Characterization of Intracellular Diffusion Properties with Diffusion Tensor Spectroscopy

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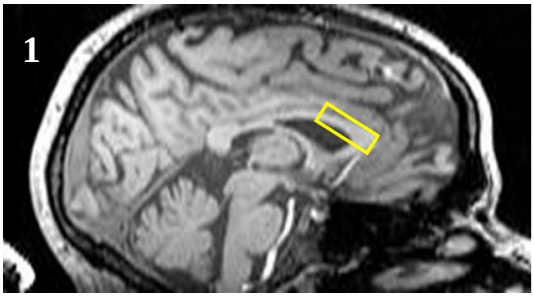
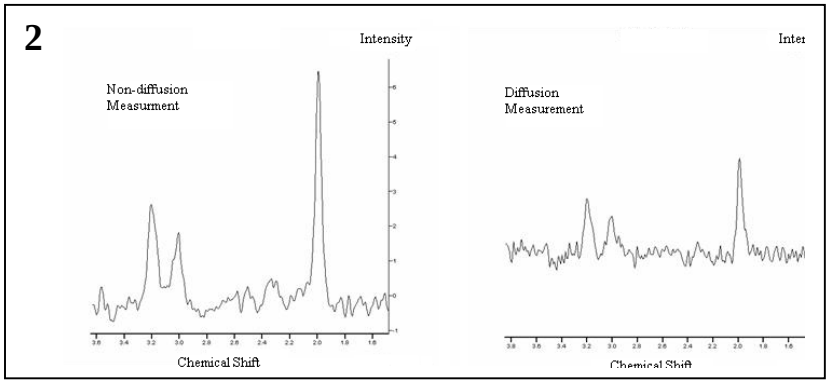
Introduction

The random movement of macromolecules within neuronal tissue is guided to varying extents by cellular structures as well as other macromolecules present within the medium. In Diffusion Tensor Imaging (DTI) the degree of directed movement or anisotropic diffusion of water molecules is exploited to characterize local neuronal microstructure and white matter fiber projections. One confounding issue of the DTI technique arises from the fact that there are intracellular and extracellular components which contribute to the overall diffusivity; thus leading to an ambiguity in determining the underlying cause of diffusion properties in a region of interest. Of particular interest is the contribution of the intracellular and the extracellular pools to the fractional anisotropy (FA). Anisotropic diffusion is believed to stem from restrictions imposed on diffusion by barriers such as cell walls, and thus the FA is intimately connected with tissue structure. Past studies have described the diffusion properties of the N-acetyl-aspartate (NAA), a solely intracellular constituent, and have found it to be a possible alternative to water molecules to probe neuronal structure properties (1,2). In this preliminary study, we combine DTI and NMR spectroscopy techniques to further characterize the diffusion properties of NAA and water molecules in a normal subject.

Materials and Methods

Diffusion spectroscopy (DS) and anatomical imaging was performed on a 3 Tesla Philips Intera Scanner. The subject in this study was a healthy right-handed adult male volunteer. DS data was obtained from a voxel, which adequately covered the anterior (genu to the body) region of the corpus callosum (Figure 1). One non-diffusion measurement and six diffusion measurements were taken to separately measure diffusion properties of water molecules and NAA. Water suppression during NAA diffusion measurements was achieved by double inversion and nulling. Diffusion weighting was accomplished by incorporating six gradient combinations into the standard PRESS technique. Prior to every non-diffusion and diffusion measurement high order shimming was performed to correct for magnetic field inhomogeneities. DS pulse sequence parameters: δ=25ms, Δ=55ms, g=1.6g/cm, b-value=1069s/mm^2, Imaging Voxel=33x25x12 mm. TE/TR=120/2000ms. Diffusion weighting was achieved using the following six gradient combinations: (X,Y,0), (X,0,Z), (0,Y,Z), (X,-Y,0), (-X,0,Z) and (0,Y,-Z).





Results and Discussion

Figure 2 shows the NAA peaks in sample spectra from non-diffusion and diffusion measurements. SNR for the NAA peak in a typical diffusion measurement was 164. Using the peak areas a diffusion tensor was obtained by calculating the dual tensor basis (3). The directions least affected by the diffusion gradients were the same for the water and the NAA measurements (in this case the 4th and 5th directions in our scheme), thus hinting that the main direction of diffusion are similar for both. The calculated apparent diffusion coefficients (ADC) and fractional anisotropy (FA) for water and NAA are given in Table 1. ADC and FA values for water obtained using the technique described above match those of previous diffusion tensor imaging studies done in corpus callosum (4). The FA value obtained for NAA was significantly larger than the FA obtained for water in the same VOI. This may indicate that the intracellular space contributes most significantly to anisotropic diffusion in neural tissue. These results are preliminary and further data collection and optimization of the acquisition parameters is needed, as well as a quantitative assessment of the error introduced by the spectroscopic measurement. The feasibility of DTI measurements based on MRS is however encouraging, and DTI-MRS may become a promising tool in the investigation of tissue structure through intracellular diffusion properties.

Table 1	Water	NAA
ADC(mm^2/s)	0.0017	0.0008
FA	0.3998	0.7991

Acknowledgements

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References

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