

WHITE MATTER AND GREY MATTER MAGNETISATION TRANSFER MEASUREMENTS IN THE LUMBO-SACRAL ENLARGEMENT: A PILOT STUDY WITH THE USE OF RADIAL ACQUISITION PROFILE AT 3T

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TARGET AUDIENCE: Neurologists with a special interest in the study of white (WM) and grey matter (GM) and their involvement in certain neurological disorders, as well as Physicists involved in the development of structural and quantitative MR imaging techniques for studying the spinal cord.

PURPOSE: To develop a reliable method for measuring WM and GM magnetisation transfer ratio (MTR) within the lumbo-sacral enlargement (LSE) *in vivo*, using a commercially available MRI system at 3T.

INTRODUCTION: Certain pathologies of the central nervous system (CNS) are known to affect the WM and GM of the spinal cord (SC). Diseases like leucodystrophies and Friedrich's ataxia, affect the WM tracts [1], while multiple sclerosis (MS) and amyotrophic lateral sclerosis (ALS) affect both the WM and GM components of the SC [2-5]. This therefore establishes the need for an appropriate method of studying WM and GM independently within the SC. In a previous study WM and GM volumes were obtained and MTR was measured within the upper cervical cord by means of commercially available MRI sequence [6] but similar investigations at other levels of the spinal cord, like the lumbar spine, pose new challenges that merit investigation in their own right. For example, differences in physiological motion at this level would require the use of regional saturation (REST) slabs to be used, with a consequent negative effect on the measurable MTR. This work presents preliminary results from a pilot study of tissue-specific MTR measurements obtained within the LSE in healthy controls; this was achieved with the use of radial acquisition profile and by taking into consideration the technical challenges associated with imaging the lumbar spine. The method presented here maybe applied in the future to study a large spectrum of neurological diseases.

METHOD: A) Participants: Five healthy subjects were recruited for the study (mean age, 29.8yrs, range 26-37yrs, 3 female). The local institutional review board approved the study and informed consent was obtained from all participants. B) MR Imaging: A 3T Philips Achieva MRI system with RF multi-transmit technology (Philips Healthcare, Best, Netherlands) and the manufacturer's product 16-channel neurovascular (NV) coil and 15-channel SENSE spine coil were used to acquire the images. A T2-weighted image of the lumbar spine in the sagittal plane was first obtained and used to facilitate prescription of the slices perpendicular to the spinal cord. The imaging volume was positioned at the T11 - L1 level, to ensure coverage of the LSE. (i) For GM and WM segmentation and mean cross-sectional area (CSA) measurements, a 3D slab-selective fast field echo (3D-FFE) sequence was used with fat suppression and the following imaging parameters: TR = 22 ms, TE = 4.4 ms, flip angle $\alpha = 10^\circ$, FOV = 180 x 180 mm; voxel size = 0.5 x 0.5 x 5.0 mm³; NEX = 8, slices = 19; slice gap = 0. (ii) MTR imaging was performed using the same scan geometry as in (i) and the following parameter details: 3D slab-selective FFE with two echoes (TR / TE1 / TE2 = 36 / 1.69 / 3.1 ms, flip angle $\alpha = 10^\circ$), with and without Sinc - Gaussian shaped MT saturation pulses with nominal $\alpha = 360^\circ$, offset frequency = 1 KHz, with a duration of 16 ms. Number of slices = 45; FOV = 180 x 180 mm; acquisition matrix = 240 x 240 mm; voxel size = 0.75 x 0.75 x 5.0 mm³ (reconstructed voxel = 0.5 x 0.5 mm). The MTR sequence was acquired using radial acquisition profile with the fold-over direction set in the foot/head (FH), therefore alleviating physiological motion artefacts arising from the kidney function/major blood vessels and respiration. Total acquisition time for both MT-off and MT-on sequences was approximately 20 mins. To maximise SNR, subjects were positioned supine and a large wedge foam pad placed under the knees to reduce the curvature of the lumbar spine, and to increase contact with the surface of the coil. To further reduce motion artefacts, immobilisation techniques were employed using Velcro straps and the participants were instructed to take slow shallow breaths. C) Imaging analysis: Using the linear registration toolkit in FSL (<http://www.fmrib.ox.ac.uk/fsl/>), the MT-off and MT-on volumes were co-registered independently to the 3D-FFE volumetric scan, prior to calculation of the MTR-map. Three slices (i.e. 15 mm) through the widest section of the lumbar spinal cord (i.e. the LSE) were extracted and segmented, using the active surface model (ASM) segmentation method in JIM 6.0 (www.xinapse.com) [7]; GM- and WM-CSA measurements were obtained as previously described [6].

