

Use of Double Inversion Recovery for Characterizing Diffusion of Myelin Water

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Introduction

In recent years, growing interest in diffusion studies of white matter has heightened the need for more sophisticated mathematical models describing white matter. Such models require an understanding of fundamental NMR and water properties of all microanatomical compartments of white matter. This study presents measurements of myelin water diffusion parameters of *in vitro* sciatic nerve using inversion pulses to saturate non-myelin water [1].

Methods

Data Acquisition: All data were acquired using a Varian console and 7T magnet. In three separate sessions, an African clawed toad was euthanized and a 5 mm segment of sciatic nerve was excised from each hind leg. Each sample was cleaned, dried of excess fluid and pulled into a 1.2 mm capillary tube. The two capillary tubes were then positioned side-by-side in a 5 mm NMR tube and filled with fomblin oil to prevent the tissue from drying. The diffusion sequence began with a double inversion recovery (DIR) segment followed by a pulsed gradient spin echo segment, which was followed by a CPMG segment. The following acquisition parameters were used for the diffusion sequence: TR = 15 s, averages = 32, 1st TE = 16 ms, 200 echoes, echo spacing = 1 ms, δ = 6 ms, and Δ = 9.5 ms, diffusion gradient amplitudes = 0, 20, and -20 G/cm. The direction of the diffusion gradient was parallel to the long axis of the nerve. A fast version of the experiment was run to find the optimal inversion times for the longer experiment. A CPMG experiment (TE=1ms, echoes=2500) was performed at the beginning and end of the imaging session. Immediately following this, the acquisitions were repeated with diffusion gradients applied perpendicular to the long axis of the nerve. To avoid gradient orientational dependence of eddy current effects, both parallel and perpendicular diffusion measurements were made with the same gradient coil by repositioning the sample. A litz coil (25 mm ID) was used for parallel diffusion and a split-ring coil (10 mm ID) was used for perpendicular diffusion. **Data Analysis:** The T₂ spectrum was calculated for each data set using a NNLS algorithm and smoothed with a minimum energy constraint [2]. Pool fractions and mean T₂ values were calculated for each of the peaks in the T₂ spectrum. In each of the diffusion data sets an apparent diffusion coefficient (ADC) was calculated using the first echo.

Results

T₂ values observed following the DIR preparation were in close agreement with the myelin component T₂ values found in the conventional T₂ spectrum derived from the CPMG measurement (Table 1), supporting the premise that the DIR preparation is myelin-selective. The myelin water ADC was found to be significantly lower than the parallel ADC ($p < 0.01$) (Table 1), and for both directions, the ADC values were lower than values previously measured in whole white matter [3]. Differences between diffusion-weighted and non-diffusion-weighted data were consistent for all time points less than the T₂ value (Figure 1).

Discussion and Conclusions

The ADC results are consistent with the interpretation that diffusion in the short T₂ water compartment (myelin water) is highly restricted, especially perpendicular to the orientation of the axon. In both directions the myelin water ADCs were found to be lower than has been previously reported [3]. Further studies will be necessary to determine whether this discrepancy is due to the different tissue types used or differences in the MR acquisition protocols, although the DIR preparation avoids the complexities inherent in T₂ spectrum estimation.

References

- [1] Travis and Does, *Mag Reson Med*, 2005, 54:743-747.
- [2] Whittall and MacKay, *J Magn Reson*, 1989, 84: 134-152.
- [3] Stanisz and Henkelman, *Mag Reson Med*, 1998, 40:405-410.

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	Parallel	Perpendicular
Myelin ADC (10^{-5} cm ² /s)	0.40 +/- 0.04	0.15 +/- 0.02
CPMG Myelin T ₂ (ms)	16.5 +/- 1.5	14.1 +/- 0.2
DIR Myelin T ₂ (ms)	14.4 +/- 1.8	15.1 +/- 1.8

Table 1. ADC and T₂ values for parallel and perpendicular diffusion

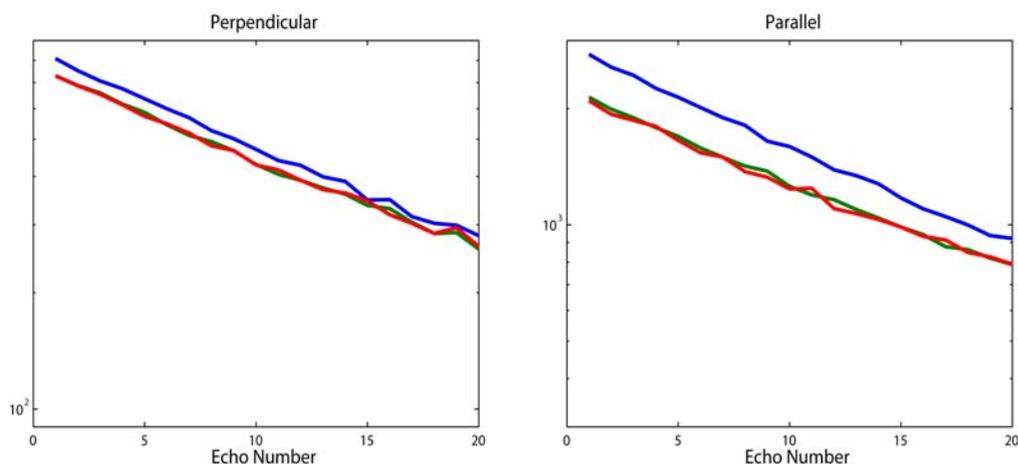


Figure 1. Typical DIR-prepared, diffusion-weighted (red and green) and non-diffusion-weighted (blue) T₂ relaxation curves for diffusion gradients parallel and perpendicular to the long axis of the nerve. (For clarity only the first 100 echoes of each curve are shown.)