Diffusion tensor MR imaging of the healthy human cervical, thoracic and lumbar spinal cord

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Introduction

Diffusion tensor imaging (DTI) allows us to examine the in *vivo* integrity of white matter microstructures[1]. Application of this technique to the injured spinal cord will enable the evaluation of white matter damage and may be used to predict outcomes and guide therapeutic intervention [2]. Despite its potential as a clinical tool, the application of DTI is limited by the absence of normative data for comparison [3]. Furthermore, estimating the stability of DTI indices in the healthy cord is required for proper group comparisons between heterogeneous patient populations and healthy controls[4]. The aim of this study was to compare DTI indices, including fractional anisotropy (FA) and apparent diffusion coefficient (ADC), for three sections of the spinal cord: cervical (C2-C7), thoracic (T3-T8) and lumbar (T10-L1) (see Fig. 1 A).

Methods

Data acquisition. A single-shot EPI sequence was used to acquire diffusion-weighted images of the cervical, thoracic and lumbar regions of the spinal cord in healthy subjects (20-35 yrs.). Images were acquired using a 3T Siemens Magnetom Trio using the following parameters: TE= 103ms, TR= 660ms, b-value=700s/mm^2, 20 directions, SENSE parallel imaging acceleration factor of 2, matrix size= 128x 128, and slice thickness= 3mm. Twenty-eight transverse interleaving slices were acquired from each section of the cord. Cardiac gating was applied to reduce the motion distortions that result from pulsating CSF.

Analysis. All analyses were completed using custom-made software, written in MatLab. For each section of the cord, three region of interest (ROI) maps were manually drawn on the B_0 maps to indicate the cord location. ROI maps were interpolated to include the full length of the cord sections. For each cord section, FA versus ADC values were plotted and a k-means clustering method was applied to partition the data into three mutually exclusive clusters (Fig. 1B). Centroids, which indicate the center point of the cluster, were computed. Clusters with high FA values and low ADC values are attributed to white matter (WM), while clusters with low FA values and low ADC values are attributed to grey matter (GM). Clusters with low FA values and very high ADC values are attributed to cerebral spinal fluid (CSF) and other noise. The 2D coordinates of the centroids are the mean ADC and FA values for each cluster, and these were compared between cervical, thoracic and lumbar regions. All comparisons were made using a 2-tailed, one sample t-test with unequal sample sizes and unequal variance, $p<0.001$.

Results

Mean FA and ADC values for each of the clusters identified with k-means clustering are listed in Table 1 below. Based on these values, we attribute the clusters to primarily white matter, gray matter, and CSF, as indicated. Comparisons between mean ADC and FA values are also shown.

	WM Cluster		GM cluster		CSF cluster	
	ADC (x10^{-3} mm^2/s)	**FA**	**ADC** (x10^{-3} mm^2/s)	**FA**	**ADC** (x10^{-3} mm^2/s)	**FA**
Cervical	0.92 ± 0.32 †	0.84 ± 0.15 ‡	1.4± 0.60 †	0.54 ± 0.15 ‡	2.6± 1.0 †	0.26 ± 0.15 †
Thoracic	0.97± 0.32 *‡	0.84± 0.15 ‡	1.5± 0.33 *	0.53 ± 0.15 ‡	2.9± 0.60 *‡	0.24 ± 0.15 *‡
Lumbar	0.93± 0.32 †	0.83± 0.15 *†	1.4± 0.33	0.52 ± 0.15 *†	2.6± 0.36 †	0.25 ± 0.15 †

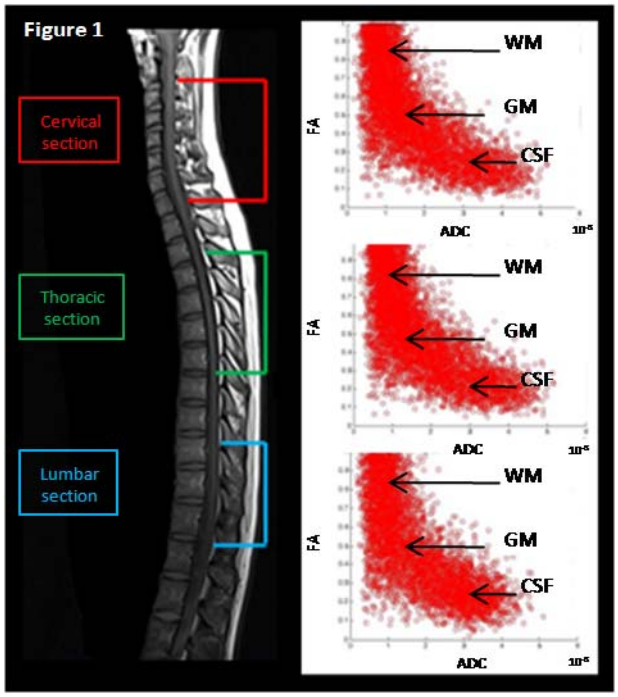

Table 1: Summary of ADC and FA values measured in the cervical, thoracic and lumbar spinal cord. The symbols *, †, and ‡,indicate significant differences ($p < 0.001$) from values measured in cervical, thoracic, and lumbar regions, respectively.

Conclusions

Although at the group level the differences in the FA and ADC values were significant, the uncertainty of measurements from each individual are large compared to the differences between the group means. Differences in DTI indices after injury are also much more pronounced than the subtle differences at the group level. Therefore, given the observed consistency of ADC and FA values along the entire spinal cord, group comparisons between injured and healthy DTI indices are expected to be valid between different sections of the cord. Data from this study will be useful for clinical comparisons of DTI indices measured with pathological conditions of the spinal cord.

Figure 1: (A) Sagittal view of the spinal cord indicating the cervical, thoracic and lumbar regions, and (B) FA vs. ADC plots for the three regions of the cord.

References

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