Detection of the Myelin Water Fraction in 4 Tesla Longitudinal Relaxation Data by Cross-Regularized Inverse Laplace Transform

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Introduction: Transverse tissue ^1H_2O relaxation gives evidences of water compartmentalization in the human brain. About 12% of water in white matter gives rise to a relaxographic component with a small T_2 of ca. 20 ms. This is attributed to oligodentrocyte intracellular water, also described as being trapped between myelin bilayers [1]. The myelin water fraction (MWF) is defined as the area of the myelin water peak divided by the total area of the T_2 relaxogram [1]. The failure to detect a myelin water fraction in longitudinal relaxation studies has been attributed to a sufficiently fast exchange of water between the intra-/extra-cellular space and oligodentrocytes [2]. We recently observed a small peak with a T_1 of ca. 200 ms in the longitudinal relaxogram obtained from the brain of a volunteer at 4 Tesla [3]. The purpose of this study is to further investigate the properties of this small T_1 peak in human brain water.

Methods: A train of PURR images [4] were acquired from two human volunteers at 4 Tesla [5]: 8 ms hyperbolic secant adiabatic inversion pulse, ca. 5° slice selective read pulses, (192×256) matrix, TE ca. 8 ms, 64 TI geometrically sampled [6] (see Table and first column of Figure). Raw-data processing included a DC-correction, an FFT (Matlab *fft*) and a phase-correction in reference to the average phase of the last 8 TI images [4,5]. A cross-regularized inverse Laplace transform (ILT) was performed with a modified CONTIN regularizor encoding an in-plane second-order regularization using a sliding 5-by-5 pixel sub-image neighborhood without constraining the relaxographic dimension (details in [7]): 40 T_1 grids logarithmically spaced between 100 ms and 7 sec. An efficiency map of the adiabatic inversion pulse was estimated with a CONTIN [8] based grid search procedure carefully designed to choose between a fast initial relaxation and an imperfect adiabatic inversion pulse. The inversion pulse efficiency map was smoothed with an 8-mm FWHM Gaussian filter and incorporated pixel by pixel into the CONTIN kernel. Peeling of the slices of subjects A and B was performed manually after the cross-regularized ILT to remove signal from the skull.

Results: The slice relaxogram displays for both subjects a small T_1 peak at respectively 215 ms and 178 ms (inset, second column of Figure). A water fraction of this small T_1 peak was computed by dividing its area by that of the total water relaxogram and is displayed as a map (third column of Figure). As seen, this map is more intense in white matter. A histogram of this fraction was computed after excluding pixels with relaxograms dominated by a strong CSF peak (more than 80% of the total water, red relaxogram in second column of Figure). The histograms are bimodal with two maxima centered at ca. 0.05 and 0.12 with a minimum near 0.09 (fourth column of Figure, top). Applying a threshold to select pixels with a water fraction of the small T_1 peak smaller or greater than 0.09 effectively performs a segmentation of white and gray matter (fourth column of Figure, bottom). The corresponding relaxograms are displayed in the second column of the Figure.

Conclusion: The average water fraction of the T_1 relaxogram peak at ca. 200 ms in white and gray matter agrees with values reported in the literature for the myelin water fraction (MWF) of T_2 relaxograms [1]. A sufficiently well sampled ^1H_2O inversion recovery from human brain appears to be in fact multi-exponential and to include a distinguishable contribution from myelin water. To our knowledge, this is the first account of a MWF peak observed in a T_1 relaxogram of the human brain. The T_1 position of the MWF does not change in white and gray matter for a given subject, suggesting similar myelin water macromolecular environments.

