Vector Analysis of Diffusion Images in Experiment Allergic Encephalomyelitis

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Introduction

Image contrast in diffusion-weighted images of the normal brain is in part related to the orientation of myelinated fibers with respect to the direction of the diffusion-sensitizing gradient. In analyzing diffusion-weighted images from animals with experimental allergic encephalomyelitis, we noticed that certain types of lesions cause a drop in white matter image intensity on all three orthogonal diffusion-weighted images, whereas other lesions differentially affect the three images. In this study, we used vector analysis to obtain images which combine information from the three orthogonal diffusion-weighted images.

Methods

Four male monkeys (Macaca fascicularis) weighing 2-2.5 kg were sensitized to myelin basic protein to induce EAE. Animals were scanned one to two times a week for 6-8 weeks (3 weeks before and 3-5 weeks after sensitization). Diffusion imaging (spin-echo) was performed on a General Electric CSI II Imager/Spectrometer (2 Tesla, equipped with actively shielded gradients). The acquisition parameters were: TR 1000 ms; TE 80 ms; diffusion gradient duration 20 ms; diffusion gradient separation 40 ms; and four slices of thickness 4 mm. At each session four multi-slices sets were acquired: zero diffusion gradient (B0) and diffusion gradients in the X (BX), Y (BY), and Z (BZ) orthogonal directions at 5 Gauss/cm. Conventional T2-weighted images (8 slices) were used to reproducibly select the diffusion image planes and also to detect the onset of edematous EAE lesions. The image intensities from the diffusion images were used to create new images using the following vector equations:

(1) $(\text{Vector length})^2 = BX^2 + BY^2 + BZ^2$

(2) diffusion vector angle between BX and BY = arctan (BY/BX)

(3) diffusion vector angle between BX and BZ = arctan (BX/BZ)

(4) diffusion vector angle between BY and BZ = arctan (BY/BZ)

Results

As EAE brain lesions developed, a 15-30% decrease in signal intensity was seen in the vector length images (equation 1) in well-defined regions of the brain. These pathologic regions were different (in position and in volume) than those seen on the T2-weighted images. There were some edematous lesions detected on T2-weighted images which were not visible at all on the vector length image. Vector length decreases were seen in 4 out of 4 of the EAE animals. A vector length image (coronal view at the level of the thalamus) is shown in Figure 1 where a dark lesion is clearly visible directly below the right lateral ventricle.

Out of the 3 different angle images (equations 2-4), the vector angle between BY and BZ (equation 4) was the most sensitive to EAE lesions where both increases and decreases in image intensity of 15-20% were observed. Equation 4 lesions were identified in 3 of the 4 EAE animals. An example of arctan(BY/BZ) image is shown in Figure 2.

Discussion

Diffusion imaging comes with a wealth of information that can be combined and displayed to emphasize certain water diffusion properties which may be specific to pathologic states of the brain. We have used vector analysis to combine diffusion-weighted images and have found the vector length image to be useful in identifying lesions which are not purely edematous. The vector length images should be sensitive to water diffusion changes where all three orthogonal images change in the same way and the vector angle images should be sensitive to changes in anisotropy between two orthogonal directions. This type of image analysis may prove useful in distinguishing different types of EAE lesions - purely edematous, inflammatory, and chronic demyelinating.

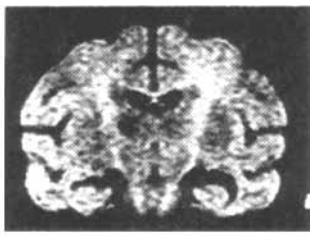

Figure 1

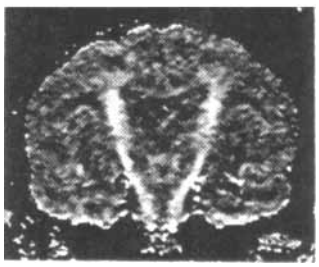

Figure 2