Two-component Low Q-space Diffusion MRI in Evaluation of Spinal Cord in Patients with Cervical Spondylosis in Vivo: a Feasibility Study

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Target audience: Researchers and clinicians who investigate the spinal cord by using diffusion-weighted imaging and diffusion metrics.

Introduction: Measuring axon diameter using diffusion-weighted MR imaging technique is expected to be a powerful tool in evaluation of microstructure of neural tissue in vivo; however, it remains to be used in daily clinical study due to several hardware limitations such as gradient strength in clinical MR imager. In the literatures, Ong and his collages showed the feasibility of implementing low q-value diffusion MRI on a 1.5T scanner to assess regional axonal architecture. The purpose of this study is to investigate two-component low q-space diffusion MRI in evaluation of microstructural changes in the spinal cord in patients with cervical spondylosis in vivo, as a feasibility study.

Methods: Five patients with known cervical spondylosis were enrolled in this study (two women and seven men, age range 26–78 y, mean age 53.4 y). After conventional MR imaging, q-space imaging data was acquired with a 3-T MR scanner with a body coil excitation and a 16-channel neurovascular SENSE coil for reception. Imaging parameters were as follows: repetition time/echo time, 4000/127 (ms/ms); number of signals acquired, three; section thickness, 8 mm; 12 slices; field of view, 64 x 51 mm^2; matrix, 64 x 51 (128 x 128 reconstructed); imaging time, approximately 13 min; 16 *b* values (0, 62, 247, 555, 986, 1541, 2219, 3020, 3944, 4992, 6163, 7457, 8874, 10415, 12079, and 13866 s/mm^2) with diffusion encoding in one direction (perpendicular to spinal cord) for every *b* value. Gradient length (δ) and the time between the two leading edges of diffusion gradient (△) were 20.9 and 62.9 ms, respectively. As described in the literature[2], two-compartment signal decay at low q-values is given by the formula. $E(q)=(1-f_I)\bullet\exp(-2\pi^2q^2Z_E^2) + f_I\bullet\exp(-2\pi^2q^2Z_I^2)$, where f_I is the relaxation-weighted intra-cellular space (ICS) volume fraction, Z_E and Z_I are root mean square displacement of water molecules in the extra-cellular space (ECS) and ICS. Z_E, Z_I, f_I and R^2 (goodness of fitting) maps were generated by using in-house software developed m-file program of MATLAB. Regions of interests (ROIs) were placed in lateral white matter columns manually. ROIs were divided into two groups, affected area, where spinal cords were compressed, and unaffected area while referring to conventional MR images, such as T2-weighted images. Statistical evaluations were performed by using IBM SPSS Statistics software (version 19.0; SPSS, Chicago, IL) using Mann-Whitney U test. P value less than 0.05 was considered to indicate a statistically significant difference.

Results: Image quality of QSI data was gradually degraded with higher b-value imaging. More than 60% images were not suitable for analysis and excluded from this study. There was a significant difference in Z_I between affected area (mean 3.53 ± 0.65μm) and unaffected area (mean 2.29 ±0.43μm) (P< .001). There was a significant difference in Z_E between affected area (mean 18.23 ± 2.41μm) and unaffected area (mean 14.73 ± 2.69 μm) (P= .029), but the Z_E values seem to be larger than the past literatures. There were no differences in f_I and R^2.

Discussion: The larger Z_I in affected area may show the pathological microstructural change in the spinal cord, such as partial axonal loss or twisting of white matter axons. More studies of the imaging pathological correlation and improvement of image quality are needed; this technique has the potential to provide new information in patients with spinal cord in vivo.

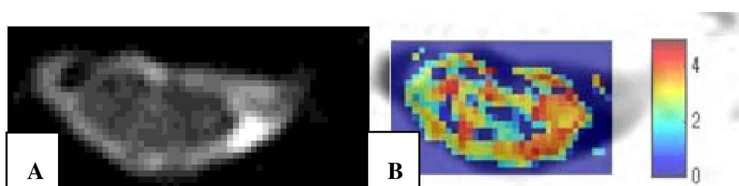

Figure 1. Representative b=0 image (A) and ZI (root mean square displacement of intra-cellular space) map. .(Unit for RMSD is µm)

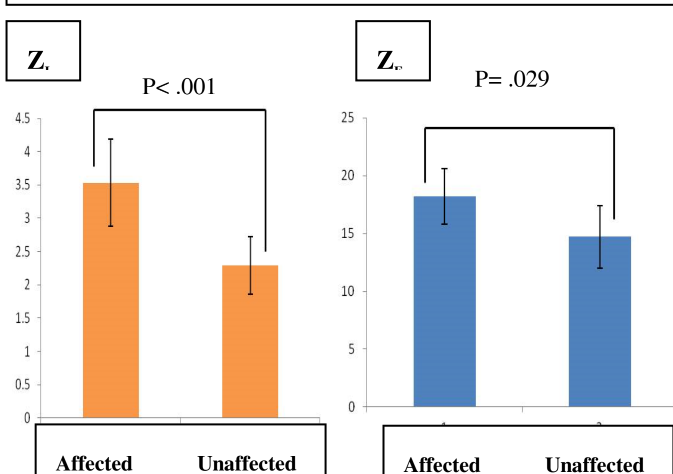

Figure 2. Bar graphs of .mean Z_I and Z_E with the standard deviation lines. (Unit for RMSD is µm)

References: **1**. Ong HH, Bhagat Y, Magland J, et al. Feasibility of low q-space diffusion MRI at 1.5T. Proc. Intl. Soc. Mag. Reson. Med. 20 (2012).**2**. Ong HH, Wehrli FW. Quantifying axon diameter and intra-cellular volume fraction in excised mouse spinal cord with *q*-space imaging. Neuroimage 2010;51(4) : 1360-1366.