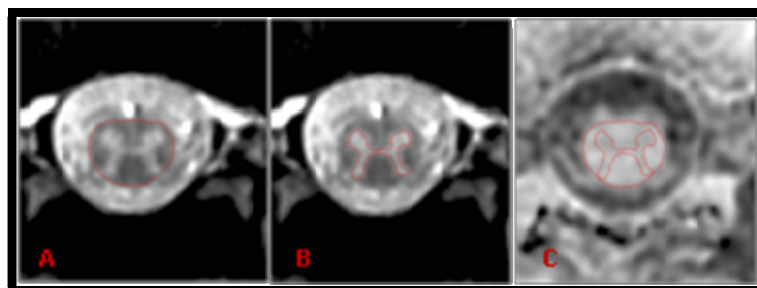


Figure 1. A) 3D-FFE axial image through the LSE showing the segmentation boundary of A) the total cord area using the active surface model and B) GM boundary C) MTR values were obtained from the MTR - map following linear co-registration.

Measures	Case 1	Case 2	Case 3	Case 4	Case 5	Mean (\pm SD)
GM-CSA (mm ²)	15.1	24.5	17.1	12.3	18	17.4 (4.5)
WM-CSA (mm ²)	37.4	44	34.9	31.3	31.3	35.8 (5.3)
GM-MTR	40.9	42.8	43.5	35.7	41.7	40.9 (3.1)
WM-MTR	42.3	44.4	44.4	37.2	43.8	42.4 (3.0)

Table 1: Volumetric and MTR measurements are shown separately for each subject (case).

RESULTS: Example of the image segmentation procedure is shown in Figure 1. In the 5 healthy controls, mean (\pm SD) GM-CSA was 17.4 (\pm 4.5) and WM-CSA was 35.8 (\pm 5.3). GM-MTR was 40.9 (\pm 3.1) and WM-MTR was 42.4 (\pm 3.0). Table 1 shows the results for each of the 4 control subjects separately. Repeated scan in one participant (scan-rescan assessment) gave a coefficient of variation (COV) of 2.7% for measuring WM-MTR and 1.2% for GM-MTR. The difference in MTR values between GM and WM was investigated using a paired t-test and this was found to be statistically significant ($p < 0.001$).

CONCLUSION: This study has shown that tissue-specific (i.e. GM and WM) MTR measurements within the LSE is possible using a commercially available MR system. The use of radial acquisition profile is valuable in controlling for extensive physiological motion artefacts associated with that level of the spinal cord without the need of regional saturation slabs, which are likely to have a negative effect on the measurable MTR. Future studies will be focused on improving the acquisition protocol, refining the image segmentation method and assessing the value of the method presented here in the investigation of neurological diseases.

REFERENCES: 1) Schiffmann, R., van der Knaap, M.S. (2009), Neurology. 72, 750-759. 2) Tsukagoshi, H. et.al. (1979), J. Neurol. Sci. 41, 287-297. 3) Gilmore, C.P., et.al. (2006), Brain. Pathol. 16, 202-208. 4) Sathasivam, S. (2010), Sing. Med J. 51, 367-72. 5) Oh, J. et.al. (2013), Neurol. 80, 540-547. 6) Yiannakas, M.C.et.al (2012), Neuroimage. 63, 1054-9. 7) Horsfield, M.A.et.al. (2010), Neuroimage.50, 446-55.