Multi-Component Fitting of T_2^* Relaxation in White Matter at 3 and 7 Tesla

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Purpose: High magnetic field strength increases susceptibility contrast in tissue, reflected in increased local resonance frequency shifts (Δf) and R_2^* ($=1/T_2^*$) decay rates. In addition, distinctions in these parameters between different cellular compartments may become more apparent at high field, leading to multi-exponential signal decay that has been suggested to allow separation of signal from the axonal lumen, the interstitial space, and that trapped between the myelin layers that surrounds axons.[1,2] The latter may have important applications for the study of myelin changes in normal aging and with disease. This study will attempt to corroborate previous findings at 7 T,[2] while investigating the feasibility of extending them to 3 T.

Method: Two separate groups of healthy volunteers were imaged using 32-channel head coils on a Siemens 3 T (n=5 females, n=4 males, ages 23-49, mean age 29) and a Siemens 7 T (n=6 females, ages 23-49, mean age 32) under IRB approval. Three of the female subjects were part of both groups. A multi-echo GRE sequence was used to map signal evolution (15 slices, 0.17-0.5 mm gap, 1.5 mm isotropic resolution, FA 60-70°, 3-5 averages, scan time 6-10 min). At 3 T, 29 echoes covered TE 3.3-60.0 ms, at 7 T 36 echoes covered TE = 2.3-61.1 ms. ROI analyses and multi-exponential fitting of multi-echo GRE images were performed using IDL. ROIs were manually selected in the splenium of the corpus callosum (SCC) in a region where fibers ran approximately perpendicular to the magnetic field (B_0). This was done to avoid variability due to known effects of fiber orientation (relative to B_0 direction) on the signal decay.[2,3]

Results: Values for relative amplitude, R_2^*, and frequency shift were comparable to previous reports of SCC at 7 T (Table 1).[2] Relative amplitude for each component was similarly distributed at 7 T and 3 T. As expected, a field dependence was observed for R_2^* and Δf values, with the 3 T values being 41-50% and 21-53% lower respectively than the 7 T values.

B_0 (T)		A_1 (%)	$R_2^*{}_{,1}$ (Hz)	Δf_1 (Hz)	A_2 (%)	$R_2^*{}_{,2}$ (Hz)	Δf_2 (Hz)	A_3 (%)	$R_2^*{}_{,3}$ (Hz)	Δf_3 (Hz)
7	AVG	12.6	149.9	34.1	51.6	39.7	2.7	35.8	22.6	-3.0
	SD	*2.8*	*18.6*	*4.7*	*4.4*	*3.8*	*0.6*	*4.3*	*2.9*	*0.6*
3	AVG	11.1	87.9	16.2	48.7	21.9	1.3	40.1	11.1	-2.4
	SD	*1.2*	*4.3*	*0.7*	*1.9*	*0.8*	*0.3*	*1.8*	*1.4*	*0.3*

Table 1. Three-component fitting of SCC at 7 T and 3 T. Mean (AVG) and standard deviation (*SD*) are reported for relative amplitude (A), relaxation rate (R_2^*), and frequency shift (Δf) for each component.

Discussion: The results presented here confirm the previously reported feasibility of separating, in a major fiber bundle, cellular compartment-specific contributions to susceptibility contrast.[1,2] They further indicate that similar findings can be obtained at the more common field strength of 3 T. This would allow quantification of the myelin water-fraction, and infer local myelin content, with possible application of studying changes in myelination with disease. Because of the reduced susceptibility contrast at 3 T, distinction between the cellular compartments may be somewhat compromised, which affects the accuracy of the component fractions. This may be mitigated by reducing the number of free parameters during the fitting process, e.g. by fixing the R_2^* values for the individual components.

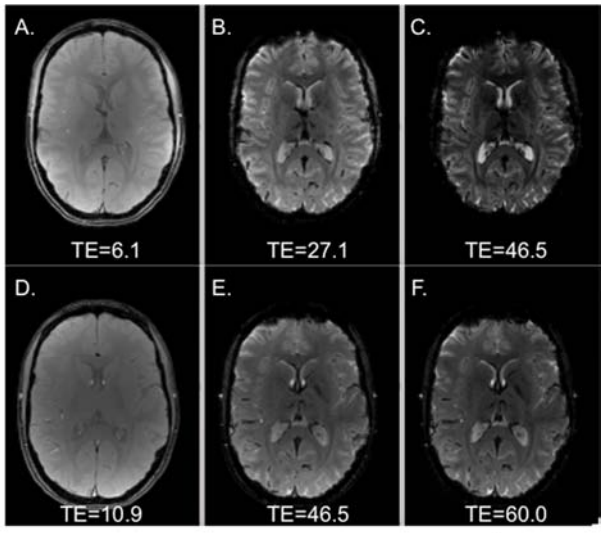

Figure 1. Approximate T_2^* contrast for each component at 7T (A-C) and 3T (D-F). Myelin water is the shortest (A, D), then axonal water (B, E), and finally interstitial water (C, F).

References:

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