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

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

Introduction

In diffusion-weighted MRI studies of neural tissue, the classical diffusion model assumes the statistical features of Brownian motion and predicts a monoexponential signal decay. However, there have been numerous reports of signal decays that are not monoexponential, particularly in the white matter. Here, we extend this work via a new, fractional order diffusion model for the NMR propagator, $p(q,\Delta)$ and the spectral entropy $H(q,\Delta)$.

Experimental

In this study 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, imaging parameters) 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

In white and gray matter regions, the Mittag-Leffler function (MLF) and entropy parameters demonstrated excellent contrast reflecting the specific choice of weighting on q and Δ (Fig. 1). The MLF parameter, α, separated the central corpus callosum, the thalamus, the cerebellum, and the cerebral cortex more clearly and with less noise than the parameter, β. The apparent diffusion coefficient, $D_{1,2}$ and the entropy, H(q,Δ), distinguished the entire cerebral cortex, more clearly than the unit preserving parameters τ and μ.

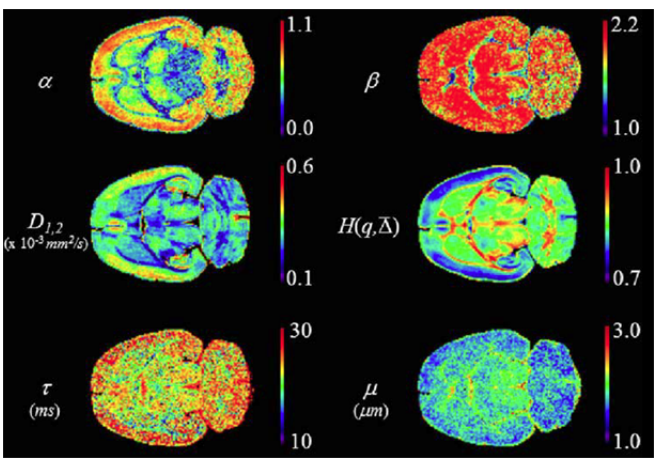

Fig.1 MLF and entropy parameter maps for a constant Δ = 17.5 ms experiment (q varied from 40 to 190 mm^{-1}). The α and β maps reflect temporal and topological features of the propagator, $p(q,\Delta)$, while the spectral entropy, $H(q,\Delta)$, combines both into a smooth measure of tissue complexity. The calculated apparent diffusion coefficient also shows excellent contrast, but not the unit preserving parameters τ and μ.

Conclusions

We demonstrate that fractional order parameters and entropy parameters can serve as biomarkers for morphology in fixed neural tissue. We propose these parameters, α, β and H(q,Δ), have the potential as biomarkers for morphology in neural tissue

Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy.

References

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