7T Diffusion Tensor Imaging and Q-Ball Imaging of the Human Brain In Vivo

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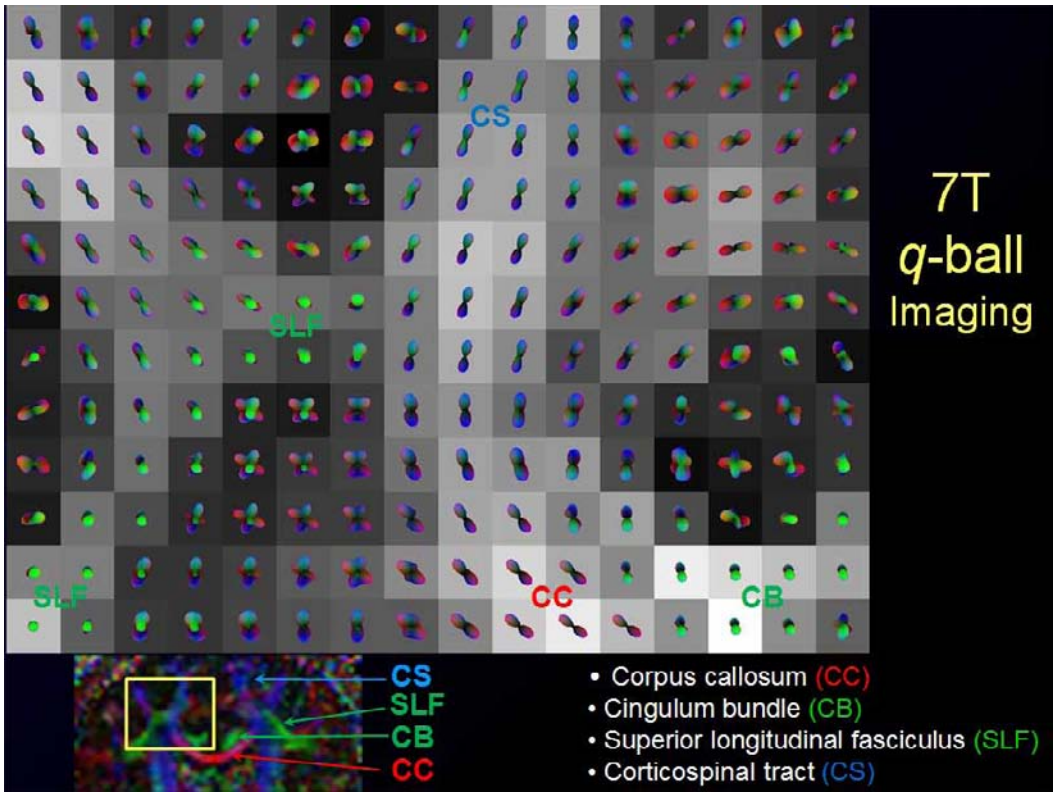
Introduction: Diffusion tensor imaging (DTI) has become a widely used technique for depicting the white matter connectivity of the human brain in scientific and clinical applications. The advent of newer high angular resolution diffusion imaging (HARDI) techniques, such as *q*-ball imaging (QBI), enables better visualization of complex white matter architecture including fiber crossings. However, these advanced diffusion imaging methods are SNR-limited and could benefit from the greater signal available at higher magnetic field strengths. In this project, we demonstrate the feasibility of *in vivo* 7 Tesla DTI and QBI of the human brain for improved visualization of white matter anatomy.

Methods: Three normal adult volunteers were imaged using a 7T GE MR scanner (GE Healthcare Technologies, Waukesha, WI) equipped with a 30-cm volume excite coil and 8-channel phased array receiver (Nova Medical, Wilmington, MA). Single-shot spin echo echoplanar (EPI) axial diffusion-weighted images incorporating a newly designed high bandwidth fat saturation pulse were acquired over the supratentorial brain with 2-mm voxels (25.6 cm FOV, 128x128 matrix, 2-mm slices with no gap) using 55 or 131 gradient directions, *b*-values of 3000 or 5000 s/mm^2, and ASSET parallel imaging with reduction factor of 2. Higher order shimming was performed prior to the acquisition [1]. Tensor analysis was performed in DTI_Studio [2] and the *q*-ball orientation distribution function (ODF) was reconstructed at each voxel using spherical harmonic basis functions [3].



Results: With higher order shimming and parallel imaging, EPI distortions were acceptable in the anterior and posterior regions of the supratentorial brain and negligible in the center. The reformatted coronal color FA image from DTI (Figure, *bottom*) shows minimal distortion with excellent depiction of the major fiber bundles. The *q*-ball ODF voxel array (Figure, *top*) from the yellow boxed inset of the color FA image demonstrates multiple fiber crossings of association (*SLF*), projection (*CS*), and commissural (*CC*) white matter pathways. The background grayscale intensity in each voxel portrays the generalized fractional anisotropy (GFA).

Discussion: When acquiring diffusion EPI images at high field, magnetic susceptibility and spectral separation increases; hence, better shimming and lipid saturation are needed. With an optimized pulse sequence and parallel imaging capability, we have successfully demonstrated DTI and QBI *in vivo* at 7T. The additional SNR available at 7T can be utilized for finer spatial resolution and/or to achieve higher angular resolution with stronger diffusion-weighting factors (larger *b*). Current limitations at 7T include strong susceptibility artifacts at the skull base that preclude infratentorial brain imaging.

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References:

1. Hammond K et al, Proc 14th Ann ISMRM 2006; P2352
2. Jiang H et al., Comput Methods Programs Biomed 2006; 81:106-16
3. Hess CP et al., Magn Reson Med 2006; 56:504-17