In-vivo Imaging of an Inhomogeneous Component of Magnetization Transfer in Human White Matter

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Introduction: The phenomenon of magnetization transfer involves a small “bound” pool of spins with a much broader line shape than the “free” water, which dominates the MR signal intensity. If the “bound” pool is sufficiently restricted, it could demonstrate solid-like properties. In particular, solids can have inhomogeneously broadened lines where the width of the line represents a spread of frequency across the population of spins, which are not in rapid exchange with each other. Off-resonance RF irradiation of an inhomogeneously broadened line saturates only the spins in the population with a nearby frequency; the remainder of the line is unaffected. Here we report evidence of an inhomogeneous component of the “bound” pool in human white matter. This property is used to generate 3 dimensional images of this inhomogeneous MT component in vivo.

Methods: Magnetization transfer sensitive imaging was achieved by applying a Gaussian RF amplitude with 336 us FWHM every 1 ms for 700 ms prior to imaging. Images were acquired with three types of MT preparation: (A) irradiation applied at the water frequency plus delta, (B) the water frequency minus delta, and (C) with the 1 ms pulses applied alternately at plus delta and minus delta. For a homogeneous MT line, subtraction of C – 0.5*(A+B) should produces zero signal. For an inhomogeneous MT line, a difference will occur if partial saturation of half the line is achieved as shown schematically in figure 1.

Imaging was performed at 3 Tesla on a GE VH/I scanner on normal volunteers using the product head coil. A stack of spirals encoding was used to acquired the entire brain in 8 shots using a prepared fast spin echo sequence. The preparation included a saturation pulse at 1.5 s and adiabatic inversions at 872 and 160 ms prior to imaging. MT saturation was applied between the two inversion pulses. The saturation and inversion greatly attenuate the signal from the tissue but unsuppressed studies indicate little attenuation of the inhomogeneous MT phenomenon. This approach was motivated by experience with background suppression for Arterial Spin Labeling(1). Unsuppressed images were also acquired to evaluate the magnitude of the effect relative to the unsaturated signal. The effect of off-resonance frequency and RF amplitude on the MT phenomenon was also explored.

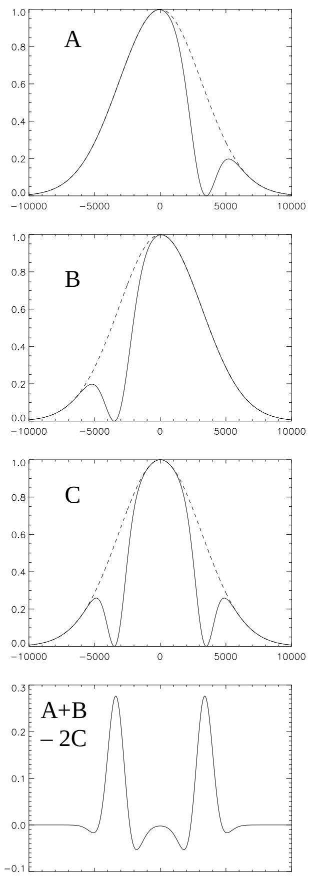

Figure 1. The irradiation strategies employed in this study. Off resonance irradiation with repeated positive frequency, A, or negative frequency, B, pulses was compared to rapid alternation of the frequency, C. For inhomogeneous lines, the difference of C – (A+B)/2 is not zero.

Results

The subtraction sequence produced images in which white matter is highlighted and gray matter is weak or invisible. Variation in the signal intensity in the white matter was observed with greatest intensity in the corticospinal tract. (figure 2) For peak RF amplitudes above 85mG and an off-resonance frequency of 4 kHz, the difference images reached a stable, RF independent value with white matter displaying a difference intensity (C – 0.5*(A+B)) of approximately 2% of the fully relaxed image signal intensity. The difference intensity decreases with increasing off-resonance frequency with a 2 fold drop reached at 8 kHz. Frequencies closer than 3 kHz could not be examined with this MT design because of direct saturation effects on the water line.

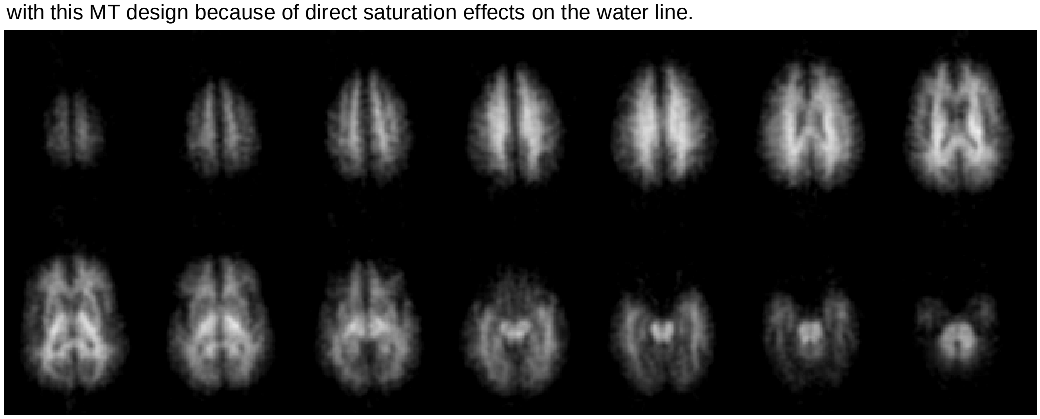

Figure 2. Selected slices from a volumetric map of inhomogeneous MT in the brain of a normal volunteer

Discussion

While preliminary, our results indicate the existence of an inhomogeneous component to the MT spectrum that can be selectively imaged with a subtraction strategy. The observed contrast is qualitatively consistent with the distribution of short T2, myelin associated water reported by others(2). Our approach makes possible whole brain mapping of this component in a short imaging time. Further investigations will be required to elucidate the exchange times and saturation properties of this component and to assess whether it will permit improved characterization of white matter and other tissues in clinical applications.

References:
1. Ye , FQ, et al. Magn Reson Med. 2000 44:92-100.
2. Mackay A et al. Magn Reson Med. 1994 31:673-677