Table	*Inversion recovery sampling*				*SNR*	*MWF peak (myelin water fraction)*			*WM peak*	*GM peak*	*CSF peak*
Subject	TI(1)	TI(2)	TI(32)	TI(64)		in WM	in GM	T_1 (sec)	T_1 (sec)	T_1 (sec)	T_1 (sec)
A)	38.5 ms	72.7 ms	2.44 sec	17.1 sec	14.04	0.125 ± 0.021	0.052 ± 0.024	0.215 ± 0.069	1.24 ± 0.31	1.67 ± 0.54	4.57 ± 0.99
B)	24.4 ms	51.6 ms	1.74 sec	11.4 sec	20.03	0.120 ± 0.016	0.047 ± 0.022	0.178 ± 0.074	1.24 ± 0.28	1.63 ± 0.42	4.05 ± 0.96

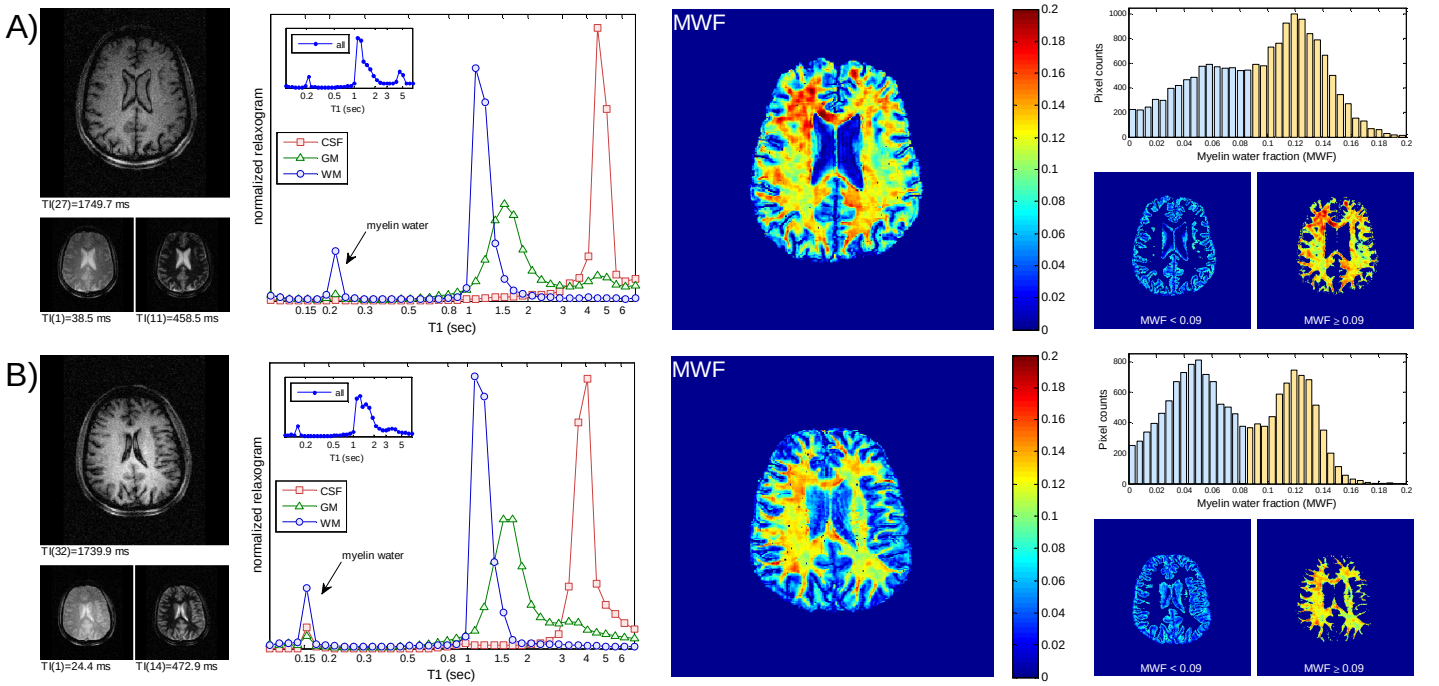

Figure: Results for subjects A and B: PURR images (first column), normalized relaxograms of WM, GM and CSF (second column), water fraction of the small T_1 peak (third column), histogram of the myelin water fraction [MWF] (fourth column, top), maps of the MWF smaller and greater than 0.09 (fourth column, bottom)

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