Optimization and Trade-offs of Multi-Spin Echo Myelin Water Imaging at 7T & 15.2T

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Target Audience:

Researchers interested in high resolution myelin water mapping in animal models

Purpose:

Myelin water imaging (MWI) by multi-exponential transverse relaxation (MET_2) provides specific information about myelin content and microstructure in white matter[1,2]. For animal studies, ultra high field MRI (≥ 7T) offers potential for high resolution MWI; and for *ex-vivo* studies, doping tissues with contrast agent can increase signal-to-noise ratio efficiency[3]. However, both increasing B_0 and adding contrast agents will reduce tissue T_2s, which makes MET_2 signal analysis statistically more difficult. Here we present measures of relaxation rate changes in excised rat brain at two B_0s and with/without added Gd. From these measures, we compute optimal 3D whole brain protocols and predicted SNRs for MWI at 7T and 15.2T.

Methods:

At 7T and 15.2T, T_1 and T_2 were measured in the white matter of perfusion-fixed rat brains after soaking (>2 wks) in 0mM and 1mM concentrations of Gd (Magnevist). The increases in R_2 (=1/T_2) due to change in B_0 and addition of Gd were assumed equal for all tissue water (i.e., myelin and intra-/extra-axonal water). With these values, we calculated the Cramer-Rao Lower Bounds (CRLB) of variance of the estimated myelin water fraction (MWF) as a function of B_0, [Gd], and echo spacing, assuming a fixed available scan time and image SNR, similar to a previous optimization of echo spacing alone[2].

Results and Discussion:

As B_0 and [Gd] increase, image SNR per unit scan time increases, but the reduction of T_2s mitigates this effect on the SNR of a MWI. Fig 1 shows that at both 7T and 15.2T, adding Gd does not result in higher MWF SNR, although the drop-off between 0-1.0 mM [Gd] is modest, so if Gd-loading is desirable for other scans protocols, the small penalty on MWI might be an acceptable trade-off. Comparing 7T and 15.2T, there is ≈15% decrease in SNR due to the shortening of T_2s from 7T to 15.2T, but this is more than outweighed by the ≈2x expected increase in image SNR (Fig 2). One complicating factor in this analysis is that the estimate of myelin water T_2, necessary for the CRLB analysis, is difficult to measure accurately. However, with the assumption that R_2 increases equally in myelin and intra-/extra-axonal water (due to B_0 or Gd), error in the myelin water T_2 estimate affects CRLB calculations of the MWI SNR and the optimal TE, but has a small effect on optimal B_0 and [Gd].

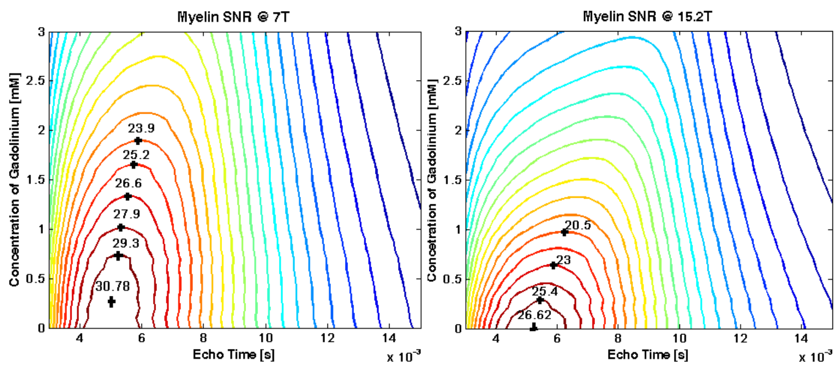

Figure 1. Myelin SNR at 7T and 15.2T based on CRLB of variance versus echo time and Gadolinium concentration, and optimal choices of TR and TE

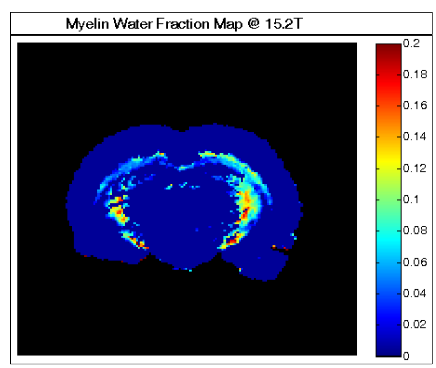

Figure 2. Myelin Water Fraction Map at 15.2T.

Conclusion:

Imaging excised and fixed rodent brains at 15.2T provides increased SNR in MWI compared to those acquired at lower static fields. At both 7T and 15.2T, the addition of Gd-DTPA, did not improve SNR efficiency, although the reduction in MWI SNR due to 1 mM of Gd was modest. Given an optimized acquisition strategy and using the EPG algorithm for B_1-insensitive fitting of T_2 spectra from multiple-spin echo data[5], whole rodent brain MWI at high and ultra high fields is a practical and potentially valuable imaging tool to evaluate microstructure changes in a variety of rodent models of neuropathology.

References:

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