MRI ACQUISITION AND ANALYSIS PROTOCOL FOR IN VIVO GREY MATTER AND WHITE MATTER CROSS-SECTIONAL AREA MEASUREMENTS IN THE LUMBO-SACRAL ENLARGEMENT AT 3T

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TARGET AUDIENCE: Neurologists studying diseases that affect the grey matter (GM) and white matter (WM) of the spinal cord (SC) as well as Physicists involved in the development of structural and quantitative MR techniques.

PURPOSE: To present a clinically viable method for measuring the mean cross-sectional area (CSA) of GM and WM within the lumbo-sacral enlargement (LSE) *in vivo* using a 3T MRI system and to provide previously unreported normative data from a pilot study on five healthy control subjects.

INTRODUCTION: The successful segmentation of GM and WM within the SC allows the study of tissue-specific disease within an important neurological structure. The SC is affected by a number of diseases including multiple sclerosis (MS) which manifests focal and diffuse abnormalities in both tissue types [1], with a resulting long-term loss of volume indicative of atrophy and correlating with neurological disability [2]. While the consequent reduction in the CSA of the SC is underestimated through conventional imaging due to signal-to-noise (SNR) limitations and movement artefact, a robust *in vivo* technique has already been demonstrated in the cervical spine [3]. Similar measurements in the lumbar spine are warranted albeit challenging due to the variable position of the LSE and differences in physiological motion affecting the image quality. This work presents an optimised, high resolution, *in-vivo* imaging protocol for imaging the LSE using a 3T MR system. The optimised protocol is used to scan a number of healthy control subjects and the subsequent images are segmented to obtain WM and GM mean CSA measurements.

METHOD: A) Study participants: five healthy control subjects were recruited (mean age 27 years, 2 male, 3 female). Informed consent was obtained from all participants and the study was approved by the local institutional review board. B) MR Imaging: Using a 3T Philips Achieva MRI system with RF multi-transmit technology (Philips Healthcare, Best, Netherlands) and the manufacturer's 16-channel neurovascular coil and 15-channel SENSE spine coil, the LSE was imaged (the first slice positioned at the superior margin of the T11 vertebral body and extending minimally to the inferior border of L1 - Figure 1), with 19 contiguous axial slices (i.e. perpendicular to the cord). An optimised fat-suppressed 3D slab-selective fast field echo (FFE) sequence was used with the parameters: TR = 23 ms; TE = 4.4ms; flip angle, $\alpha = 10°$; FOV= 180 x 180 mm; voxel size = 0.5 x 0.5 x 5 mm^3; NEX = 8; for a scanning time of 19:27 min. To minimise motion during imaging, particular attention was given to subject comfort and immobilization and involved placing a large foam wedge beneath the subject's legs with a combination of torso restraints and a compatible cervical collar. All participants underwent repeated scans on three separate occasions to ensure scan-rescan reproducibility; expressed as a percentage coefficient of variation (COV%). Intra- and inter-observer reproducibility in terms of COV% was established by the observer assessing the subjects' first scan on three separate occasions and by comparing their performance with that of a second and third observer. C) Imaging analysis: Using the Jim Software (Xinapse systems, www.xinapse.com) and the active surface model (ASM), seed points were initially positioned in the central cord of all axial slices and CSA measurements were obtained. In each subject, the slice with greatest CSA was identified and included for further study along with the two adjacent slices (i.e. 15 mm section) whereas GM segmentation was performed based on a previously reported method [3] (Figure 2). Statistical analysis was performed using SPSS.

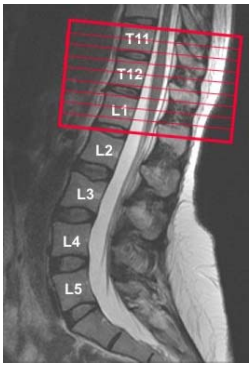

Figure 1. Example position of axial slices

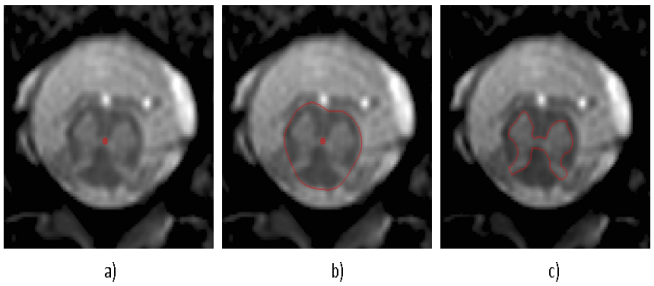

Figure 2. Segmentation of the LSE using the ASM model a) Axial 3-D FFE image (resolution = 0.5 x 0.5 x 5mm^3) through the LSE with seed point in situ b) delineation of cord boundary where LSE-CSA is measured c) GM segmentation where LSE-GM-CSA is measured.

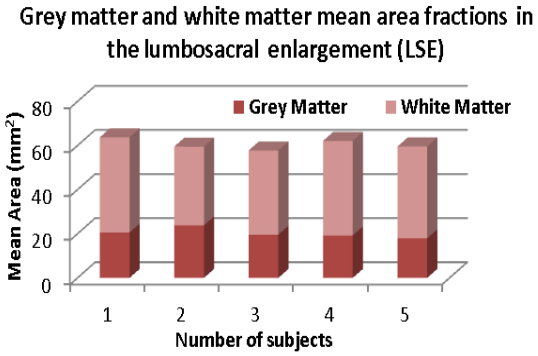

Figure 3. GM and WM mean area fractions measured in a 15mm section though the LSE in 5 healthy subjects.

RESULTS: Mean LSE-CSA (± SD) for the five subjects was 60.8 (± 1.5) mm^2 and the mean (± SD) LSE-GM-CSA was 17.1 (± 0.6) mm^2. Figure 3 shows the GM and WM mean area fractions measured in a 15mm section though the LSE in 5 healthy subjects. The mean scan-rescan, intra- and inter-observer % coefficient of variation for measuring the LSE-CSA were 2%, 2% and 2.5%, respectively. The mean scan-rescan, intra- and inter-observer % coefficient of variation for measuring the LSE-GM-CSA were 7.8%, 8% and 8.6%, respectively.

CONCLUSION: A method has been presented here which enables tissue-specific CSA measurements in the LSE of healthy control subjects with the use of a clinically available MR system. Optimisation of MR parameters for use within the lumbar spine coupled with effective subject immobilisation allow CSA measurements of the GM and WM with a good scan-rescan, intra- and inter-observer reproducibility. Future investigations will be directed at assessing the potential of the method presented here to study the SC in disease state as well as its potential to facilitate multi-parametric research MR investigations.

REFERENCES: 1) Gilmore C. P et al, (2009), Multiple Sclerosis, 15: 180-188. **2)** Losseff N. A et al, (1996), Brain, 119: 701-708. **3)** Yiannakas M. C et al, (2012), Neuroimage, 63: 1054-1059.