

Diffusion Tensor Fiber Tracking of Human Brain Connectivity to Localize Intractable Seizures in Epileptic Patients

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Introduction

Epilepsy is a disorder in which the nerve cells of the brain produce abnormal electrical impulses causing transient paroxysmal disturbances in the nervous system function known as seizures (1). Temporal lobe epilepsy (TLE) is the most common type of partial epilepsy in adults and is commonly characterized by hippocampal sclerosis. Hippocampal sclerosis is manifested in a pattern of neuronal loss and gliosis with secondary atrophy within the hippocampus. When the amygdala and parahippocampal gyrus are also involved, the disorder is termed mesial temporal sclerosis (MTS) (2).

Diffusion tensor magnetic resonance imaging (DTI) is a noninvasive technique that can be used to assess the integrity of the microstructures of cerebral tissue. Diffusion tensor imaging-derived tractography (fiber tracking) can be used to obtain structural information on the connectivity of the various brain structures by the white matter fiber (3). The aim of this study was to define abnormalities in the hippocampus and afferent and efferent tracts connecting to the hippocampus which would lead to the understanding of the pathophysiology of temporal lobe epilepsy. While previous studies of TLE using DTI have focused on fiber tract abnormalities on fornix and cingulum (2), we have studied the fiber tracts traversing the whole hippocampus. This technique could potentially be used for pre-surgical planning, both to help better define the most suitable surgical candidates, and to better delineate the area for surgical resection.

Materials and Methods

Subjects: Six patients with established TLE with hippocampal sclerosis, two left and four right hippocampus, and six age matched healthy controls in the age group of 25-50 years participated in this study. TLE diagnosis was based on the volumetric analysis, electroencephalography (EEG) and video EEG findings.

Scanning Procedure: All experimental data were acquired using a Siemens MAGNETOM Symphony 1.5T MRI scanner (General Siemens Medical Systems, Erlangen, Germany). Anatomical data were obtained as a set of 105 slices with voxel dimensions of 0.51 mmX0.51 mmX1.5 mm. The DTI sequence was acquired in 60 noncollinear directions with the following parameters: TR=11900 ms, TE=111 ms, flip angle=90, image matrix=128×128, FA threshold =0.4, B0=1000 mm²/s, slice thickness = 2.2 mm, and slice gap = 2.2 mm.

Image Processing and Data Analysis: First, 3D anatomical volume of each subject was registered to the subject's B0 volume using a 12 parameter affine registration model. Next, a trained resident manually traced hippocampi on the registered 3D volumes. Coordinates of the traced hippocampi were then determined using Region of Interest (ROI) tool of ANALYZE software (Analyze Direct, Inc., Overland Park, Kansas). These coordinates were then fed to a specialized diffusion tensor software called DTI Task Card (Massachusetts General Hospital and Harvard Medical School Boston, MA) for fiber tracking. Fractional anisotropy (FA), volume, and number of fiber tracts passing through each hippocampus were determined and the results were visualized using the DTI Task Card. Figure 1 shows image processing steps on DTI Task Card and our findings.

Comparison of FA values of hippocampi was performed between the epilepsy patients and control group. The significance of the differences was assessed using a Student's t-test. FA value, volume, and number of fiber tracts for both hippocampi, with established MTS and normal, were determined and compared.

Results

Student's t-test showed significant difference in hippocampal FA values between epilepsy patients and control subjects ($p < 0.05$). As shown in the table in Figure 1, FA, volume, and number of fiber tracts passing through the hippocampus with sclerosis were less than that of normal hippocampus in epilepsy patients. Five out of six epilepsy patients had lower FA in the hippocampus with sclerosis than normal hippocampus. Similarly, five out of six epilepsy patients had smaller hippocampal volume of the hippocampus with MTS. For all epilepsy patients, the number of fiber tracts traversing the hippocampal ROI was significantly lower for the side with established MTS compared with the normal side. Figure 2 shows fiber tracts passing through hippocampi of a control subject and an epilepsy patient.

Conclusion

DTI showed a correlation between decreased FA value in the hippocampus and the presence of hippocampal sclerosis. DTI-derived tractography also showed similar correlation with decreased number of fiber tracts traversing through the hippocampus with sclerosis.

This study showed that DTI could be potentially useful tool for understanding of the pathophysiology of temporal lobe epilepsy. Furthermore, DTI tractography of the entire hippocampus could potentially be used to delineate efferent and afferent pathways connecting to the hippocampus to better understand the disease process and for pre-surgical planning.

References

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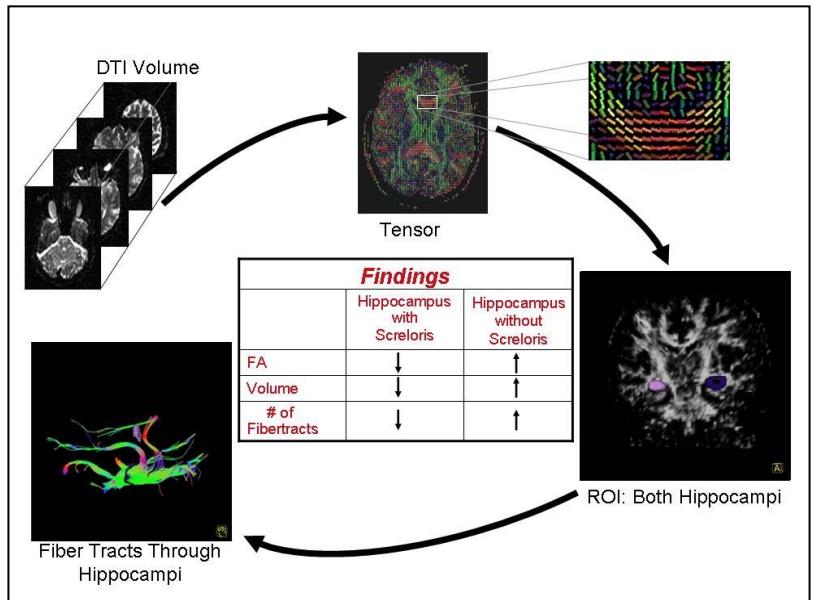


Figure 1. Image processing steps and findings.

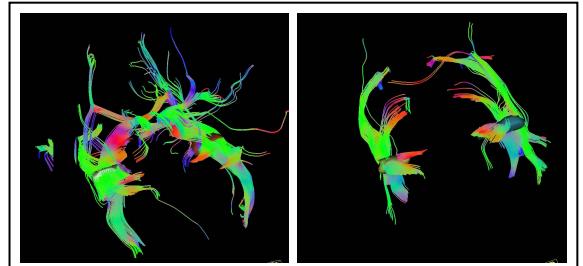


Figure 2. Fiber tracks traversing through the hippocampi of a) a control and b) an epilepsy patient.