Human Spinal Cord Diffusion Tensor Imaging at 3T

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Introduction

The spinal cord is subject to severe susceptibility artifacts from bone and lung, as well as respiratory motion and movement of the cord itself. These have severely limited efforts to study the microstructure of the cord using MR diffusion tensor imaging (DTI). Intracranial DTI is typically performed using spin-echo echo-planar (SE-EPI), but this technique is prone to distortion due to susceptibility artifacts. Turbo-spin echo (TSE) and line-scan (LS) are possible alternative sequences. Recently, dedicated receiver coils, and higher performance gradients have allowed image degradation to be greatly through echo-time shortening, and optimal signal detection. We make use of these hardware improvements in the present study comparing SE-EPI and TSE based DTI of the spine at 3T.

Methods

This preliminary investigation involved initial evaluation in 4 volunteers. Experiments were performed on a 3T whole body MR scanner (Intera, Philips Medical Systems, Best, NL) equipped with 80 mT/m, 100 mT/m/ms gradients, and using up to 6 elements of a dedicated 12-element, phased-array spine coil suitable for imaging the entire spinal cord.

DTI with the acquisition of six diffusion weighted directions and a single reference image were obtained using SE-EPI and TSE pulse sequences. Assessment was made with b-values of 400 s/mm^2 and 750s/mm^2 for each acquisition technique in the sagittal (1 slice) and axial planes (8 slices). Imaging parameters were: TR / TE / Shots / NEX: 2 heartbeats / 69 – 89ms / 9 / 2, FOV / SLT / AcQ Matrix / Recon Matrix: 90mm / 5mm / 90^2 / 128^2. Fractional anisotropy and apparent diffusion coefficient maps were calculated at the scanner using the manufacturer's software. The images were transfered off-line where eddy-current-induced image warping was removed from the DTI data with a 3D-registration algorithm [1], and the diffusion tensor was derived by singular value decomposition. For the fiber-tracking, multiseed-forward-integration was applied. All the tracking and visualization was performed using a custom-made software component integrated into a commercial 3D-visualisation-environment (Imaris, Bitplane AG, Zurich CH) [2].

Results

The sagittal TSE-DTI images showed excellent anatomic detail with fewer distortions than the SE-EPI scans. Ghosting artifacts however, were more severe, resulting in an inhomogeneous appearance of the spinal cord on the T2 -weighted (b-value = 0 s/mm^2) reference image. This artifact corrupted subsequent calculations of ADC and FA, but did not affect the averaged diffusion-weighted scan.

In the axial orientation, the SE-EPI sequence produced images of significantly higher signal to noise ratio than the TSE-DTI scans. The b-value = 750s/mm^2 images were subject to very low SNR and more severe distortion resulting in noisy estimates of fractional anisotropy and eigenvector determination as compared to the b = 400s/mm^2 images.

Fiber tracking started in seed areas placed in the lateral funiculi at the expected anatomical location of the lateral corticospinal tracts, generated 3D depictions of rostrocaudaly oriented fiber trajectories without crossing corresponding well to the known anatomical arrangement of this white matter fiber system.

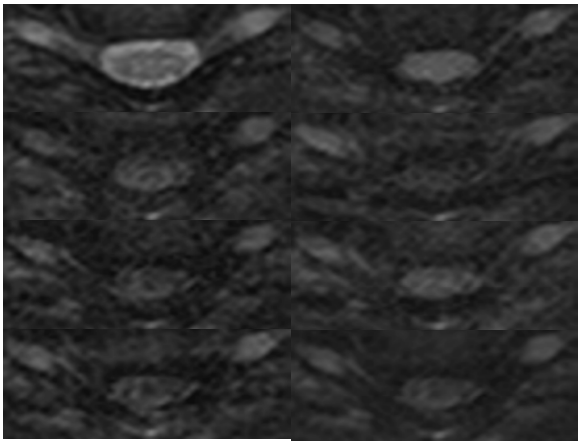

Figure 1 (left). Axial SE-EPI DTI obtained at the C4 vertebral level. Top left – T2 weighted reference image. Lower right – mean diffusion weighted image. The remaining images orientation dependent attenuation of the spinal cord signal due to the 6 diffusion weighting gradients.

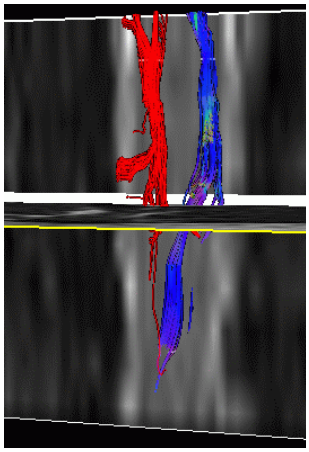

Figure 2 (right). 3D rendering of fiber-tracking results based on seed regions placed bilaterally (red = right, blue = left) on the expected location of the lateral corticospinal tract in the lateral funiculus.

Discussion

Our results suggest sagittal TSE-DTI should be well suited to generating diffusion weighted images in the clinical setting. Further optimization is required to reduce the effects of cord and CSF motion motion before tensor-related parameters can be reliably extracted from MR DTI data. SE-EPI studies appear in this preliminary work, superior to TSE-DTI for axial imaging of the spinal cord. Higher b-values may be required to better resolve the diffusion tensor components. Greater image resolution is also desirable to improve the realism of the reconstructed fiber tracts. These improvements can be achieved at the expense of increased scanning time, decreasing the appeal of the technique for routine clinical applications. Nonetheless, multi-slice SE-EPI with appropriate adaptation to avoid the effects of CSF and cord motion is a promising approach to achieve fibre-tracking in the spinal cord.

References. 1. Netsch et al. Proc ICCF 2001;6:718-25, 2. www.bitplane.com