Evidence of Changes in Gray/White Matter in Epileptic Rat Brain Using Fractional Order Diffusion Tensor Imaging (fDTI) at 17.6 T

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Introduction

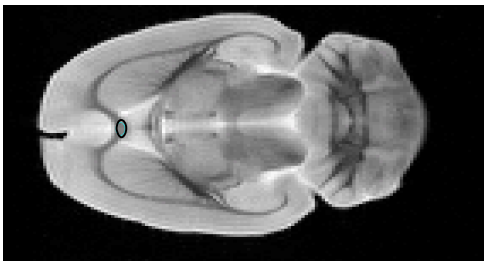
It is well known that diffusion-induced MR signal loss deviates from mono-exponential decay, particularly at high b-values (e.g., > 1,500 s/mm^2 for brain tissues). A number of models have been developed to describe this anomalous diffusion behavior and relate the diffusion measurements to tissue structures. The goal of this study is to acquire high field NMR data (a set of high b-value diffusion weighted 3D images) from which we can identify changes in brain structure in controls and in rat brains with epilepsy. These preliminary studies will use fixed brain tissue to establish correlations between fractional-order measures of anomalous diffusion (e.g., diffusion coefficient D, fractional order derivative in space β, and a fractional order derivative in time, α, and anatomically identified brain lesions.

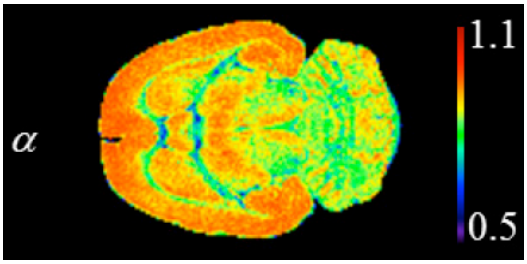
Experimental

From an ongoing study of structural changes taking place during the evolution of the injured brain into epilepsy we selected fixed brains (4% paraformaldehyde) from controls and from rats observed to have developed spontaneous seizures. Prior to imaging, the excised brain were soaked overnight in phosphate buffer saline then imaged in a 20 mm tube of Fluorinert (3M Corp.). After imaging, the brain was returned to the fixative solution. MR images were acquired in AMRIS using the 17.6 T (750 MHz) NMR imaging spectrometer with a 20 mm diameter imaging coil. Data were acquired (June 21-23 and Aug. 18-20) using a pulsed-field-gradient spin echo, multiple-slice 3D sequence with 15 b-values ranging from 0 to 25,000 s/mm^2. The protocol for data acquisition was optimized using a phantom consisting of N-tridecane (diffusion rate similar to brain tissue). Images were acquired with isotropic resolution (0.2 mm x 0.2 mm x 0.2 mm) using diffusion weighting directions distributed uniformly over a hemisphere and fit to a previously derived fractional order stretched exponential model (1-3).

Results and Discussion

A sample image of a control rat brain (left) and a map of the (α) parameter for the entire slice. The regions of interest in an around the corpus callosum shown diffusion enhanced signal complexity for a gradient oriented along the principle fiber direction. Similar images were obtained for the (β) parameter.





Conclusions

Fractional order analysis of diffusion weighted images from control rat brains exhibit a directional dependent non-exponential signal decay. In the next year of this pilot project this dependence will next be further investigated in fixed brains from animals with epilepsy.

References

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[3] Zhou, X.J., *et al.*, Magn Reson,Med, **63**, 562-569 (2010).