Apparent Diffusion Coefficient and Fractional Anisotropy of Spinal Cord: Changes Related to Age and Cervical Spinal Spondylosis.

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INTRODUCTION.

Cervical spondylotic myelopathy is a clinical entity that sometimes is associated with intramedullary high signal lesions on T2-weighted images. In cervical spondylosis patients with neurological symptoms, early decompression of the compressed spinal cord segment is considered necessary for optimal prognosis. However, standard and objective criteria upon which surgical indications should be based have not yet been established. Consequently, therapeutic success tends to be highly variable. The important anatomic information seen on diagnostic MRI complements clinical findings and informs the decision to perform surgery in symptomatic cervical spondylosis. The presence of high signal intensity lesions on T2-weighted MR images of the spinal cord, however, is not a reliable indicator of spinal cord damage typically associated with this syndrome. Indeed, the success of decompression surgery is difficult to predict from T2-weighted images alone [1]. We explored diffusion imaging as a new approach to assess patho-physiological changes in the spinal cord. We applied line scan diffusion tensor imaging to cervical spondylosis patients in order to determine changes in water diffusion at the affected level of the spinal cord.

MATERIALS AND METHODS.

The imaging protocol included T1-weighted localizing scans, T2-weighted fast spin echo sagittal images, and sagittal line scan diffusion-weighted tensor scans. Line scan diffusion imaging (LSDI)[2] was performed on a 1.5 Tesla GE Horizon whole-body MR system in 11 normal volunteers and 80 clinically diagnosed cervical spinal spondylosis patients. Seventy-two patients were without any abnormal lesions on the T2-weighted images and 8 patients demonstrated T2-weighted signal abnormality. Diffusion-weighted imaging was performed with the following parameters: TR/TE, 2714/118 ms; rectangular FOV, 220 x 110 mm; slice thickness, 4 mm; matrix size, 128 x 128 (frequency x column); bandwidth, +/- 3.91 kHz; number of excitations, 1. Images were scanned at two different diffusion weightings (b-factors of 5 and 1000 s/mm^2). Diffusion weighting for the high b-factor was applied along 6 non-collinear directions. Scan time per slice was 65 seconds. A phased array spine coil was used for all scans. For each subject, the mean apparent diffusion coefficient (ADC) and fractional anisotropy (FA) value were determined within two regions of interest (ROIs); one at the relatively wide upper spinal canal level C2 to C3, and one at a narrow spinal canal level (C4 to C7 in normal subjects and at the level of the most severe canal stenosis in patients). For the patients with high signal lesions on the T2-weighted images, the narrow spinal canal measurement was performed within the area of the lesion.

RESULTS.

For all subjects, ADC value within the normal spinal cord at the wide spinal canal level correlated positively with age (correlation coefficient, 0.244), and FA value correlated negatively with age (correlation coefficient, -0.242, Fig. 1). The mean ADC value of 11 normal volunteer scans at the upper wide spinal canal level C2 to C3 was 0.81 +/- 0.03 µm^2/msec. At the lower narrow spinal canal level C4 to C7, the mean ADC was 0.75 +/- 0.06 µm^2/msec, which was lower than upper wide spinal canal level (p=0.01). Mean FA value within the spinal cord in normal volunteers was 0.70 +/- 0.05 at the upper wide spinal canal level, and 0.66 +/- 0.03 at the lower narrow spinal canal level, i.e., lower than narrow spinal canal level (p=0.02). ADC change in spinal cord at the wide and narrow/ed spinal canal level for all subjects is shown in Fig. 2. Forty-six percent (Patient Group A in Fig. 2) of all spondylosis cases showed no elevation in ADC and no decrease in FA value of the spinal cord at the narrowed spinal canal level compared with the value within the normal spinal cord at the wide spinal canal level, while 54 % (Patient Group B in Fig. 2) showed elevated ADC (p<0.001) and decreased FA (p<0.05) value within the spinal cord at the narrowed spinal canal level (example case shown in Fig. 3). Fifteen out of 39 patients with diffusion abnormality within the spinal cord at the narrowed spinal canal level demonstrated clinical signs of myelopathy. The cases without diffusion abnormality did not present clinical myelopathy, but radiculopathy and neck and shoulder pain. Average age of patients with diffusion abnormalities was 13 years older than patients without diffusion abnormalities. High signal lesions on T2-weighted images presented statistically significant elevated (p<0.05) ADC and decreased FA (p<0.05) values compared with the values in the normal spinal cord section. Average ADC and FA of T2-weighted high signal lesions were 1.28 +/- 0.33 µm^2/msec and 0.46 +/- 0.12, respectively.

