PRELIMINARY INVESTIGATION OF ULTRASHORT T2* IN HEALTHY CERVICAL CORD GREY MATTER AND WHITE MATTER IN VIVO AT 3T

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TARGET AUDIENCE: Physicians and Physicists interested in spinal cord imaging and myelin content in the spinal cord

PURPOSE: To investigate the feasibility of short T2* component measurements in grey matter (GM) and white matter (WM) in the healthy spinal cord

INTRODUCTION: Pathological studies have shown that diseases such as amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS) and neuromyelitis optica (NMO) can affect grey matter (GM) and white matter (WM) differentially in the spinal cord [1-3]. Therefore, tissue-specific (i.e. GM and WM) quantitative MR investigations in the spinal cord have real potential to provide clinically relevant information in conditions like these. Ultrashort echo time (UTE) MRI is a method more commonly used to study tissue components that have very short T2* relaxation times i.e. < 5ms (e.g. bone, tendons) and which are usually undetected with the echo times (TE) used in conventional clinical imaging [4]. Recently, the use of UTE has been proposed for the study of nerve tissue showing potential for probing myelin content [5]. In this work we present a pilot investigation into the feasibility of measuring ultrashort T2* in healthy cervical GM and WM using 3D UTE MRI by sampling two ultrashort echo times, chosen such that any signal decay between these would depend predominantly on the ultrashort T2* components, with negligible influence from the longer T2* components.

METHOD: A) Study participants: Five healthy control subjects were recruited (mean age 35.6 years, range 31-45, 3 male). 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 (Philips Medical Systems, Best, Netherlands) and only the neck elements of the manufacturer's product 16-channel neurovascular (NV) coil, the cervical spine was imaged in the axial plane (i.e. slices perpendicular to the cord) with the centre of the imaging volume positioned at the level of the C2-3 intervertebral disc (Figure 1A). To achieve the short echo times needed, a 3D-UTE excitation with a radial stack of stars readout was used with TR = 37ms; TE = 0.16 / 1.7 ms; pixel BW = 660 Hz; flip angle $\alpha = 10°$; FOV= 80 x 80 mm^2; voxel size = 0.5 x 0.5 x 5 mm^3; NEX = 1; 46 contiguous slices; scanning time ~ 15min (per TE); total scan time was ~30min. C) Image analysis: The two volumes acquired using different TE were first cropped in the x-y plane and then registered using the linear registration toolkit within the FSL software package (http://www.fmrib.ox.ac.uk/fsl/). Using the Jim Software (Xinapse systems, www.xinapse.com) a 15 mm segment was analysed by extracting the same three slices (middle slice through the C2-3 intervertebral disc) from each one of the registered volumes. Image segmentation was performed using the sum-of-echoes image (Figure 1B), firstly by segmenting the total cord volume (TCV) of the 15 mm segment using the active surface model [6] and, secondly, by extracting the total grey matter volume (TGMV) with a semi-automated method that uses the fuzzy connector tool [7] available with the Jim software as previously described using the same image resolution [8] (Figure 1C). A linear fit of the natural logarithm of the signal intensities in the two echoes (2-point fit) was computed within the GM and WM masks independently.

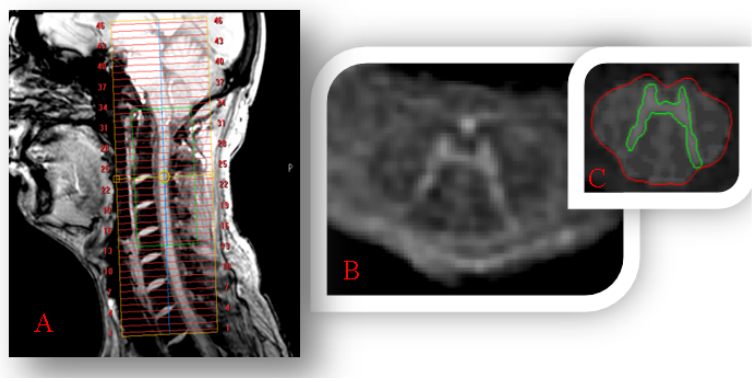

Figure 1. A) Prescription of the 3D-UTE volume in the axial plane B) Sum-of-echoes image (TE=0.16/1.7ms) through C2/3 disc C) GM and WM segmentation boundaries

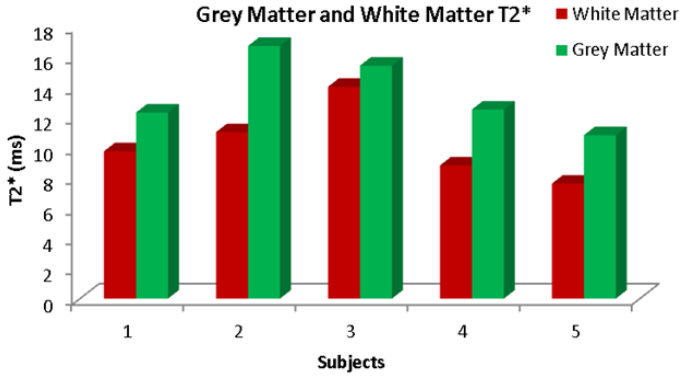

Figure 2. GM and WM T2* measurements in 5 healthy control subjects.

RESULTS: The UTE images obtained using our optimised protocol were of sufficient quality and contrast to visually depict GM and WM clearly. In 5 healthy control subjects, mean (± SD) T2* in GM was found to be 13.6 (± 2.4) and in WM was 10.3 (± 2.4). Figure 2 shows a bar chart of the values obtained in each healthy subject independently. The difference in short T2* values between GM and WM was investigated using a paired t-test and this was found to be statistically significant ($p<0.001$).

CONCLUSION: The results from this study suggest that the short T2* of GM and WM tissue, calculated using ultrashort TE's is statistically different. The values obtained in this pilot study are unlikely to represent a direct measure of myelin but it can be postulated that the contribution from myelin is likely to be substantial. This is further supported by considering the known difference in myelin concentration between GM and WM. However, the exact nature of the measured values obtained in this study is likely to be affected by contributions from a range of macromolecular structures, such as phospholipids in cell membranes. Although for the absolute measurement of T2* components multiple echoes should be acquired, these would not be clinically feasible. Here we have demonstrated that it is possible to characterise WM and GM short T2* of the spinal cord using a two-point fit in healthy subjects *in vivo*. The sensitivity to pathological changes of this measure will reveal its clinical utility. Post mortem studies will be required to validate the measurements against histological findings in order to determine the specificity of the proposed measure.

REFERENCES: 1) Tsukagoshi, H et al, (1979), J. Neurol. Sci. 41: 287–297 2) Gilmore, CP et al, (2006), Brain Pathol. 16: 202–208 3) Jarius & Wildemann, (2010), Nat. Rev. Neurol. 6: 383–392 4) Robson, MD et al, (2003), J Comput Assist Tomogr, 27: 825-846 5) Horch RA et al, (2011), MRM, 66: 24-31 6) Horsfield M, A et al, (2010), Neuroimage, 50: 446-455 7) Udupa JK, Samarasekera S. (1996), Graphical Models and Image Processing, 58: 246-261 8) Yiannakas, MC, (2012), Neuroimage, 63: 1054-1059.