

## Voxel-based quantitative MRI in multiple sclerosis

Maria Engström<sup>1,2</sup>, Jan B M Warntjes<sup>2,3</sup>, Anders Tisell<sup>2,4</sup>, Anne-Marie Landtblom<sup>2,5</sup>, and Peter Lundberg<sup>2,4</sup>

<sup>1</sup>Radiology, Linköping University, Linköping, Sweden, <sup>2</sup>Center for Medical Image Science and Visualization (CMIV), Linköping University, Linköping, Sweden,

<sup>3</sup>Clinical Physiology, Linköping University, Linköping, Sweden, <sup>4</sup>Radiation Physics, Linköping University, Linköping, Sweden, <sup>5</sup>Neurology, Linköping University, Linköping, Sweden

### Target audience

MR-physicists, neuroimaging researchers, neurologists, and neuroradiologists will benefit from the information given in this abstract.

### Purpose

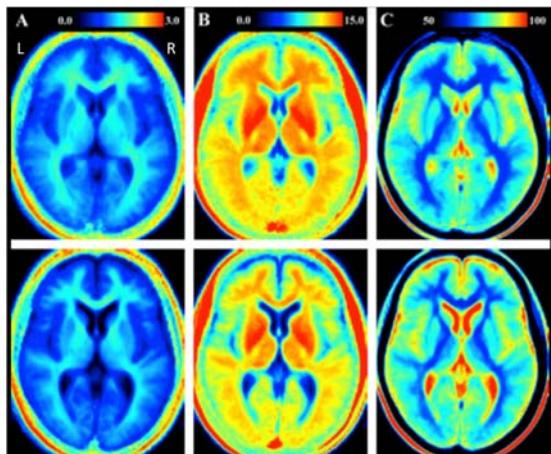
The purpose of the study was to improve objective measures for brain tissue characterization and visualization in groups using quantitative MRI in combination with brain normalization.

### Methods

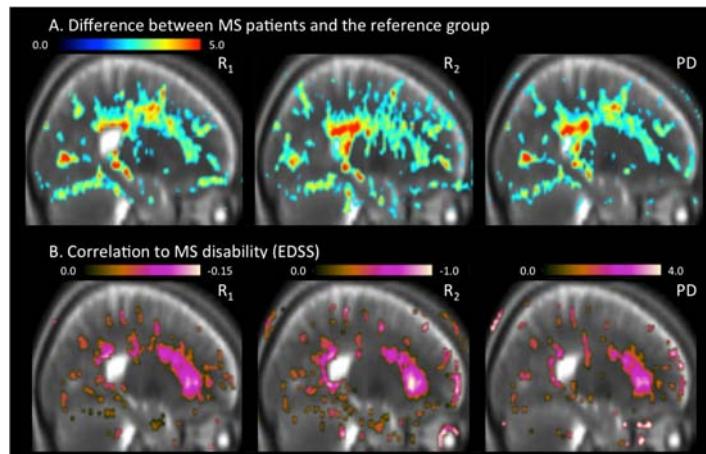
Nineteen patients with multiple sclerosis (MS) and 20 healthy controls were recruited to the study (mean age = 48 years). Quantitative MRI (qMRI) data were acquired on a Philips Achieva 1.5 T scanner using the QRAPMASTER sequence<sup>1</sup>, which is a multi spin-echo saturation recovery sequence with 4 saturation delays and 5 echoes. Images of the relaxation rates,  $R_1$  and  $R_2$ , and the proton density (PD) were created and normalized to a standard stereotactic space in Montreal Neurological Institute (MNI) co-ordinates using SPM8 (Wellcome Department of Imaging Neuroscience, University College, London, UK), as described in previous works by us<sup>2</sup>. Voxel-wise differences in  $R_1$ ,  $R_2$ , and PD between MS patients and healthy controls were estimated by two-sample t-tests controlling for age. For the MS group,  $R_1$ ,  $R_2$ , and PD values in each image voxel were correlated to the Expanded Disability Status Scale (EDSS) with age as a nuisance variable. EDSS is an instrument to measure disability (0-10 points), putting weight on motor dysfunction.

### Results

The  $R_1$ ,  $R_2$ , and PD maps could discriminate between the different tissue types, such as cerebrospinal fluid (CSF), white matter (WM), and grey matter (GM), see Fig. 1. By inspecting the images it is not completely evident to discriminate differences between the MS patients and the controls. By voxel-based statistical analysis, distinct tissue differences between the two groups were detected (Fig. 2A). Generally MS patients had lower  $R_1$  and  $R_2$ , and higher PD as compared to the controls. Marked differences between MS patients and healthy subjects showed up in periventricular WM and in central cortical and sub-cortical structures. When comparing the voxel-based differences between the groups and the EDSS correlation maps (Fig. 2B) some overlap was observed. However, MS-related tissue abnormality in frontal WM was highly correlated with EDSS, whereas WM changes in the posterior corpus callosum were only highlighted in the group difference maps.



**Fig. 1:** Quantitative maps of the reference group (top row) and MS patients (bottom row). (A)  $R_1$  on a scale 0–3  $s^{-1}$ , (B)  $R_2$  on a scale 0–15  $s^{-1}$ , and (C) PD on a scale 50–100%, where 100% corresponds to pure water at 37°C.



**Fig. 2A:** Voxel-based statistical differences of the quantitative parameters  $R_1$ ,  $R_2$ , and PD between MS patients and controls. **2B:** Voxel-wise correlation between EDSS scores and  $R_1$ ,  $R_2$ , and PD, respectively, in MS patients. Non-significant values were masked.

### Discussion

In this study we explored the ability of voxel-based image analysis of qMRI data to assess disease-specific features in groups. We showed that different multi-parametric representations could visualize different brain tissue properties, especially regarding WM, in MS patients and in healthy individuals. The voxel-based statistical analysis showed which brain areas had shared tissue aberrations in the MS patients as a group. The correlation analysis showed that frontal WM changes were more related to disability in MS patients compared to posterior WM changes. The cause of this is not clear, but further studies, looking at the individual level may reveal the relationship in more detail. The advantage with the presented qMRI method is the short scanning time and the simultaneous acquisition of  $R_1$ ,  $R_2$ , and PD.

### Conclusion

Quantitative MRI together with voxel-based statistical analysis and multi-parametric visualization is an up-and-coming method to study neuropathology. There is an interesting potential to analyze neuroanatomical correlation to clinical symptoms and permanent disability characteristics for an entire patient group like MS. Such systematic information may also give clues to the pathological processes, still partly unsolved in this devastating disease.

### References

1. Warntjes JBM, Dahlqvist Leinhard O, West J, and Lundberg P. Rapid magnetic resonance quantification on the brain: Optimization for clinical usage. *Magn Res Med.* 2008;60:320-329.
2. Warntjes JBM, Engström M, Tisell A, and Lundberg P. Brain characterization using normalized quantitative magnetic resonance imaging. *Plos One.* 2013;8:e70864.