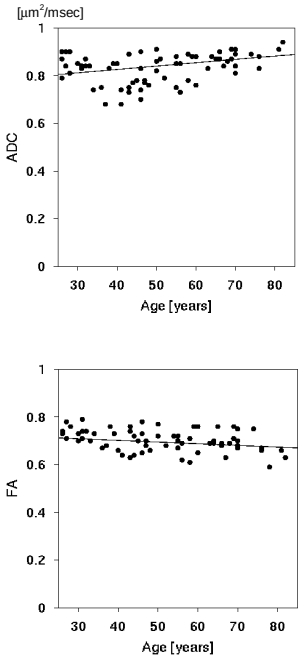

Fig. 1: Age vs. FA and ADC.

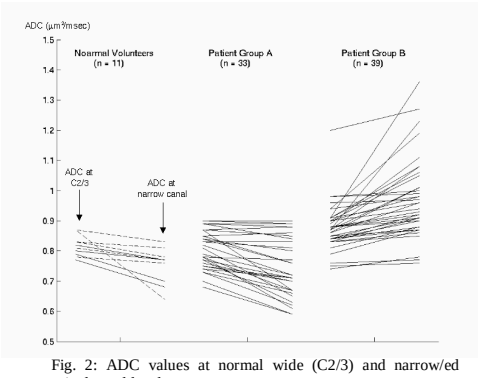

Fig. 2: ADC values at normal wide (C2/3) and narrow/ed spinal canal level.

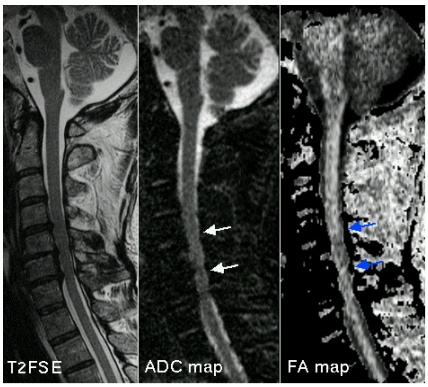

Fig. 3: Patient without abnormal signal on T2-weighted image demonstrates slightly elevated ADC and decreased FA in the segment between the arrows.

DISCUSSION.

The mean ADC of the normal spinal cord at the upper wide spinal canal level increases slightly with age, whereas the mean FA value decreases slightly with age. In normal adult brain, increase in ADC and decrease in FA values with age has been reported [3]. Our results indicate that patients with clinical myelopathy demonstrate diffusion abnormalities within the affected section of the spinal cord, and even though a patient does not show clinical sign of myelopathy, ADC and FA may be indicators of early change in the affected spinal cord. Cervical spinal spondylosis is one of the aging syndromes and more severe cases should have had spondylotic canal stenosis for longer period of time. Long-standing spinal canal stenosis causes blood circulation disturbnace and may have a role in water diffusion change of the spinal cord. Although histopathologic study or cohort study should be conducted to prove relationship between diffusion abnormality and spinal cord pathology, ADC elevation and FA decrease that occurs prior to signal elevation on T2-weighted images may have a strong correlation to early changes in the spinal cord tissue at the section of the chronically narrowed spinal canal. Moreover, it may prove useful in assessing the severity of long-standing ischemia of spinal cord and in facilitating adequate timing of decompression surgery before irreversible changes in the spinal cord occur.

REFERENCES.

[1] Okada et al., *Spine* 18:2024-2029. [2] Gudbjartsson et al., *MRM* 36(4):509-519. [3] Pfefferbaum et al., *MRM* 44(2):259-268.