

## Diffusion tensor echo-planar imaging of human brain

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### Introduction

Diffusion tensor imaging reveals microstructural and physiological information within a voxel that scalars (such as proton density,  $T_1$ , and  $T_2$ ) do not. While this concept has been demonstrated with spin-echo MRI of phantoms<sup>1</sup> and *ex vivo* cat brain<sup>2</sup>, long acquisition times and sensitivity to motion artifacts precluded its clinical implementation. We now demonstrate the clinical feasibility of diffusion tensor imaging in human brain using echo-planar MRI.

### Materials and Methods

Using a 1.5-T GE Signa imaging system, we obtained 144 coronal diffusion-weighted echo-planar images<sup>3</sup> of living human brain in less than 20 minutes. Diffusion gradients were applied in the read and/or phase directions (but not in the slice direction, due to the limitations of our EPI software).  $A(TE)$ , the magnetization amplitude at echo time TE, was measured in each voxel. We optimally estimated  $\underline{D}^{eff}$  and  $A(0)$  in each voxel by weighted multivariate linear regression of the following formula<sup>1</sup>:

$$\ln\left(\frac{A(TE)}{A(0)}\right) = - \sum_{i=1}^3 \sum_{j=1}^3 b_{ij} D_{ij}^{eff} \quad (1)$$

Above,  $b_{ij}$  are elements of the b-matrix<sup>1</sup>, calculated analytically, off-line from the diffusion and imaging gradient pulse sequences<sup>7</sup>. The complex multiple interactions between them require the b-matrix to be calculated accurately for each image<sup>4</sup>.

We exploit the phenomenon of anisotropic diffusion in white matter<sup>5-7</sup> in order to image the local fiber-tract direction, which coincides with the eigenvector of  $\underline{D}^{eff}$  associated with its largest eigenvalue (principal effective diffusivity)<sup>1</sup>.

### Results

Fig. 1 shows a coronal section through the base of the lateral ventricles containing the corpus callosum, over which a diffusion ellipse image, constructed from  $\underline{D}^{eff}$  in each voxel is superimposed. Each ellipse is a projection of a diffusion ellipsoid<sup>1</sup> onto the coronal plane. The lengths of each ellipse's two principal axes (for a given diffusion time) are the projections of the local average molecular displacements (along the tissue's orthotropic directions) onto the coronal plane. The ellipse's long axis shows the white matter fiber-tract direction, which correlates well with known anatomy. Note especially the change in fiber-tract orientation between the left and right sides of the corpus callosum. Gray and white matter are also easily distinguishable. High isotropic diffusion is seen in the ventricles.

### Discussion and Concluding Remarks

We have successfully demonstrated the feasibility of clinical diffusion tensor echo-planar imaging (DTEPI). Images obtained by EPI are not marred by motion artifacts; acquisition times of less than 20 minutes make DTEPI clinically practicable.

DTEPI reveals functional information about intravoxel water mobility, and should improve the assessment of the physiological state and microstructure of tissue (e.g., in stroke or tumor monitoring).

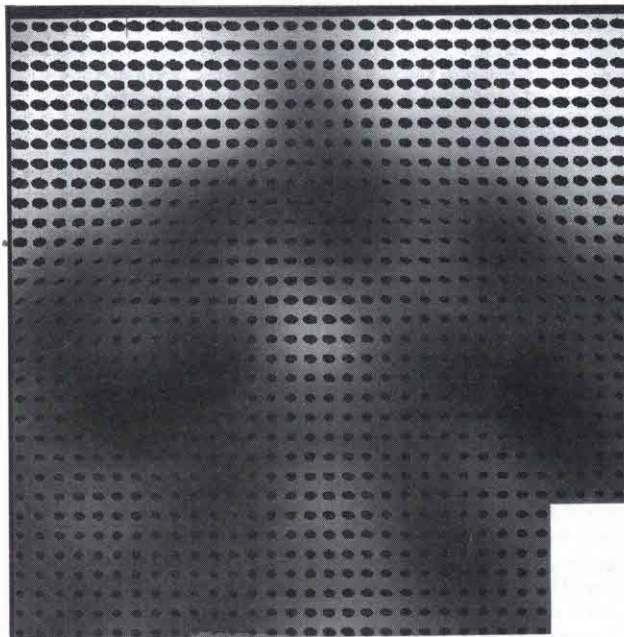


Fig 1. Diffusion ellipse image of human brain (coronal section).

### References

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