

MR Diffusion Tensor Imaging in Cervical Spondylotic Myelopathy

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Introduction: Greater than half of the middle-age population demonstrates radiological or clinical evidence of degenerative changes in the cervical spine.¹ Cervical spondylotic myelopathy (CSM) is the most common type of spinal cord dysfunction where the spinal cord is compressed and if left unabated, can cause debilitating quadraparesis with loss of mobility, balance, bladder and bowel control.¹ CSM patients undergo surgery to prevent further neurological deterioration with the hope of some functional recovery. Unfortunately, the outcome of surgery can be unpredictable leading to ~35% improvement, ~25% worsening and no change in ~40%.^{2,3} A potential barrier to restoring function is permanent anatomical changes and functional reorganization of the central nervous system. Diffusion Tensor Imaging (DTI) provides information about the structural integrity of axonal white matter by measuring the directionality (anisotropy) and magnitude of water diffusion in the brain. The purpose of this study was to assess the Fractional Anisotropy (FA) and Mean Diffusivity (MD) in the motor and sensory cortex of CSM patients compared to healthy controls.

Methods: Seventeen patients with CSM (10 males, 15 right-handed, age 52.5 ± 10.1) and ten healthy controls (6 males, 10 right-handed, age 45.4 ± 12.5) underwent DTI. All MR data were acquired on a 3.0 T Siemens Magnetom Tim Trio (Erlangen, Germany). Anatomical MPRAGE images (192 slices, 1 mm isotropic, TR/TE = 2300/3.42 ms, TI = 900 ms) were acquired in each subject. Diffusion weighted scans of the brain were acquired using 15 diffusion encoding directions (75 slices, 30 directions, iPAT=3, TR/TE = 10000/83 ms, b-value=1000s/mm²) using a twelve channel head coil with a neck and spine array. The diffusion weighted scan was approximately 6-8 minutes. Brain Voyager QX V2.2 was used for DTI analysis. A diffusion-weighted magnetic resonance image (DMR) and a volumetric magnetic resonance image (VMR) was defined for each subject. The VMR data was used to strip the skull and create a mask of the brain to avoid processing background noise. The DMR was then co-registered with the VMR. A volume diffusion weighted (VDW) image was generated and subsequently used, along with the mask created previously, to measure FA and MD. Regions of interest were defined for each subject in the white matter adjacent to the motor and sensory cortex (Figure 1). Functional assessment was completed by each subject at the time of the MRI scan including Neck Disability Index (NDI), American Neurological Classification of Spinal Cord Injury (ASIA) and Japanese Orthopaedic Association (JOA) questionnaires. NDI, ASIA and JOA scores were compared using a two-tailed Student's t-test with alpha error at 0.05. FA and MD values were compared between groups using a two-tailed Student's t-test with alpha error of 0.05. Spearman rank correlation was used to determine the association between the FA and MD values and questionnaire scores.

Results and Discussion: Figure 2 shows the coronal T1 weighted anatomical image (left) with the corresponding FA (middle) and MD (right) maps of a CSM patient. CSM patients demonstrated an increased FA in the right motor cortex compared to the healthy controls (0.40 ± 0.04 and 0.37 ± 0.02 respectively, $p = 0.02$). There was a trend towards increased left motor cortex FA in the CSM patient group compared to controls (0.42 ± 0.03 and 0.38 ± 0.05 respectively, $p = 0.05$). Increased FA may be a response to the natural resolution of inflammation as observed in previous spinal cord studies.⁴ Inflammation and degradation of neurons may be separated and occurring at different time points of the disease. Increased FA may also represent a decrease in the freedom of the motion/diffusion of the water in the neuron due to increased glial activity. There were no statistically significant differences in MD. The CSM and control groups were significantly different in the functional NDI, ASIA and JOA scores. Interestingly, the right sensory cortex FA correlated with the JOA score ($r^2 = 0.37$, $p = 0.006$) in the CSM patient group suggestive of axonal loss in patients with advanced sensory decline.

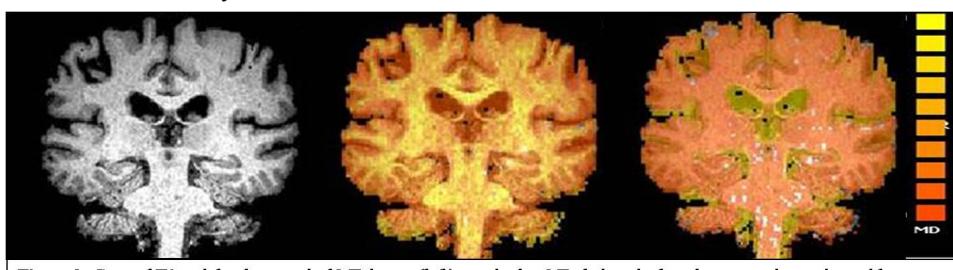


Figure 2: Coronal T1 weighted anatomical MR image (left) acquired at 3 Tesla in spinal cord compression patient with corresponding FA (middle) and MD (right) maps from the brain.

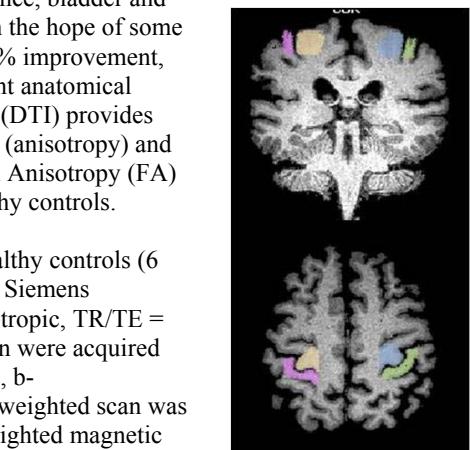


Figure 1: Region of interests (ROI) used for FA and MD analysis. Yellow and blue ROIs depict the left and right primary motor cortex, respectively. Pink and green ROIs depict the left and right primary sensory cortex, respectively.

Conclusions: FA values were significantly increased in the CSM patient group compared to controls in the right motor cortex and a similar trend was observed in the left motor cortex. FA in the right sensory motor cortex correlated with the patients JOA scores. Future work will include assessment of FA and MD in white matter tracts leading to these cortical areas.

References: [1] Bernhardt M *et al.* J Bone Joint Surg 75A:119-126, 1993. [2] Fager CA. Clin Neurosurg 25:218-244, 1978. [3] Bishara SN. J Neurol Neurorug Psychiatry 34:393-395, 1971. [4] Facon D *et al.* AJNR Am J Neuroradiol 26:1587-1594, 2005.