Comparison of Diffusion Tensor Imaging between Temporal Lobe Epilepsy and Normal Controls using Statistical Parametric Mapping

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Purpose

Diffusion tensor imaging (DTI) can provide information regarding early pathological changes, such as neuronal cellular changes in gray matter (resulting in increased Apparent Diffusion Coefficient -ADC) or demyelination in white matter tracts (resulting in decreased fractional anisotropy -FA). These abnormalities may be associated with compromised neural connectivity. Voxel-based statistical analysis can be performed to compare changes in a group of patients or each individual patients to a control group, however, spatial normalization is required to minimize the anatomical variability between studied subjects. In this study we investigated whether the seizure focus in patients with temporal lobe epilepsy (TLE) can be identified compared to controls. The templates for ADC and FA were generated from the control subjects. Each individual TLE patient was compared to the normal group data to investigate whether the seizure focus can be identified. Also the group comparison was performed using statistical parametric mapping (SPM) analysis.

Methods

Ten normal control (36±7 yo) with no history of neurological disease, and 10 TLE patients (30±10 yo) diagnosed with temporal lobe epilepsy were included in this study. All TLE patients had documented EEG evidence demonstrating the seizure location in the left temporal lobe. The seizure onset age was 22±12 yo, seizure history was 8 ± 7 years, and seizure duration 1.8±1.5 minutes. All subjects received a standard MRI scan with DTI. The study was performed on a GE 1.5 T scanner, and DTI was acquired using single-shot CSF-suppressed diffusion-weighted echo planar imaging. Scan parameters were as follows: rectangular FOV (field of view) 220 × 165 mm; 128 × 128 scan matrix (256 × 256 image matrix); slice thickness 4 mm; interslice distance 1 mm; receiver bandwidth ± 4kHz; TE (64 ms); scan time 60 s/slice section. ADC and FA maps were calculated from the diffusion-weighted images using the method proposed by Basser and Pierpaoli [MRM 1998; 39:928-934]. The ADC and FA maps from the 10 normal controls were used to generate templates for SPM analysis. The ADC and FA maps acquired from each patient was compared to the normal group data, and also the whole patient group was compared to the control group on a voxel-by-voxel basis using SPM ANCOVA analysis, with age, seizure onset, history, and duration as covariance. For each subject, the nonlinear transformation and warping was generated using mutual information (MI) registration between the subject's reference DTI (i.e. T2-weighted image) and the target image using SPM2. The statistical analysis was performed using two sample t *test* at a threshold of P <0.01 uncorrected for multiple comparisons.

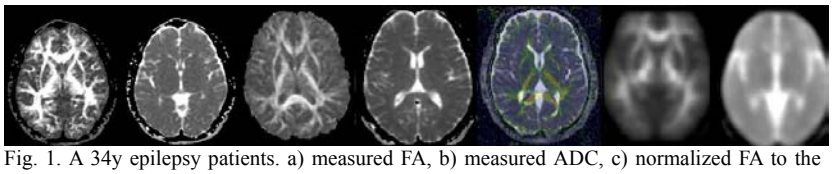

Fig. 1. A 34y epilepsy patients. a) measured FA, b) measured ADC, c) normalized FA to the template, d) normalized ADC to the template, e) color-coded FA overlaid on ADC f) generated FA template g) generated ADC template.

Results

Figure 2 shows the comparison of ADC maps from 6 individual patients to the normal control group using the SPM analysis. In patients #1 to #3, a well localized region in the temporal lobe gray matter was found to show significantly increased ADC, which might be associated with the seizure focus. In patient #4, no elevated ADC regions were found, but 2 areas with decreased ADC were found in the frontal lobe. Patient #5 demonstrated bilateral regions in the temporal lobe with increased ADC. In contrast, a normal subject did not show any regions with significantly increased or decreased ADC. The analysis was also performed between the group of all 10 patients to the controls, and the results also revealed a significantly increased ADC in the temporal lobe. Given that patient #1 showed a strong and relatively large area with increased ADC, it may have a dominant effect in the group comparison. When the other clinical parameters such as age, seizure onset age, history, and duration were used as covariance, the results varied to some extent, but all showed a significantly increased ADC in the temporal lobe region. Similarly, the FA maps measured from the patient group were compared to the normal control group data. Surprisingly an area with significantly increased FA was found from the same location as in ADC study. Since this region was mainly consisting of gray matter, the significance was very possibly mediated from ADC, not a true FA effect.

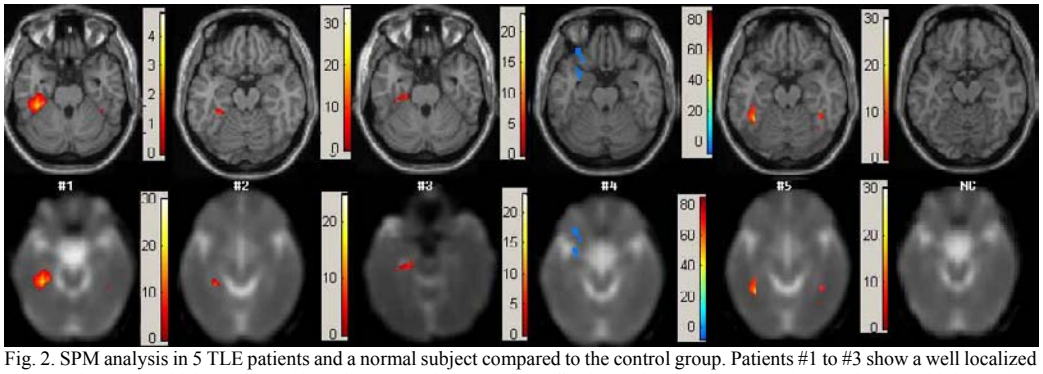

Fig. 2. SPM analysis in 5 TLE patients and a normal subject compared to the control group. Patients #1 to #3 show a well localized focus in the temporal lobe with significantly increased ADC. Patient #4 shows decreased ADC regions in the frontal lobe. Patient #5 shows bilateral foci in the temporal lobe with increased ADC. Lastly a normal control subject does not show any increased or decreased regions. The increased ADC may be associated with tissue damage caused by long-term seizure.

Discussion

In this study we investigated whether the patients with temporal lobe epilepsy showed abnormality in DTI compared to normal controls. As the long-term seizure may damage the tissues, the involved areas may show changes in DTI. The ADC and FA maps measured from all 10 normal controls were used to generate templates for SPM analysis. Then the ADC maps measured from each patient were compared to the normal group data. Every patient showed a different pattern, some with a well-localized focus with increased ADC which might be associated with seizure focus. On the other hand, 2 patients did not show a significantly increased ADC, rather a decreased ADC elsewhere. In other patients increased ADC was found in multiple regions, suggesting that they may have generalized rather than focused seizure. Due to the disease diversity in patients, the group comparison may be dominated by some individuals. The FA maps were also analyzed, however no significant changes were found localized in the white matter, rather in the same gray matter area, suggesting that the effect was mediated from ADC changes. Since seizure occurs in neurons, analysis of FA in this patient group is not likely to reveal useful information as in other patient groups with disease involving white matter, such as multiple sclerosis. In summary, the SPM analysis of ADC maps acquired from each individual patient compared to a normal group might provide a means of accurately identifying focal abnormalities prior to more invasive diagnostic procedures and possible epilepsy surgery. The occult epileptogenic regions may be identified using voxel-based statistical analysis of ADC.