Non Parametric Approach for Axon Diameter Distribution Estimation from Diffusion Measurements

Y. Assaf[1], and P. J. Basser[2]

[1]Department of Neurobiochemistry, Faculty of Life Sciences, Tel Aviv University, Tel Aviv, Israel, [2]National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, MD, United States

Introduction

Diffusion imaging enables microscopic assessment of tissue structure by measuring the displacement of water molecules. Several models have been proposed to relate diffusion weighted MR signals and various structural features of the tissue. One recent model, the composite hindered and restricted model of diffusion (CHARMED), was shown to be able to extract white matter fiber orientation (even in areas with complex white matter architecture) [1]. An extension of this framework (AxCaliber) provides an estimate of the axon diameter distribution of fascicles within white matter [2]. This distribution is obtained by performing diffusion weighted MR experiments with multiple diffusion times and multiple diffusion weighting. Previously, it was assumed that the axon diameter distribution was given by a known parametric function, a γ-variate distribution. Yet this approach is problematic in diagnostic applications, and more generally, when one does not know the parametric form of the diameter distribution beforehand. In this work we have developed a non-parametric approach for estimating the axon diameter distribution, extending the range of applications of the AxCaliber framework.

Methods

MR experiments: Experiments were performed on a 7T MRI system (Bruker, Germany). Porcine optic and sciatic nerves were freshly excised and placed in an NMR tube. High b-value DW spectra were acquired with the following parameters: TR/TE=3000/166ms, δ=2.5ms, G_{max}=120 Gauss/cm, number of averages = 8, with diffusion time, Δ, varied from 20ms to 150ms in eight increments. Diffusion gradients were applied only perpendicular to the nerve axis with 16 increments in gradient amplitude per diffusion time. The entire DW data set consisted of 128 spectra acquired in 51 minutes.

Data Analysis: Analysis of experimental MR data was performed using the AxCaliber framework described previously[2]. Within AxCaliber we used an n-bar function, which models the diameter distribution as a histogram, where each of n-bars in the function is weighted by a free parameter. The values of the axon diameter histogram were initialized by running AxCaliber in order to obtain an estimate of the two free parameters of the γ-distribution. These were then used to generate the initial guesses for the non-parametric histogram. *A priori* physical constraints were applied to reduce the number of free parameters to estimate.

Results & Discussion

Experimental data: Non-parameteric AxCaliber analysis of the optic and sciatic nerve data was able to reproduce a mono-phasic axon diameter distribution with high similarity to known histological appearance of those tissues (Figure 1). The independent n-bar function resulted in a narrow axon diameter distribution for the optic nerve and much broader distribution for the sciatic nerve as well as a higher mean value.

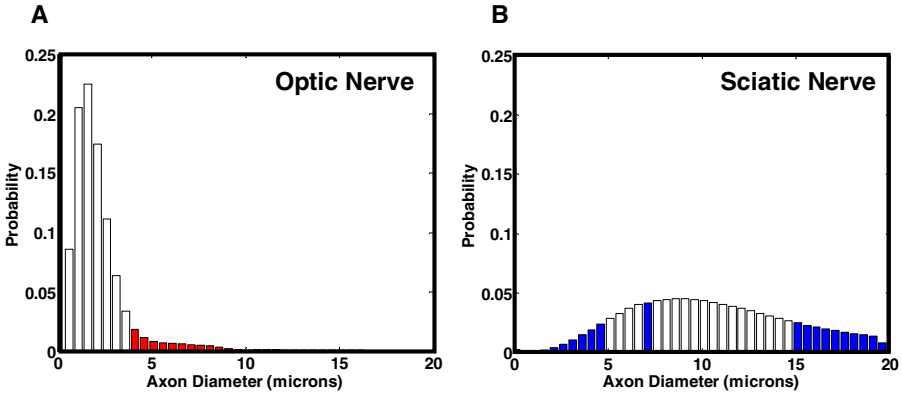

Figure 1

Conclusion

This non-parametric AxCaliber framework does not necessitate using a pre-determined axon diameter distribution, and thus may be informative for studying white matter structures in which the axon diameter distribution is multi-modal, or in which specific bands within the diameter distribution are affected, as is believed to occur in trauma or in ALS.

References:

1. Y. Assaf, PJ. Basser. Neuroimage 2005, 27, 48-58.
2. Y. Assaf, T. Blumenfeld, G. Levin, Y. Yovel, PJ. Basser. Proc. Intl. Soc. Magn. Reson. Med. 2006, 14, 637