High-sensitivity and High-specificity of Traumatic Brain Injury diagnostic method using Magnetic Resonance Imaging – Diffusion Tensor Imaging

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1. Introduction

Traumatic brain injury (TBI) is a leading cause of injury, death, and disability in the United States, affecting individuals of all ages, races/ethnicities, and incomes [1]. The purpose of this study is to improve sensitivity and specificity in diagnosing the TBI patients by finding out the white matter (WM) abnormality based on the MRI DTI images. Fractional anisotropy (FA) is the measure of the WM tract directionality. When the directionality and/or connectivity of the WM tracts are altered, the patients are likely to have a neurological abnormality. By providing the patterns of white matter abnormality for TBI patients, characterization of TBI can be achieved with high-sensitivity and high-specificity.

2. Methods

(1) Image acquisition : Magnetic Resonance Imaging (MRI) for 18 TBI patients were performed to acquired 1 non-diffusion image volume followed by 20 volumes of images with Diffusion Tensor Imaging (DTI) for 20 directions. The MRI scans were performed for 28 healthy controls from four different scanners from Functional Bio-Informatics Research Network (FBIRN) sites, such as UCI, UCLA, DUKE, and UNM.

(2) Image Data Processing : *(a) Image Registration:* By using a series of FSL utilities, the image volumes are registered to a standard space. First, the images in all the volumes are aligned to the first volume of the non-diffusion image for the motion and the eddy-current correction. The fractional anisotropy (FA) and mean diffusivity are calculated based on the eigen-values and eigen-vectors. The FA map is registered to the FMRIB58_FA followed by registration to the MNI152_T1 image with the voxel size of 1mm^3 [2]. *(b) Tractography and Dissection:* By using Diffusion ToolKit/TrackVis, the tractography for each subject is generated, and the individual dissections of WM tracts are drawn by specifying the ROIs (eg. corpus callosum and cingulate) [3].

(3) Image Data Analysis : *(a) T-test:* The registered mean FA maps are evaluated with t-test for group comparison between the patient group and control group. The same test was performed for individual comparison between each of 46 subjects versus the control group.*(b) ROI analysis:* The region of interest (ROI) analysis was also carried out for the areas in negative z-values from t-test. The most affected areas from negative z-maps of individuals are chosen for the ROI analysis.
(c) Sensitivity and specificity: Sensitivity and specificity were measured from the test to determine if each of z-maps belong to a patient or a control. The tests were done by a group of researchers who are familiar with the patterns of the WM tracts abnormality for the patients.

3. Results

(1) Abnormality of WM tracts

The t-test results from group comparison show that the mostly affected WM tracts are corpus callosum, cingulum, internal capsule, and superior longitudinal fasciculus (Fig.1). The tracts are recognized by the ICBM-DTI-81 White-Matter Labels. Although there are some differences between patients in the severities and regions affected, it was also found that there were similarities in the abnormal WM tracts among patients in the form of decrease in mean FA values.

(2) ROI analysis

In Fig. 2, the negative z-map for a patient resulted from t-test super-imposed onto the patient's FA map. The ROIs are marked by yellow circles, which correspond to the areas in corpus callosum. Figure. 3 shows that the mean FA values for the areas ROI#1 and ROI#2 shown in Fig. 2 are low compared to the controls, with significances of 7.7 (STD 0.089) and 9.3 (STD 0.068), respectively.

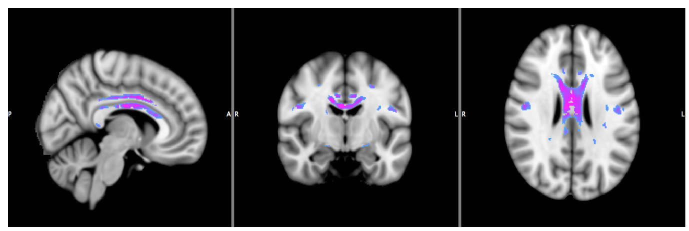

Fig. 1. From left-to-right, Sagittal, Coronal, and Transaxial view of the negative z-map superimposed on to the MNI152 standard space with the voxel size of 1mm^3. The negative z-maps shown in blue (low in z-value) and in purple (high in z-value) are the t-test results of the 18-patient group versus the 28-control group.

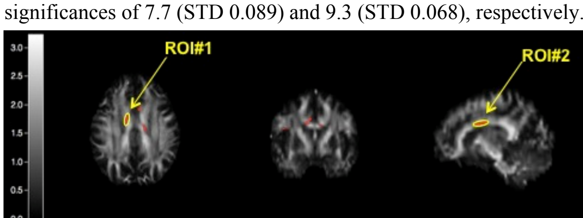

Fig. 2. ROIs that are used for the ROI analysis. The areas in red are indicating the regions lower in mean FA value for the patient, with respect to the control group. The areas in the yellow circles were selected for ROI analysis.

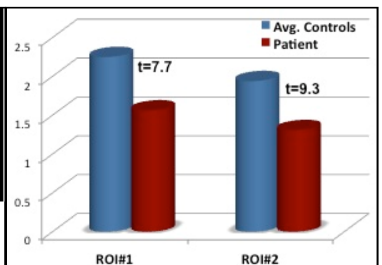

Fig. 3 ROI analysis results

(3) Sensitivity and Specificity

The 95.7% sensitivity and the 98.2% specificity were found from the test consisting of 184 cases.

(4) Tractography

Figure. 4 shows that the dissections of corpus callosum of the control on the left and the patient on the right. The colors of each tract indicate the direction of each tract based on the FA. The patient's tracts show that the connections are lost at the body of corpus callosum and the directions are altered at the splenium of corpus callosum.

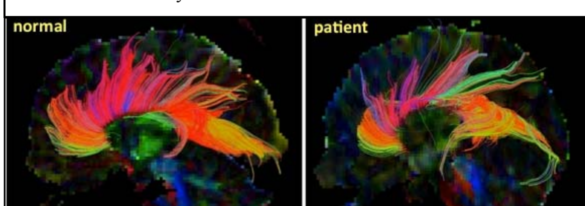

Fig. 4. The dissections of corpus callosum WM tract for a control (left) versus a patient (right). The colors of each tract in these figures indicate the directions of the tracts. The figures show that the significant differences between in existence and directionality of the tracts.

4. Conclusions

Using MRI DTI data, the WM abnormalities among TBI patients were observed within the corpus callosum, cingulum, internal capsule, and superior longitudinal fasciculus. The t-test results show that the alteration of directionality and loss of connectivity in TBI patients. In addition, the ROI analysis results shows that the degree of alteration and loss of WM tracts. Moreover, the dissections of the tracts agree with the results from the previous two tests. These results provide the high-sensitivity and high-specificity diagnostic method for TBI.

5. Acknowledgement

This research was supported by U24-RR021992 to the Function Biomedical Informatics Research Network (BIRN, http://www.birncommunity.org), that is funded by the National Center for Research Resources (NCRR) at the National Institutes of Health (NIH).

6. References

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