Neural Tissue Characterization using Integrated Relaxometry Analysis

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Intro: Integrated T_1 and T_2 characteristics of white matter in a rat brain were studied in vivo at 9.4T. Understanding micro anatomical structure of white matter is of distinctive value in determining the origin and establishment of image contrast in MRI. The characterization of multi-exponential T_1 and T_2 (MET_1,MET_2) properties may permit quantification of the relative tissue fraction of the postulated components, myelin, in particular (1). Two water pool relaxation times and water pool fractions were calculated using a multi-echo, single-slice acquisition sequence at each of five inversion recovery times (T_I). The shortest T_2 component is commonly attributed to myelin, based on the relative component size and its correlation to the amount of water in the myelin. In addition, this component has been shown to disappear following a state of demyelination (2, 3). The remaining white matter components are intracellular and intercellular water. The observance of MET_1 has been reported *in vivo* in peripheral nerve (4), but not yet in white matter of the brain. MET_1 is more readily observed using integrated T_1-T_2 measurements as opposed to the conventional 1D inversion or saturation recovery sequences (5).

Methods: Male Sprague-Dawley rats with a typical weight of 150 g were anesthetized using isofluorane/oxygen gas mixture, induction at 5% and maintenance at 2%, while respiratory rate was measured. Body temperature was monitored using a rectal thermocouple and maintained near 37°C. Imaging was performed at 400 MHz on a Varian 9.4 T magnet with maximum gradient strength of 40 G/cm. A 38 mm litzcage coil was used for RF transmission and signal reception. Multi-echo, single-slice images were acquired (T_R/T_E = 3390/8 ms) with five inversion times (T_I = 0.01, 0.23, 0.55, 1.28, 3.00s) to perform integrated T_1-T_2 measurements. Thirty-two echoes were acquired with 8 averages to ensure a SNR > 220 for all inversion times. A data matrix of 96 x 96 was acquired over a 30 mm field of view (FOV), resulting in an approximate voxel size of 313 µm x 313 µm for the 2 mm slice. This imaging geometry was chosen to provide sufficient resolution in all three dimensions in an attempt to avoid partial-volume averaging of white matter and surrounding tissue. The resulting T_2-decay was analyzed using MATLAB, and fit to an exponential decay using a non-negative, least-squares method. The integrated areas of each T_2 peak were fitted to Eq. [1], yielding a T_1 estimate for each T_2 component. Where the variable $T_x = -T_R+T_E(N_E+1/2)$, which accounts for the multi-echo sequence contribution to T_1 estimation.

$$M = abs\left(M_o * \left(1+\exp\left(-T_x/T_1\right)-2*\exp\left(-T_I/T_1\right)\right)\right) \quad [1]$$

The T_2 spectra, seen in Figure 1A, were created by defining a broad and finely sampled T_2 domain in conjunction with a minimum energy-smoothing constraint, performed iteratively with varied weighting of the constraint until the degree of smoothing is such that the spectrum contains no spurious components.

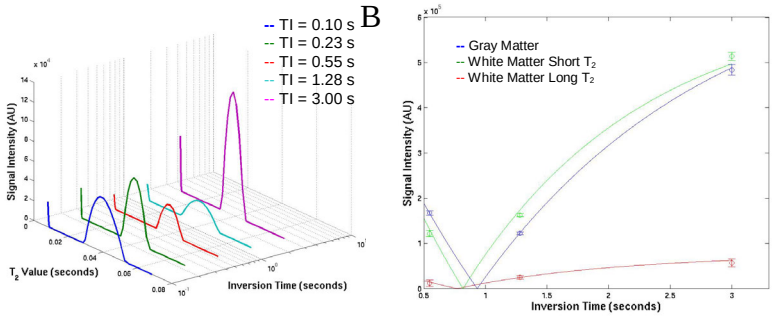

Figure 1 - A) Spectrum for onee integrated data set, T_I as indicated. B) Inversion recovery data with caluculated fit values using Eq. [1], component indicated.

Results: The spectrum from white matter produced two peaks, with average T_1, T_2, and fractional values shown Table 1. Analysis of gray matter resulted in a monoexponential decay and a single T_1 value, while of white matter revealed two T_2 components, consistent with previous studies (6), each of which had a unique T_1 value. Typical IR curves for each white matter T_2 component and gray matter are shown in Fig. 1B. The T_1 value of the myelin T_2 component is similar to that found from peripheral nerve (4). The multiexponential analysis of the MR signal will allow understanding of the T_1 characteristics of myelin that could be useful in the design of and inversion recovery (IR) or double IR to observe myelin (6).

	T_2 (ms)	Fraction	T_1 (s)
Short Component	8.281 +/- 0.556	0.141 +/- 0.054	1.188 +/- 0.088
Long Component	37.685 +/- 3.520	0.859 +/- 0.088	1.453 +/- 0.140
Gray Matter	40.424 +/- 2.591	1.000 +/- 0.292	1.624 +/- 0.169

Table 1 - Average T_1, T_2, and fractional values with standard deviations. (n = 5)

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