Diffusion Tensor Imaging at 7 Tesla: Initial Application to Multiple Sclerosis

M. Metcalf[1], D. Pelletier[2], D. Xu[3], D. T. Okuda[2], R. Srinivasan[3], D. Kelley[4], S. J. Nelson[1,3], and D. B. Vigneron[1,3]

[1]UCSF/UCB Joint Graduate Group in Bioengineering, University of California, San Francisco, CA, United States, [2]Neurology, University of California, San Francisco, CA, United States, [3]Radiology, University of California, San Francisco, CA, United States, [4]GE Healthcare, San Francisco, CA, United States

Introduction: Diffusion tensor imaging (DTI) is an MR technique that is highly sensitive to tissue microstructure changes that occur preceding widespread morphological changes.[1] DTI has been applied extensively to multiple sclerosis (MS), and has been an important imaging tool for elucidating the pathophysiological processes that occur with disease activity in the CNS. In clinical settings with 1.5T and 3T scanners, in order to obtain sufficient SNR, typical DTI protocols use voxels that are 2-3mm on a side (8-27 mm^3). The relatively large voxel size results in images that have significant partial volume effects, making the distinction between lesion and healthy tissue, and boundaries between grey matter, white matter, and CSF difficult. The goal of this project was to take advantage of the greater signal associated with the increase in field strength to obtain higher resolution DTI data from MS patients. In this study, we developed specialized 7T DTI techniques and applied them in volunteers and MS patients for the first time.

Methods: Normal volunteers and patients with clinically definite MS were scanned on a 7T GE Signa MR scanner (GE Healthcare, Waukesha, WI) with 40 mT/m maximum gradient amplitude and a 30-cm volume excite coil with an 8-channel phased array receiver (Nova Medical, Wilmington, MA). Diffusion-weighted single-shot EPI images were acquired using a custom sequence with ASSET parallel imaging and incorporating a newly designed high bandwidth fat saturation pulse to collect images with 1mm in-plane resolution (25.6 cm FOV, 256x256 matrix, 2-mm slices with no gap, 25 directions, b=1000s/mm^2, ASSET R=2, acquisition time = 3 minutes). Higher order shimming was performed prior to the acquisition.[2] Patient exams also included a high-resolution GRE to acquire T2* weighted images with an in-plane resolution of 215x286 μm (TE = 15 ms, TR = 250 ms, 22 cm FOV, 1024x768 matrix, 20° flip, BW = 31.25, 2 mm thick, 4 mm skip, 2 NEX, acquisition time = 6:28). Image processing and calculation of diffusion tensor parameters was done using in-house software.

Results: The high-resolution DT-images had good SNR (14.9 for b=0 and 5.8 for b=1000) despite the small voxel size of 2 mm^3 and use of parallel imaging. The anterior/posterior distortions from EPI were acceptable with the use of parallel imaging and the high order shimming routine. The lesions are well visualized on the b=0 image, and also on the apparent diffusion coefficient (ADC) and relative anisotropy (RA) map. The hyperintensity of the lesions on the ADC map and the hypointensity on the RA correspond to previous findings that diffusion increases and the anisotropy decreases in MS lesions.

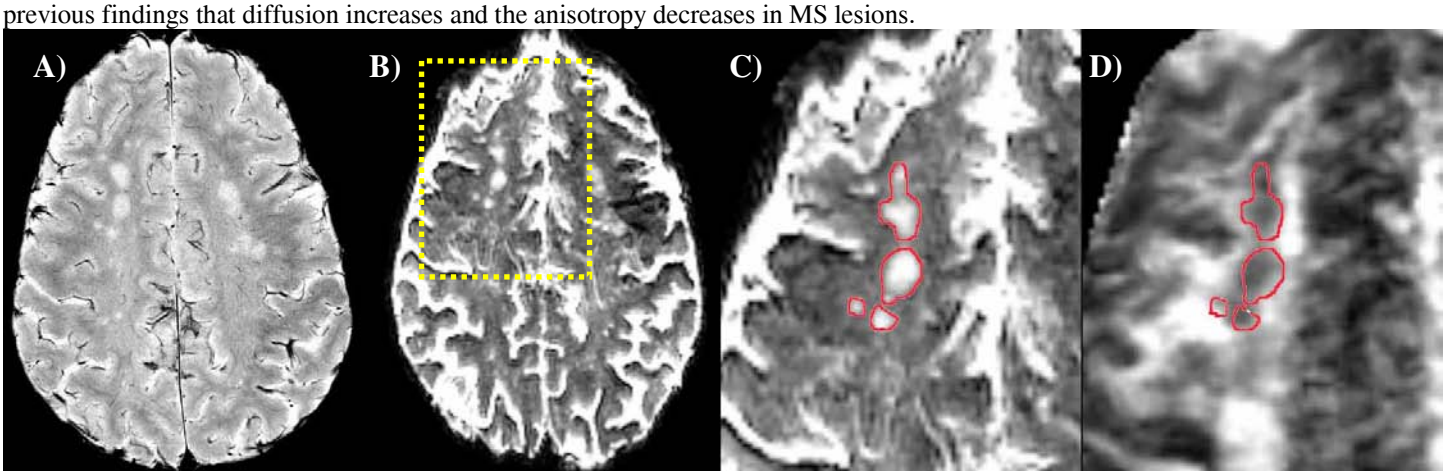

Figure: A) High resolution (215x286 μm in-plane, 2mm slice thickness) T2* weighted image with visible white matter lesions. **B)** T2-weighted b=0 image from the diffusion acquisition. **C)** Enlarged ADC map from region indicated in (B). **D)** Enlarged RA map from region indicated in (B).

Conclusion: This study demonstrates the feasibility of *in vivo* high resolution DTI in MS patients at 7T. The high sensitivity provided by 7T allowed the detection of diffusivity and anisotropy changes in MS lesions at a much higher spatial resolution (1x1x2mm) than has been previously reported. Although magnetic susceptibility increases with magnetic field, the use of parallel imaging and higher order shimming substantially reduced EPI distortion allowing the measurement of DTI parameters in MS lesions at 7T. However, regions of the brain around the sinuses and the more inferior parts of the brain are still difficult to image using EPI-based diffusion sequences at 7T.

References:

[1] LeBihan D. NMR in Biomedicine 1995; 8:375-86. [2] Hammond K, *et al*. Proc 14th Ann ISMRM 2006; P2352.

Acknowledgements:

This research was supported in part by NIH RO1 NS40117 and UC Discovery grants LSIT01-10107 and ITL-BIO04-10148, in conjunction with GE Healthcare .