Diffusion weighted EPI with Magnetization Transfer Contrast

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Synopsis
We have performed diffusion weighted (DW) echo planar imaging (EPI) with and without magnetization transfer preparation pulse to see the effect of macromolecular suppression on apparent diffusion coefficient (ADC) in the brain parenchyma of 10 healthy volunteers. There was a significant increase in the ADC values in different locations of the brain parenchyma after the application of Magnetization Transfer (MT) preparation pulse, suggesting that there is some relationship between the macromolecular concentration and water diffusivity across the cell membrane. This information may be of value in better understanding the pathological processes with variable macromolecular concentrations.

Introduction
DW-EPI has made its greatest impact on the imaging evaluation of ischemic stroke. It has been used occasionally in evaluation of intra-axial tumors and also to detect and distinguish between acute hemorrhagic and non-hemorrhagic stroke. DW imaging is exquisitely sensitive to axonal directionality in white matter, and can hence be used for the study of demyelination due to trauma or axonal disruptions. MT contrast has proved to be a useful diagnostic tool in characterization of a variety of central nervous system pathologies including infection, demyelination, and other neurodegenerative conditions. Studies performed by Stanisz et al (1) indicate that MR parameters like T1 and T2 relaxation times, MT effect and diffusion anisotropy are very good indicators of nerve damage. We hypothesized that the macromolecular concentration should influence the water molecular motion across the cell membrane. The aim of this study is to evaluate the combined effects of diffusion and magnetization transfer on normal brain parenchyma, and to study whether the combination of two could be exploited for better tissue characterization and improved image contrast than either of the techniques.

Materials and Methods
A total of 10 healthy age and sex-matched volunteers were scanned after taking their informed consent. All these volunteers were male between 27-35 years of age. Imaging experiments were performed on 1.5-T clinical MR scanner (Signa; GE Medical Systems, Milwaukee, WI), using a quadrature head coil available with the scanner. All experiments were carried out with a modified single shot SE-DW-EPI pulse sequence, with and without MT preparation pulse. The imaging parameters used were: TR/TE = 10.5s/110ms (minimum TE), FOV = 40 cm, number of excitation = 1, slice thickness = 5 mm, interslice gap = 0.1 with matrix size of 128 x 128. Diffusion gradients were applied along all orthogonal directions (namely X, Y and Z) with a b value of 1000 s/mm2. The MT RF pulses used were Fermi pulses of 16 ms duration with a flip angle of 670° and resonance offset of 1200 Hz. The MT pulses were applied in every TR. All parameters for MT-prepared DW imaging were identical to those with DW sequence except for the addition of the off resonance pulse. An apparent diffusion coefficient (ADC) map for both sets of data was generated using a commercial package on the GE Medical Systems post-processing workstation. Region of interest (ROI) analysis from different locations in the white matter was done in corresponding set of images with and without the off-resonance pulse. The region of interest analysis was done by placing voxel of 2x2 in frontal, occipital lobes and basal ganglia. Care was taken to avoid regions with CSF and increased susceptibility while placing ROI. Mean and standard deviation from the ADC values obtained from these different locations without and with MT preparation pulse were calculated and compared to look for any statistical significance using student’s t-test. Probability (p) values equal or less than 0.05 were considered as statistically significant.

Results
The results of these experiments are summarized in Table 1. We found mean ADC values without the application of MT preparation pulse of 0.78 ± 0.05 x 10^-3 mm²/s, 0.74 ± 0.04 x 10^-3 mm²/s, 0.77 ± 0.05 x 10^-3 mm²/s, from the frontal lobes, basal ganglia and occipital lobes, respectively. ADC values after adding the MT preparation pulse from the same location in the frontal lobes, basal ganglia and occipital lobes were found to be significantly higher (p<0.05) when compared with ADC values without MT preparation pulse.

<table>
<thead>
<tr>
<th>Location</th>
<th>ADC values (a) x 10^-3 mm²/s (Mean±SD)</th>
<th>ADC values (b) x 10^-3 mm²/s (Mean±SD)</th>
<th>p- Value (a Vs b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal lobe</td>
<td>0.78±0.05</td>
<td>0.80±0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Basal Ganglia</td>
<td>0.74±0.04</td>
<td>0.77±0.04</td>
<td>0.007</td>
</tr>
<tr>
<td>Occipital lobe</td>
<td>0.72±0.05</td>
<td>0.80±0.06</td>
<td>0.03</td>
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</tbody>
</table>

Table 1: Apparent diffusion coefficient values from different regions of the brain parenchyma with and without MT preparation pulse (a= Without MT preparation pulse; b= With MT preparation pulse)

Discussion
Diffusion weighted MRI and magnetization transfer MRI are individually established as diagnostic tools in various clinical conditions. MT ratio is known to suffer from the effect of intrinsic parameters namely T2 and T1 relaxation of the tissues under evaluation. The ADC map is independent of these parameters and is thus considered more reliable for the purpose of quantification. The motion of water molecule across the cell membrane is dependent on temperature and viscosity of the medium. The macromolecular concentration in a given medium contributes to the viscosity of that medium. In this experiment we have tried to see the effect of macromolecular suppression using MT preparation pulse on the diffusion coefficient of the normal brain parenchyma. The results suggest that there is a significant increase in diffusivity of water after the contribution of the macromolecules to the free water is suppressed.
We conclude that this information will be of value in the evaluation of various pathological processes with varying macromolecular concentration that may have implications in clinical practice.

References