3D Myelin Water Imaging in the Spinal Cord at 3.0T

E. L. MacMillan[1], B. Mädler[2], S. H. Kolind[1], E. Yip[1], and A. L. MacKay[1,3]

[1]Physics & Astronomy, University of British Columbia, Vancouver, BC, Canada, [2]Philips Medical Systems Canada, University of British Columbia Hospital, Vancouver, BC, Canada, [3]Radiology, University of British Columbia, Vancouver, BC, Canada

Introduction

Spinal cord injuries (SCI) and degenerative diseases have a major impact on the quality of life of those affected; however, to date there are no therapies directed at the spinal cord itself. Current clinical approaches include relieving compression, reducing swelling, and increasing emergency care and rehabilitation. Research into therapies directed at the spinal cord focuses on the neurite growth inhibiting properties of myelin associated proteins and proteoglycans [1]. Thus, a non-invasive technique to determine myelin content in the spinal cord will be required to assess the efficacy of such treatments and track recovery of myelin following treatment.

Magnetic resonance multi-echo T_2 relaxation experiments in normal central nervous system white matter reveal three pools of water protons with different T_2 relaxation times. The shortest T_2 pool at approximately 20ms is attributed to water trapped between the myelin bilayers, and the relative size of this pool is called the myelin water fraction (MWF) [2,3]. MWF has been shown to correlate strongly with luxol fast blue staining for myelin in formalin fixed multiple sclerosis brains, indicating that MWF is a surrogate marker for myelin [4]. Multi-echo T_2 relaxation experiments to measure spinal cord MWF in normals and multiple sclerosis have previously been implemented at 1.5T [5,6]. The goal of this study was to determine MWF in a volume centered at the C6 level of the normal human spinal cord at 3.0T.

Methods

MR Experiment: Ten healthy adults (6 female, 4 male, mean age 25 years, range 22-30 years) were scanned on a 3.0T Philips Achieva system with a phased array spine coil using only the first four channels. The T_2 relaxation measurement was performed using a 3D 32 echo modified Carr-Purcell-Meiboom-Gill sequence consisting of a 90° slice selective pulse followed by 32 slab selective 180° pulses (first echo at 10ms, echo spacing of 10ms, TR=1300ms, eight 5mm thick axial slices perpendicular to the spinal cord, 256×128 matrix, FOV 180mm×135mm, single acquisition)[7]. The volume of interest was centered at the C5 vertebrae.

Data Analysis: For each axial slice, a region of interest (ROI) was drawn on the 10ms image to select the entire spinal cord. The 32 echo decay curves of each ROI were decomposed into an unspecified number of exponentials using a regularized non-negative least squares algorithm with 120 input relaxation times spaced logarithmically from 15ms to 2s. Both χ^2 and solution roughness were minimized such that χ^2 fell between 1.02 and 1.025 times the minimum χ^2 from the non-regularized least-squares solution. The MWF was defined as the fraction of the T_2 signal below 40ms relative to the total T_2 signal. The MWF for the entire ROI was calculated, as well as a pixel by pixel analysis to produce a myelin water map for each ROI. The first and eighth slices were discarded due to aliasing along the slice selective direction, and in three subjects an additional one or two slices near the C7 vertebra were discarded due to phase wrap artefact that overlapped with the spinal cord signal. Scans from two of the subjects (both male) were discarded due to motion artifact or fold-over artefact in all of the slices. All errors are expressed as standard errors.

Results

A total of 42 axial ROIs of the spinal cord cross section were examined in eight subjects. Multiexponential fits of the T_2 signal decay curves from these ROIs resulted in residuals less than 2% of the maximum signal amplitude and an average MWF of 0.226 (0.006). Comparison of MWF across slices did not show a significant trend, as shown in Figure 1. The average standard deviation of MWF between slices in each subject was 0.025 (0.004). Myelin water maps showed reduced intensity in the central grey matter regions of the cord as expected, as shown in Figure 2..

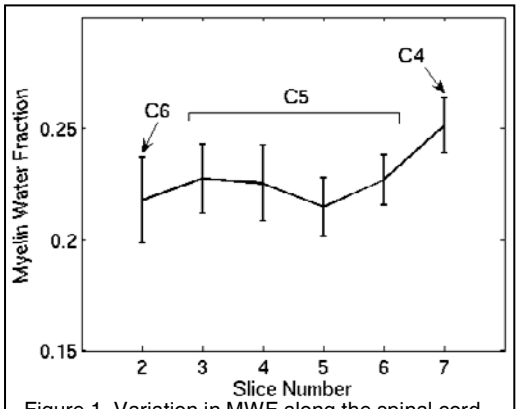

Figure 1. Variation in MWF along the spinal cord. Error bars represent standard error.

Conclusions

3D measurement of myelin water fraction is feasible in the spinal cord at 3.0T. Spinal cord MWF observed at 3.0T agree within standard error with previously reported by Minty *et al.*, and are very close to those found by Wu et al. [5,6]. This study advances the use of myelin water imaging to investigate changes in myelin content due to spinal cord injury, and neurologic or degenerative diseases of the spinal cord.

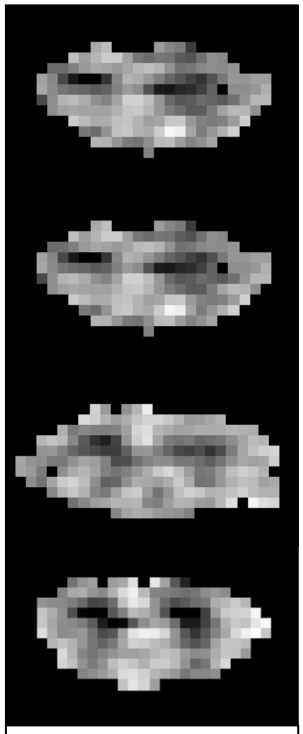

Figure 2. Myelin water images of the cervical spine in C4 (top two) and C5 (bottom two).

References

[1] Simonen, M *et al*. Systemic Deletion of the Myelin-Associated Outgrowth Inhibitor Nogo-A Improves Regenerative and Plastic Responses after Spinal Cord Injury. Neuron 2003;38:201-211.

[2] MacKay, A *et al*. *In vivo* visualization of myelin water in brain by magnetic resonance. Magn. Reson. Med. 1994:31;673-7.

[3] Whittall, KP *et al*. *In Vivo* Measurement of T_2 Distributions and Water Contents in Normal Human Brain. Magn. Reson. Med. 1997;37:34-43.

[4] Laule, C *et al*. Myelin Water Imaging in Multiple Sclerosis: Quantitative Correlations with Histopathology. *Multiple Sclerosis* In Press 2006.

[5] Minty, EP *et a*l. Measurement of myelin water in human and bovine spinal cord. 10th ISMRM, 2002.

[6] Wu, Y *et al*. Myelin Water Fraction in Human Cervical Spinal Cord In Vivo. *J. Comput. Assist. Tomogr.* 2006:30;304-306.

[7] Mädler, B *et al*. *In-vivo* 3D Multi-component T2-Relaxation Measurements for Quantitative Myelin Imaging at 3T. 14th ISMRM, 2006.