Introduction

Until recently, functional imaging techniques have been developed predominantly to improve visualization of epileptogenic foci in grey matter for focal-onset epilepsy. However, few techniques assess the degree of ictal-associated connectivity between different zones in the epileptogenic cortex through white matter (WM) axonal paths, thus neglecting a crucial step towards understanding epileptic networks. Subtracted Post-ictal Diffusion Tensor Imaging (SpiDTI) is a novel imaging technique developed at our laboratory with the objective of identifying transient water diffusion changes during the early post-ictal state in such pathways.

SpiDTI is used to locate transient changes in white matter produced by stereotypic complex partial seizures without generalization. Fractional Anisotropy (FA) is computed in inter-ictal and post-ictal diffusion tensor imaging (DTI) sequences. The results are subtracted. A threshold of 1.5-3 std dev from the mean is then used to identify regions with significant changes in FA.

Methods

A post-ictal (up to 4hrs following seizure termination) and an inter-ictal (no electrocerebral seizures for at least 24hrs) high resolution DTI datasets were acquired. Imaging parameters consisted of 2mm-HACK oblique slices in 60 non-collinear directions with a diffusion factor of 900 s/mm² in a 3 Tesla MR scanner. Eddy current and motion corrections were applied to these volumetric datasets using TORTOISE v2.0.1. The resulting volumes were registered to a SPGR MRI dataset. Fractional anisotropy (FA) measures were obtained after performing a tensor reconstruction using FSL FMRIB’s Diffusion Toolbox (Oxford, UK, 2015). Comparisons among the inter-ictal and post-ictal FA were achieved through the development of a custom program in MATLAB v2014. Specifically a "voxel per voxel" subtraction was accomplished between the interictal and post-ictal FA values following a Gaussian filter. Finally, statistical cleaning of the subtracted FA values was performed to differentiate substantial changes in FA by applying a threshold of 1.5-3 standard deviations.

Results

The protocol was applied to 4 patients at Rush University Medical Center. SpiDTI demonstrated a decrease in FA following stereotypic complex partial seizures without generalization secondary for each patient. SpiDTI regions of interest demonstrated a statistically different anisotropic to isotropic water diffusion difference (p<0.05). The SpiDTI datasets complemented grey matter dominant blood flow patterns captured by subtracted ictal SPECT co-registered to MRI (SISCOM).

Conclusions

SpiDTI is a novel imaging technique that can facilitate identifying ictal-associated WM propagation pathways for patients who have not generalized secondarily. Furthermore, this method can be used to facilitate predicting optimal depth placement implant sites for direct neurostimulation therapy where depth electrode lead placement is critical for interfacing with extensive WM connected epileptogenic regions.