Entropy as a Measure of Non-Gaussian Diffusion in Fixed Rat Brain Tissues

R.L Magin (University of Illinois at Chicago, Bioengineering), C. Ingo (University of Illinois at Chicago, Bioengineering), L. Colon-Perez (University of Florida, Gainesville, Physics), and T.H. Mareci (University of Florida, Gainesville, Biochemistry)

Introduction

Fractional-order dynamic models (e.g., systems of ordinary and partial differential equations of non-integer order in time and space) are becoming more popular for simulating the behavior of complex systems (1). Recently, a stretched exponential decay model has been fit to NMR measurements of anomalous diffusion performed in solutions of dispersed microbeads (2). Here, we extend this work via a new, generalized diffusion model for the NMR propagator, $p(q,\Delta)$ and the spectral entropy $H(q,\Delta)$.

Experimental

Here], we examined water diffusion in heterogenous white matter (WM) and homogenous gray matter (GM) regions of a fixed rat brain using a modified Pulsed Gradient Stimulated Echo pulse sequence on a Bruker spectrometer (17.6 T, 750 MHz, 89 mm bore) located in the Advanced Magnetic Resonance Imaging and Spectroscopy Facility of the National High Magnetic Field Laboratory at the McKnight Brain Institute of the University of Florida, Gainesville.

Results and Discussion

The signal decay plots for the ROIs selected in the corpus callosum, thalamus, and cortex show clear divergence from the mono-exponential decay on the linear-log scale (Fig. 1). The MLF parameter, α, separated the central corpus callosum (0.42 ± 0.04), the thalamus (0.57 ± 0.07), and the cerebral cortex (0.76 ± 0.05) (Fig. 2a). The entropy, H(q,Δ), distinguished the central corpus callosum (0.93 ± 0.01), the thalamus (0.86 ± 0.01), and the cerebral cortex (0.81 ± 0.01) (Fig. 2b). We observed the best image contrast in the constant Δ = 17.5 ms PGSTE DWI experiment, in which q was arrayed over the largest range of gradient strengths.

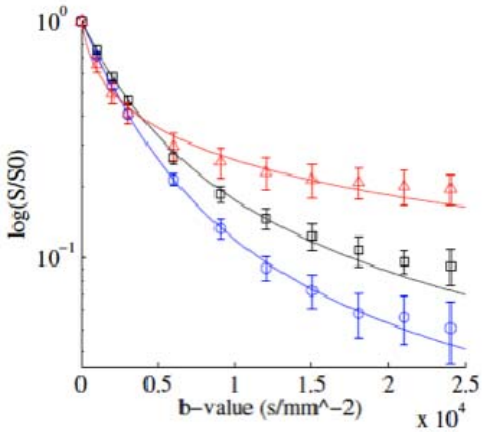

Fig. 1: Signal plots and MLF fits for the corpus callosum (red triangles), thalamus (black squares), and cortex (blue circles).

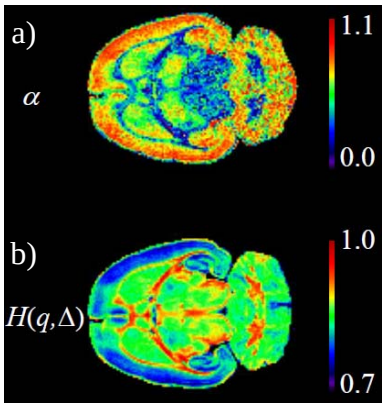

Fig. 2: Parameter maps for a) α, and b) $H(q,\Delta)$ in an axial slice through a fixed rat brain.

Conclusions

We demonstrate that fractional order parameters and entropy parameters can serve as biomarkers for morphology in fixed neural tissue.

Acknowledgements

This project was supported, in part, by an External User's grant to RLM from NSF through the NHMFL.

References

[1] Metzler, R. and Klafter, J. Phys Rep. **39(1)**:1-77 (2000).
[2] Zhou, X.J., *et al*., Magnetic Resonance in Medicine, **63(3)**, 562-569 (2010).