Assessment of Cervical Spinal Cord Injuries with Readout-Segmented Multi-shot (RESOLVE) Diffusion Tensor Imaging and Fiber Tractography

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Target Audience: People interested in clinical application of diffusion tensor imaging (DTI) for cervical spinal cord injuries (CSI)

Purpose:
The functional loss of the patients with cervical spinal cord injuries cannot robustly match the edema and compression shown in their MR images. Single-shot DTI in axial and sagittal planes causes marked distortion and lengthy scan time. To provide reproducible values with limited distortion with RESOLVE-DTI in sagittal sampling of the whole cervical spinal cord

Methods: From May 2012 to May 2014, we recruited 17 patients with cervical spinal cord injuries (8 male, 9 female, aged 22-77 years old, mean 52.5+/- 20.05) and 22 normal volunteers (11 male, 11 female, aged 24-50 years old, mean 36.73 +/- 8.74) for DTI of cervical spinal cord on a 3T whole-body scanner (Tim Trio, Siemens Healthcare). In the 17 patients, there were 10 patients with mild CSI (ASIA grade C–D) and 7 patients with severe CSI (ASIA grade A-B). Parameters: Anatomical images acquired with a sagittal T2WI [TR=3200ms,TE=139ms,slice thickness=3mm with gap of 0.3mm, FOV=300×300mm^2, matrix=512×358] and a transverse T2*WI [TR=3200ms, TE=137ms, slice thickness=5 mm without gap, FOV=120×120 mm^2, matrix 192×192]; RESOLVE-DTI were acquired with TR=2500ms, TE=65ms and 96ms, slice thickness=1.5 mm, FOV=120×120 mm, matrix 96×96, reconstructed image resolution 1.25 mm×1.25 mm, b value= 600 s/mm^2 in 30 directions of diffusion gradients, NEX 2, and GRAPPA 2. **DTI analysis:** RESOLVE-DTI and tractography calculation were performed using MRtrix (MR tractography including crossing fibers, http://www.nitrc.org/projects/mrtrix/) and Matlab 7.0 (MathWorks, Natick, Mass). A deterministic streamline tracking method was used by initiating at voxels with fractional anisotropy (FA) > 0.2 and stopping at voxels with FA < 0.1. The step size is set to be 0.1 mm. The tracks were defined by passing through 5 manually positioned ROIs at C2/C3, C3/C4, C4/C5, C5/C6 and C6/C7 disc levels. Then fibers passing through any 2 of ROIs were estimated. Their radial diffusivity (RD), axial diffusivity (AD), ADC and FA values were also evaluated, besides FA-value oriented color tractography.
Fiber-tracking algorithms: Datasets of whole cervical spinal cords were converted by specifying the masks. ROI of C2/C3 was chosen to be the threshold and multiple ROIs could be specifically added above, at and below the injured levels and adjacent disc levels. Statistics: FA and ADC values above, at, and below the injured levels of the cords were compared with the normal values.

Results: Lower FA values were found in the more severely injured patient group (ASIA grade A-B), but there was no significant difference in ADC values (Figure 2 & 3). Though severe spinal stenosis and cord edema might be seen on T2WI, no insignificant difference was found in FA values between the normal group and mild injured group (ASIA grade C-D), explaining well about the common mismatch between clinical symptoms and imaging severity. RESOLVE-DTI dramatically reduces the traditional image distortion (Figure 1) in single-shot DTI and offers valuable and optimal image evaluation of the cervical spinal cord. FA had a tendancy to decrease from C2/C3 to C6/C7, while MD and AD tended to increase.
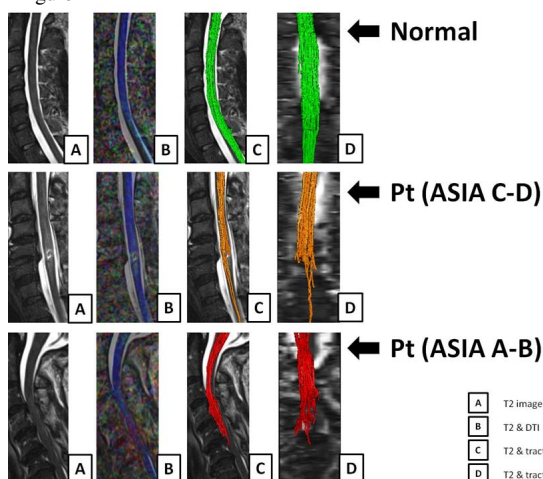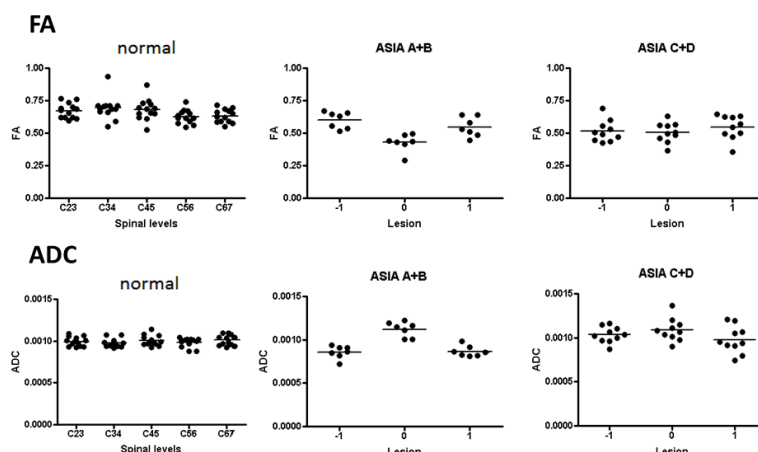
Figure 1

Figure 2

Figure 3

		Lesion			ONE-WAY ANOVA
		1	0	-1	
ASIA A+B (n=7)	FA	0.60 ± 0.064	0.43 ± 0.067	0.55 ± 0.075	P = 0.0005
	ADC (X10^{-3})	0.86 ± 7.39e^{-2}	1.12 ± 8.63e^{-2}	0.87 ± 6.10e^{-2}	P<0.0001
ASIA C+D (n=10)	FA	0.52 ± 0.083	0.51 ± 0.077	0.55 ± 0.092	p = 0.5522
	ADC (X10^{-3})	1.04 ± 9.15e^{-2}	1.09 ± 0.13	0.98 ± 0.15	P = 0.1596
Normal (n=22)	FA		0.66 ± 0.071		P = 0.0554
	ADC (X10^{-3})		0.99 ± 5.709e^{-2}		P = 0.4664

Conclusion:
RESOLVE-DTI is a useful tool to assess the cervical spinal cord injury, and provides reproducible quantitative values with limited distortion. FA is a better indicator in assessing the severity of CSI. Further follow-up DTI of the injured patient group may offer their prognostic values. Tractography offers optimal illustration and helps the surgeon to make plans of the surgical routes.

References:
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