In vivo Ultra-High Resolution Diffusion Tensor Imaging of the Medial Temporal Lobe in Patients with Epilepsy

Mansi B Parekh[1], Robert Fisher[2], Kevin Graber[2], Ryan Purcell[3], Rishi Raman[3], Leandro Bouzon[3], Scott Atlas[1], Samantha Holdsworth[1], Stefan Skare[1], Rolland Bammer[1], and Michael Zeineh[1]

[1]*Radiology, Stanford University, Stanford, California, United States,* [2]*Neurology & Neurological Sciences, Stanford University, Stanford, California, United States,* [3]*Stanford University, Stanford, California, United States*

Introduction: Temporal lobe epilepsy (TLE) is one of the most common types of intractable epilepsies. Damage to the hippocampus and parahippocampal gyrus is commonly observed in both patients and animal models of TLE. However, TLE is often undetected by traditional MR imaging. We postulate that high-resolution diffusion tensor imaging (DTI) may be more sensitive to identifying sub-structural abnormalities and can offer further diagnostic information [1]. Here we apply newly developed ultra-high resolution DTI of the temporal lobe to discern the microscopic pathology in cases of known TLE.

Methods: Four subjects with imaging evidence of unilateral mesial temporal sclerosis (MTS) were imaged on a GE 750HDx 3.0T magnet using an 8-channel receive head coil and body transmit using a 2nd order high-order shim. Axial DTI utilized: GRAPPA R 2, two shots, b=1500 s/mm^2, TR 3150 ms, TE 69 ms, partial Fourier acquisition, single-refocused, 70 directions, 10 T2s, phase encoding A/P, fat saturation, 128 x 128, 18cm FOV, 1.4mm thick contiguous, 27 slices, 1.4mm isotropic, 8.5 min per repetition, 6 repetitions (one patient could tolerate only 4 repetitions). Eddy currents and motion were corrected according to our prior work [2]. Diffusion tensor processing and tractography were performed using Camino with a non-linear least squares model. A detailed hippocampal subregional segmentation was performed according to anatomic atlases [2]. Fractional anisotropy (FA) and mean diffusivity (MD) were computed for each region of interest (ROI). These ROIs served as seeds and targets for bidirectional tractography to characterize seven key MTL pathways.

ROI	Pt 1	Pt 2	Pt 3	Pt 4
Entorhinal	0.937*	1.018*	0.975	1.013
Perirhinal	0.935	1.038	0.974	0.971
Parahippocampal Cortex	0.998	1.014*	1.005	1.009
CA 1	0.686*	1.312*	0.828*	0.843*
CA 3 and Dentate	0.676*	1.364*	0.783*	0.854*
Subiculum	0.852*	1.019	0.966	0.936
Alveus & Fornix	0.884	1.151*	0.901	0.855

Table 1: ROI-based left/right MD ratio of TLE patients. Asterisks mark p<0.05 when compared to normal controls. All had radiographic right MTS except patient 2, who had left MTS.

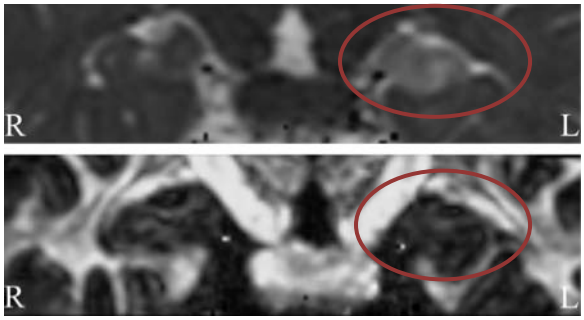

Figure 1: MD (top) and FA (bottom) images from a patient with left MTS shows increased MD in the hippocampus on the ipsilateral side.

Track	Pt1	Pt2	Pt3	Pt4
Parahippocampal Cingulum	0.948	1.059	0.863*	0.987
Perforant	0.968	1.235*	1.014	1.020
Alveus & Fornix	0.794*	1.087*	0.776*	0.844*
Schaffer Collaterals	0.719*	1.164*	0.797*	0.864
CA 1 to Subiculum	0.991	1.102*	0.913	0.881
Entorhinal to Subiculum	0.890	1.061	1.002	0.990
Entorhinal to Perirhinal	0.873*	0.984	0.863*	0.977

Table 2: Tract-based left/right MD ratio of TLE patients. Asterisks mark p<0.05 when compared to normal controls.

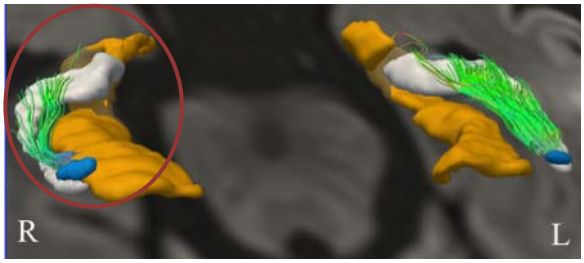

Figure 2: Tractography showing reduced fibers in the fimbria of the fornix in a patient with right MTS.

Results: ROI-based MD was lower on the side of hippocampal sclerosis in the CA1 and CA3-dentate gyrus regions in all patients. Tract-based MD showed a reduction in MD in the fornix on the ipsilateral side in all patients and in the Schaffer collaterals in 3/4 patients. Track-based FA lateralized in the cingulum in 3/4 patients. Tract counts in the ipsilateral CA 1 to subiculum were lateralizing in 2/4 patients.

Conclusions: ROI and track-based MD demonstrate sensitivity to subregional cell-loss in mesial temporal sclerosis, demonstrating promise for such measures in cryptogenic MTS. This technique may eventually allow for better lateralization of the epileptogenic focus in cases where conventional MRI does not provide enough contrast.

References: 1. Duncan, J.S., Imaging in the surgical treatment of epilepsy. Nat Rev Neurol, 2010. 6(10): p. 537-50.
2. Zeineh, M.M., et al., Ultra-high resolution diffusion tensor imaging of the microscopic pathways of the medial temporal lobe. Neuroimage, 2012. 62(3): p. 2065-82.

Acknowledgements: GE Healthcare