Inhomogenous Magnetization Transfer Imaging: A Potentially Specific Marker for Myelin

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Introduction: Magnetization Transfer Imaging (MTI) has been extensively evaluated for its ability to characterize myelination changes in the brain. While MTI has proven useful in this role, the fractional differences in MTI between white matter and gray matter, which has much less myelin, and between normal white matter and partially demyelinated regions are small. An alternative approach to characterizing myelination is the extraction of a short T2 component of the signal in brain(Mackay et al. Magn Reson Med. 1994 31:673-677). This component appears to be more specific for white matter and shows spatial distribution in white matter consistent with the extent of myelination of different tracts. This T2 approach requires careful imaging at multiple echo times and a multi-exponential analysis, which have limited its use mostly to single slice studies at a few centers. We recently reported a novel property of magnetization transfer which is most apparent in white matter(Alsop et al., Proc ISMRM 2004 p. 2324). Approximately 10% of the magnetization transfer in white matter behaved as an inhomogeneously broadened line. A 3 way subtraction experiment was proposed that strongly highlighted white matter. Here we report quantitative analysis of the phenomenon using a 2D single shot fast spin echo sequence to explore the spatial distribution and parameter dependence of the MT effect in more detail.

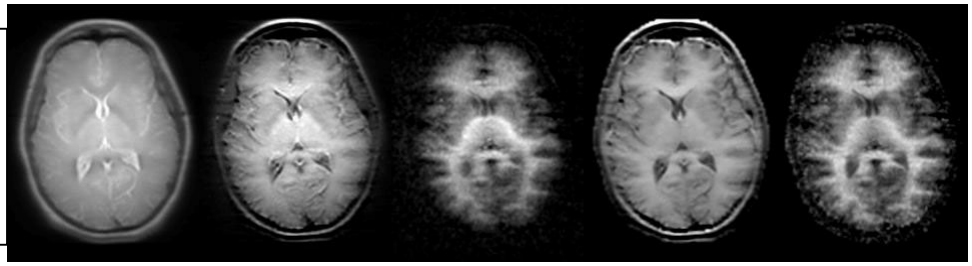
Methods: 4 normal adult volunteers were studied following a protocol approved by our Institutional Review Board. All imaging was performed at 3 Tesla on a GE VH/I scanner using the product head coil. The MT preparation described below was followed by a full k-space, centric ordered single-shot fast spin echo sequence with a 24x18 cm FOV, 128x96 matrix, 6 mm slice thickness and a TR of 5 s. The scan was performed in an axial slice approximately mid-ventricle.

MT preparation was achieved with 336us FWHM Gaussian shaped pulses applied at 1 ms intervals. For a given magnitude of frequency offset, three difference images were acquired. One used all pulses applied at positive frequency, one used all pulses at negative frequency, and another used alternating positive and negative frequency pulses. 32 images were acquired for each scan with 8 positive frequency, 8 negative frequency, and 16 alternating frequency preparations interleaved in time over the 2.5 minute scan. A nonselective saturation was applied 2 seconds before imaging to decrease artifacts from pulsating CSF and a crusher gradient was applied following the MT pulses and before imaging. Images were acquired with 1020ms of applied MT at a 5 kHz frequency offset with peak B1 amplitudes of 0, 30, 45, 60, 80, and 100 mG, and at peak B1 of 80 mG at frequency offsets of 12, 9, 7, 5, 4, and 3 kHz. Finally images were acquired with frequency offset of 5 kHz, peak B1 of 80 mG, and MT durations of 68, 204, 408, 612, and 1020 ms.

Regions of interest were drawn in the posterior limb of the internal capsule, the occipital white matter, the frontal white matter, and occipital gray matter. The inhomogenous MT component was calculated as the positive frequency image + the negative frequency image – twice the alternating frequency image. Signal intensities were normalized to the baseline signal intensity when B1 of 0 was applied.

Results: MTI properties were highly reproducible across subjects. The inhomogeneous component reached a maximum of 6% of the background signal intensity in the white matter of the internal capsule but a maximum of only 3% in occipital gray matter. MTR images calculated from the inhomogeneous component was highly selective for brain tissues and white matter.

Figure 1: Example images from a volunteer. Images are, from left to right,
1. Image with zero off-resonance power,
2. Difference between zero and 80mG/8kHz MT
3. Inhomogeneous component
4. Traditional MT ratio image
5. Inhomogeneous MT ratio image



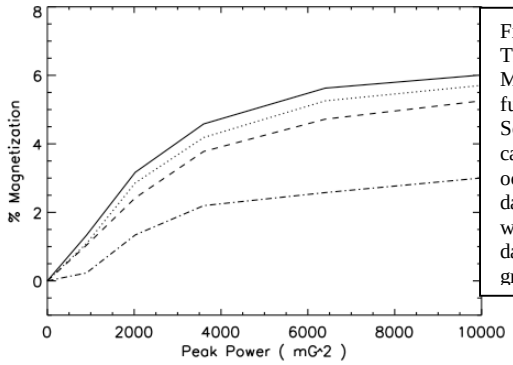
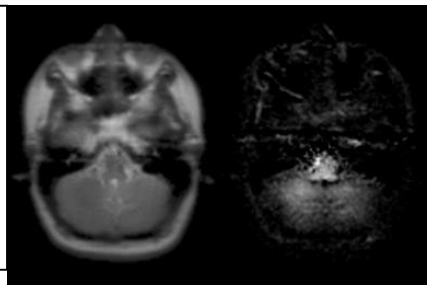


Figure 2: The inhomogeneous MT component as a function of RF power. Solid line:internal capsule, dotted line: occipital white matter, dashed line: frontal white matter, and dot dashed line:occipital gray matter

Figure 3: Baseline image left, and inhomogeneous MT, right, in the brainstem. This location highlights the specificity of this MT component for brain tissue and white matter.



Discussion: These results further support a selective sensitivity to white matter and myelin containing tissues with the three point subtraction approach. Images as in figure 1 can be acquired in under three minutes and are quite practical for clinical research studies. Further studies of the mechanisms of this phenomenon and implementation of robust approaches for greater slice coverage are planned.