive at the first-order approximation that $\Delta R2^* = MWF \times (R2_m - R2_w)$.

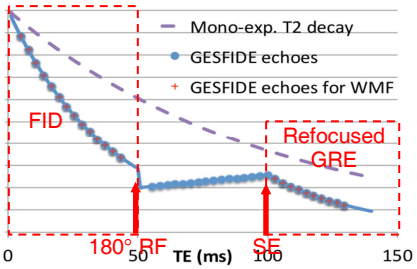


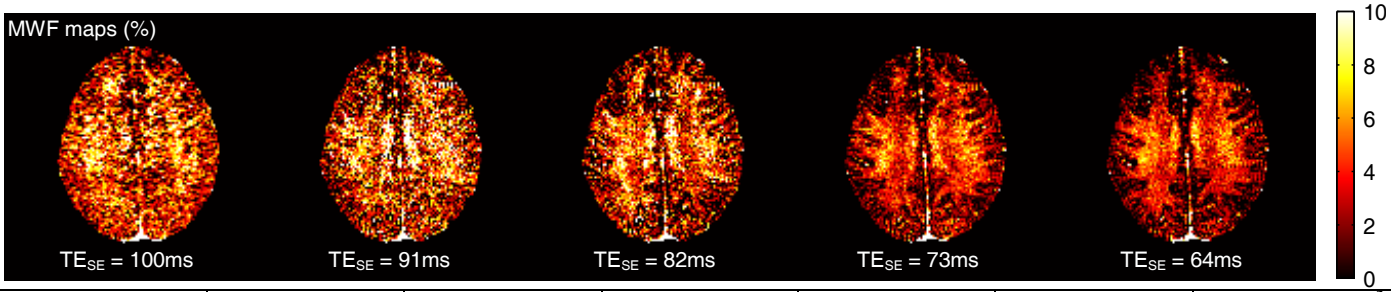
Fig. 1: Idealized mono-exponential GESFIDE signal curve with all acquired echoes and those used for MWF calculation.

Results and Discussion: Using 15ms and 80ms (literature gives range 50-600ms)[2] for $T2_m$ and $T2_w$ (where T2=1/R2) respectively, we calculated MWF in GM, WM, splenium, and genu of the corpus callosum (CC), and found the results to be mostly consistent with literature values (Fig. 2). Comparing to T2-based methods[1], our approach has low SAR (one 180° pulse per slice per TR) and much shorter acquisition time. Unlike T2*-based methods[3], our method is also insensitive to B0 heterogeneity. However, problems remain: 1) low spatial SNR, partly due to thin slices (1.5mm instead of 2.5-5mm in literature[1]); 2) strong dependence on TE_{SE}, which is not yet optimized; 3) bi-exponential model assuming a single $T2_w$ when intra- and extra-cellular water compartment produces a wide range of T2 [2]; 4) no accounting for diffusion effects; 5) inadequate GM/WM segmentation allowing partial volume effects to corrupt mean values. To address these shortcomings, we plan to improve segmentation, implement 3D GESFIDE and increase slice thickness to improve SNR, as well as to construct numerical models for more accurate representation of tissue relaxation behavior and optimization of imaging parameters. We also plan to explore alternative analysis methods, such as performing mono-exponential fitting through the difference in normalized signal values from the two sections.

Conclusion: This study demonstrated the feasibility of measuring MWF using FID and refocused gradient echoes acquired with the GESFIDE sequence. Though further work is needed, this method is promising for performing fast and low-SAR MWF quantification.

References: 1. T Prasloski *et al.*, NeuroImage, 2012. 2. K Whittall *et al.*, MRM, 1997. 3. Y Du *et al.*, MRM, 2007. 4. N Fujita *et al.*, NeuroImage, 2003.

Acknowledgements: NIH 1R01NS066506, NIH 2R01NS047607, NCRR 5P41RR09784, Stanford Graduate Interdisciplinary Fellowship program.



	TE_{SE} = 100ms	TE_{SE} = 91ms	TE_{SE} = 82ms	TE_{SE} = 73ms	TE_{SE} = 64ms	Literature values[2]
R2*A (s^{-1})	17.4	17.4	17.4	17.5	17.4	-
R2*C (s^{-1})	13.5	13.8	14.3	14.8	15.1	-
MWF (%)						
GM[a]	3.5	3.4	2.7	2.0	1.2	3.13 ± >0.54
WM[a]	11.2	10.2	9.1	8.3	7.5	11.28 ± >0.96
Splenium[b], CC	15.0	14.8	13.6	14.3	14.5	13.05 ± 0.96
Genu[b], CC	10.4	10.5	10.6	9.8	7.5	9.86 ± 0.96
MWF ratio, WM/GM	3.3, (3.3 median)	3.1, (2.9 median)	3.7, (3.1 median)	4.5, (3.7 median)	7.9, (5.7 median)	3.60
MWF ratio, sple./genu	1.5	1.4	1.3	1.5	2.2	1.32

[a]*Averaged over all 12 slices in 5 subjects;* [b]*Splenium and genu of CC imaged in 2 subjects only.*

Fig. 2: MWF maps calculated from scaled ΔR2* maps and summary of mean values with comparison to literature values. MWF ratios eliminate the dependence of MWF % values on the choice of T2m and T2w, and hence provide a more reasonable comparison with literature values.