

## Estimation of total myelin volume in the brain

J. Warntjes<sup>1,2</sup>, J. West<sup>1,3</sup>, O. Dahlqvist-Leinhard<sup>1,3</sup>, G. Helms<sup>4</sup>, A-M. Landtblom<sup>5</sup>, and P. Lundberg<sup>6,7</sup>

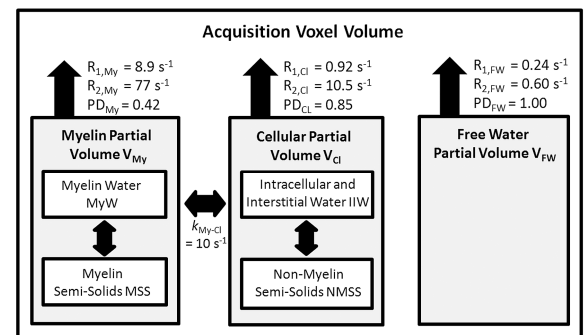
<sup>1</sup>Linköping University, Center for Medical Image Science and Visualization, Linköping, Sweden, <sup>2</sup>Department of Medicine and Health, division of clinical physiology, Linköping, Sweden, <sup>3</sup>Department of Medicine and Health, Division of Radiation Physics, Linköping, Sweden, <sup>4</sup>University Medical Center, MR-Research in Neurology and Psychiatry, Göttingen, Germany, <sup>5</sup>Department of Clinical Neuroscience, Linköping, Sweden, <sup>6</sup>Linköping University, Dept of Radiation Physics and Dept of Radiology, IMH, University of Linköping, Linköping, Sweden, <sup>7</sup>University Hospital of Linköping, Dept of Radiation Physics and Dept of Radiology, CKOC, University Hospital of Linköping, Linköping, Sweden

**Introduction.** Myelin content of the brain is an important parameter to study diseases such as Multiple Sclerosis or Alzheimer's disease. A model is proposed to estimate the myelin partial volume from absolute measurement of the  $R_1$  and  $R_2$  relaxation rates and proton density PD. Summation of all myelin partial volumes results in the total myelin volume of the brain. The approach was validated on repeated measurements on healthy subjects at different in-plane resolutions. A pilot study was performed on MS patients.

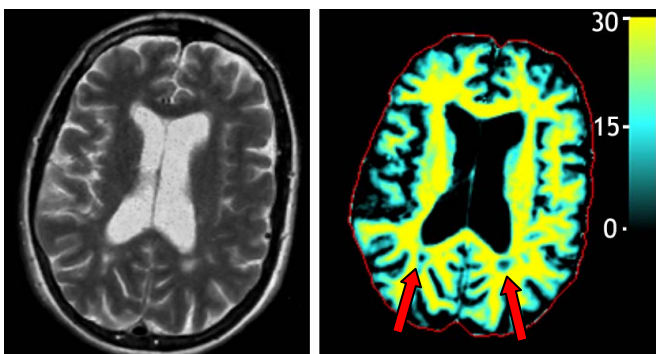
**Methods.** The  $R_1$ ,  $R_2$  and PD quantification sequence<sup>1</sup> was a multi-echo, saturation recovery sequence with 6 echoes of 15 ms and 4 saturation delays of 130, 380, 1630 and 3370 ms with a TR = 3.5 s. In total 30 slices were acquired of 5 mm thickness and 1 mm in-plane resolution. For 10 healthy subjects the scan was repeated using an in-plane resolution between 1.0 to 2.0 mm in steps of 0.2 mm. In total 20 healthy subjects (mean age 40 years in the range 20-63) and 10 patients diagnosed with Clinical Deficit Multiple Sclerosis (mean age 48 in the range 23-62) were scanned at 1.0 mm resolution. The scanner was a 1.5T Philips Achieva (Best, the Netherlands). In the model the observed  $R_1$ ,  $R_2$  and PD of each acquisition voxel is the result of a myelin partial volume  $V_{My}$ , a cellular partial volume  $V_{Cl}$  and a free water partial volume  $V_{FW}$  (Fig. 1), where each partial volume has its own properties in  $R_1$ ,  $R_2$  and PD. The  $V_{My}$  consists of a myelin water pool and a myelin semi-solids pool, the  $V_{Cl}$  consists of an intercellular and interstitial water pool and a non-myelin semi-solids pool<sup>2</sup>. A coupled numerical Bloch simulation was performed to assign the *in-vivo*  $R_1$ ,  $R_2$  and PD measurements to a distribution of the three partial volumes. The myelin calculation was added as a feature in SyMRI Brain Studio (SyntheticMR, Linköping, Sweden).

**Results.** The mean standard deviation of the myelin volume of the repeated measurements of 10 healthy subjects was 4.1 mL (2.2%). No significant relation was seen between resolution and total myelin volume. The total myelin volume of the MS patients was  $171 \pm 34$  mL, compared to  $156 \pm 25$  mL for all healthy subjects. Normalized on skull volume this was  $13.1 \pm 2.1\%$  and  $11.0 \pm 1.0\%$ , respectively. The brain volumes were on average smaller for the patients,  $88.2 \pm 4.2\%$  versus  $90.4 \pm 2.1\%$  of the skull, leading to an average myelination of the brain of  $14.8 \pm 2.0\%$  and  $12.1 \pm 0.9\%$ , respectively.

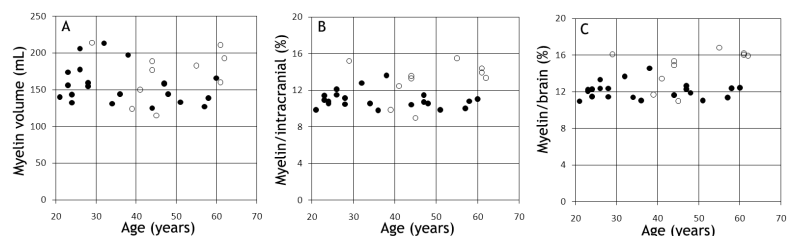
**Discussion.** The patients clearly showed MS lesions in their white matter where the estimated myelin partial volume was strongly reduced, in combination with smaller brain volumes. Still, the absolute as well as the relative myelin content was higher than for the healthy group. This may indicate some form of compensation or change of myelin in the remaining white matter of the MS group.



**Fig. 1.** The proposed model with myelin partial volume, cellular partial volume and free water partial volume for an acquisition voxel. The properties for each partial volume were set to match observed qMRI data of the healthy brain at 1.5 T.



**Fig. 3.** Example of an axial slice of the brain of an MS patient. Myelin partial volume calculations are displayed on a scale 0-30%. The MS lesions posterior of the lateral ventricles are clearly visible as holes in the myelin map (arrows). The red line indicates the intracranial volume.



**Fig. 2.** Pilot study on the myelin estimation in the brain of 20 healthy subjects (dots) and 10 MS patients (circles). A) Total myelin volume, B) Ratio of myelin volume and intracranial volume, C) Ratio of myelin volume and brain volume. The standard deviation of the repeated measurements corresponds to the size of the dots.

**Conclusion.** Estimation of total myelin volume can be achieved with a standard deviation of 4.1 mL in a scan time of 7 minutes. A pilot study indicated that MS patients may have an elevated myelin content in spite of local destruction of myelin in the lesions.

[1]Warntjes JBM, Dahlqvist-Leinhard O, West J, Lundberg P. Magn Reson Med 2008;60:320-329.

[2]Levesque R, Pike GB. Mag Reson Med 2009;62:1487-1496.