Diffusion tensor imaging and quantitative tractography in chronic spinal cord injury

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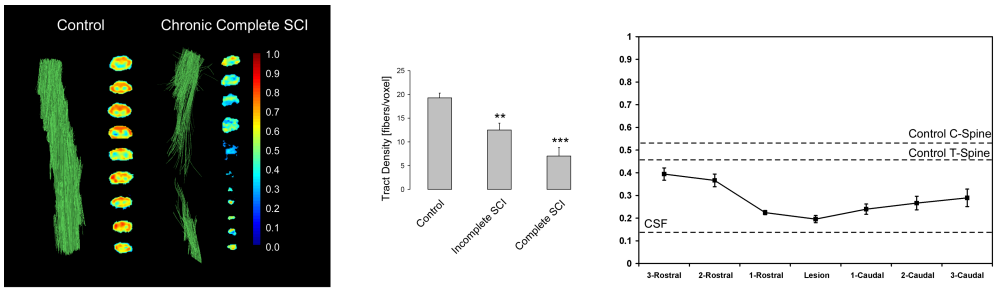
Introduction

Diffusion tensor imaging (DTI) has been used to evaluate acute spinal cord injury (SCI) in both humans and animal models; however, no studies have examined changes in diffusion characteristics in the chronic stage of injury. In this study we have examined diffusion characteristics and quantitative tractography in human subjects with chronic SCI.

Methods

Axial DTI of the entire spinal cord (C1 – L1) was performed in 13 neurologically-intact and 10 chronic SCI subjects using a clinically available single-shot, twice-refocused, spin-echo echoplanar pulse sequence. A CTL spine coil (GE Medical Systems, Milwaukee, WI) and 1.5-T clinical MR scanner (GE Signa Excite, GE Medical Systems, Milwaukee, WI) were used for all image acquisitions. Contiguous images were acquired with TE/TR = 96.3 ms/ 6000 ms, matrix size = 128x128, NEX = 1, FOV = 20 cm, and a slice thickness of 5 mm. Diffusion weighted images (DWIs) were collected with b = 1500 s/mm^2, in 25 directions, and a single T2-weighted (b = 0 s/mm^2) was collected for each slice. AFNI (http://afni.nimh.nih.gov) was used for Fourier transform-based affine registration of DWIs to the T2-weighted reference image using a constrained nonlinear least squares approximation [1]. Diffusion tensor tractography was performed in all subjects using the DTIQuery v1.1 software package (http://graphics.stanford.edu/projects/dti/dti-query/) using the TEND method [2], path step size = 2 mm, seed point spacing = 0.5 mm, FA termination threshold = 0.15, angle termination threshold = 45 degrees, minimum pathway length = 0.1 mm, and maximum pathway length = 30 cm. Tract density images, where contrast is based on the number of fibers passing through each respective voxel, were saved in NIFTI format and used for quantitative analysis.



A B C

Figure 1. A) DTI tractography and FA images of a control subject and subject with complete SCI. B) Fiber tract density for control, incomplete SCI, and complete SCI evaluated using DTI tractography. ** = $P < 0.01$ *** = $P < 0.001$. C) Group FA values 3 levels rostral to 3 levels caudal from lesion epicenter. Results show rostral-caudal asymmetry about the lesion site and decreased anisotropy compared to control subject

Results

Results indicated significant decrease in FA (*ANOVA*, $P < 0.001$) in chronic SCI subjects compared to intact subjects. Diffusion measurements indicated a significant increase in transverse, longitudinal, and mean diffusion at and around the lesion epicenter, along with a significant decrease in diffusion magnitude in the upper cervical spinal cord (*ANOVA*, $P < 0.001$). Quantitative tractography indicated significant differences between intact and chronic SCI subjects (*Tukey*, Control vs. Incomplete, $P = 0.003$; Control vs. Complete, $P < 0.001$). Significant rostral-caudal asymmetry was also observed in the FA (*Tukey*, $P < 0.001$ for all comparisons), which defined as differences between symmetric rostral and caudal levels (e.g. 1 level rostral compared to 1 level caudal). Results of this study show unique diffusion characteristics of chronic SCI compared to neurologically-intact subjects. Results are also unique compared to those reported in acute SCI[3], namely rostral-caudal asymmetry and a decrease in mean diffusion distal from the injury epicenter.

References

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