Diffusion Tensor Imaging with FLAIR: The Effect of Eliminating CSF Contamination

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SYNOPSIS

FLAIR was used in diffusion tensor imaging (DTI), and the resultant fractional anisotropy (FA) was compared with that obtained with conventional DTI in the human brain. DTI data were obtained from six normal volunteers, demonstrating that the application of FLAIR, which suppresses CSF signal, results in an increase in FA, particularly in the gray matter. This improved diffusion tensor measurement can be potentially used for differentiating directional dependent structure in gray matter and tracking fibers in the gray matter.

Introduction

DTI is a useful tool for measuring the directional dependence of the water diffusion and visualizing the white matter in the brain (1). The measurement of directional dependent structure in gray matter, however, has been challenging due to the complex tissue structure of gray matter and its much less directional dependence of water diffusion if there is any. The understanding of the diffusion anisotropy in the brain and the improvement of its measurement will help better understand the neurological pathways and connectivity. It has been reported that CSF may contaminate the ADC measurement in DWI in acute stroke (2). However, the effect of CSF on the measurement of diffusion anisotropy has not been well studied and reported. In this study we compared FLAIR-DTI with conventional DTI in normal volunteers in order to investigate whether suppression of CSF signal improves the measurement of diffusion anisotropy, particularly FA, in human brain.

Methods

Diffusion tensor images were acquired using diffusion weighted single-shot spin echo EPI sequence. A dual spin echo technique was employed to minimize the geometric distortion induced by eddy currents. Diffusion weighted gradients were applied in 12 directions. In FLAIR-DTI, the DTI sequence was proceeded with an inversion recovery pulse (TI=2250ms) to suppress the CSF signal.

Six normal volunteers, who provided informed consent, underwent MRI DTI examination. All studies were carried out on a 3 T Siemens Trio system. The following parameters were used: TR=2500ms, TE=85ms, FOV=22cm×22cm, slice thickness=5mm, slice gap=2.5mm, number of slices=5, b=0, 1000s/mm², and 6 averages. The total imaging time for FLAIR-DTI and conventional DTI are 8:25 minutes and 3:30 minutes, respectively. Images (128×96 matrix size) were acquired in the axial orientation. The diffusion tensor was calculated for each voxel, and the fractional anisotropy (FA) maps were generated using DtiMap (Johns Hopkins Univ.) (3).

Results and Discussions

Representative FA images obtained using conventional DTI and FLAIR-DTI from a normal subject are shown in Fig. 1. Increase of FA in gray matter can be readily seen by comparing these images. On the average, the FA in the gray matter increased by 100% in the FLAIR-DTI result. FA values in gray matter of the frontal, parietal, and occipital regions, and white matter in the splenium and genu of the corpus callosum (CCs and CCg), obtained using the both techniques, were calculated and listed in Table 1. A paired t-test revealed that the increase in FA in gray matter is statistically significant (p < 0.001).

The increase in FA can be intuitively understood based on the following argument. Diffusion in CSF is likely isotropic, and partial voluming between brain tissue and CSF leads to a reduction of FA in the measured data. Therefore, elimination of CSF signal increases the observed FA. This increase is more prominent in the gray matter, where CSF contamination is more significant. The increase of measured FA in the gray matter may make it possible to track fibers in the gray matter, a possibility that will significantly expand the utility of DTI in neuroscience.

Table 1. Comparison of conventional and FLAIR-DTI FA values in gray/white matters in volunteers. Average made across all 6 normal volunteers.

<table>
<thead>
<tr>
<th></th>
<th>Frontal lobe</th>
<th>Parietal lobe</th>
<th>Occipital lobe</th>
<th>CCs</th>
<th>CCg</th>
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<tbody>
<tr>
<td>Conventional DTI</td>
<td>0.105 ± 0.017</td>
<td>0.090 ± 0.020</td>
<td>0.128 ± 0.047</td>
<td>0.706 ± 0.037</td>
<td>0.611 ± 0.030</td>
</tr>
<tr>
<td>FLAIR-DTI</td>
<td>0.197 ± 0.029</td>
<td>0.197 ± 0.028</td>
<td>0.205 ± 0.045</td>
<td>0.761 ± 0.037</td>
<td>0.683 ± 0.032</td>
</tr>
<tr>
<td>Increase</td>
<td>0.092 ± 0.028</td>
<td>0.107 ± 0.039</td>
<td>0.078 ± 0.040</td>
<td>0.053 ± 0.024</td>
<td>0.072 ± 0.022</td>
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Figure 1. FA maps of the same imaging slice in a volunteer using (a) conventional DTI, (b) FLAIR-DTI. (c) and (d) showed enlarged (a) and (b) in the left frontal area, respectively. Note that FLAIR-DTI produced higher FA in gray matter areas.

Conclusions

FLAIR-DTI can suppress CSF and long T1 component in DTI and improve the accuracy of FA measurement in the brain. FA maps obtained by using FLAIR-DTI sequence illustrate the potential for assessing directional dependent structure in gray matter.

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References