In Vivo, High Resolution Diffusion Tensor Imaging (DTI) on Naive Rat Spinal Cord: from Cervial to Sacral Cord

J. H. Kim[1], K. E. Chaffee[1], and S-K. Song[1]
[1]Radiology, Washington University, St. Louis, Missouri, United States

Introduction: Preclinical studies of spinal cord injury and disease typically use rodent models. Diffusion tensor imaging (DTI) has been employed as a non-invasive diagnostic methodology to examine rodent spinal cord injury. Since DTI-derived parameters are independent of magnetic field strength, *in vivo* studies could allow for the inter-lab comparison and evaluation of these parameters. In this study, we present *in vivo* DTI parameter maps of the rat spinal cord encompassing the cervical, thoracic, lumbar, and sacral spinal cord regions at 4.7 T. The pixel-by-pixel fractional anisotropy (FA), axial diffusivity (λ‖), and radial diffusivity (λ⊥) maps accurately reflect spinal cord tissue structures.

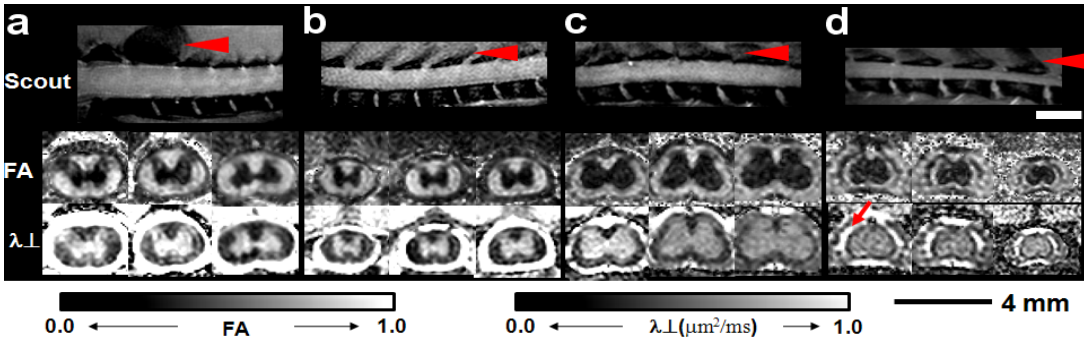

Figure. 1. Shown the representative FA and λ⊥ maps at cervical (a), thoracic (b), lumbar (c), and sacral cord (d). In scout images, the distinct shape of dorsal vertebrae, indicated by arrow head, differentiates the spinal cord levels. The both FA and λ⊥ maps provides clear gray/white matter contrast. The CSF, shown bright in λ⊥, clearly localize spinal cord parenchyma even at sacral cord.

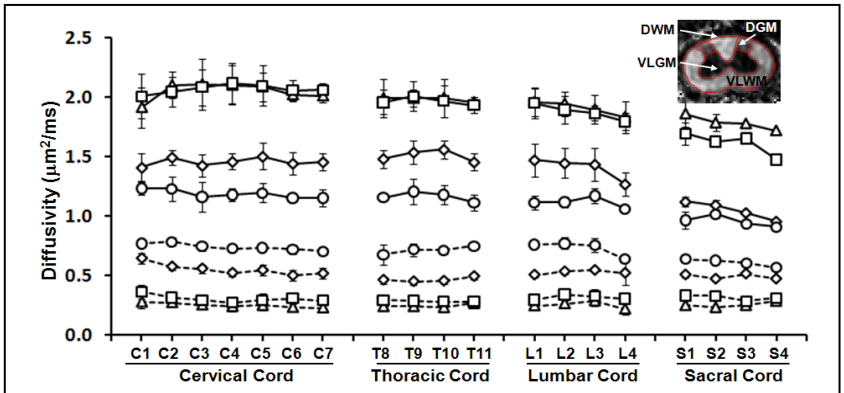

Figure. 2. The quantified λ‖ (solid line) and λ⊥ (dotted line) of DWM (△), VLWM (□), DGM (◇), and VLGM (○). n = 7 (mean ± SD).

Methods and Materials: Seven female Sprague Dawley rats weighing 200 – 225 g were employed. *In vivo* DTI studies were performed on a 4.7 T Varian scanner. A 12-cm inner diameter Helmholtz volume coil as an RF transmitter and 1.8 cm x 3 cm surface coil as an RF receiver were used producing images with an in-plane resolution of 156 μm × 156 μm × 1500 μm. The spin echo diffusion imaging parameters were: time between application of gradient pulses (Δ) 20 ms; diffusion gradient duration (δ) 5 ms; b-values of 0 and 1.0 ms/μm^2; and 6 icosa diffusion sensitizing gradients orientations.

Table 1. *In vivo* DTI parameters of rat spinal cord

		DWM[a]	VLWM[b]	DGM[c]	VLGM[d]	P a vs b	a vs c	a vs d	b vs c	b vs d	c vs d
FA	Cervical	0.87 ± 0.04	0.86 ± 0.04	0.56 ± 0.06	0.32 ± 0.03	0.05	✱	#	✱	#	✱
	Thoracic	0.88 ± 0.02	0.85 ± 0.02	0.60 ± 0.05	0.32 ± 0.02	0.03	✱	#	✱	#	✱
	Lumbar	0.86 ± 0.02	0.82 ± 0.01	0.55 ± 0.05	0.28 ± 0.03	0.04	✱	#	✱	#	✱
	Sacral	0.85 ± 0.03	0.79 ± 0.03	0.48 ± 0.07	0.32 ± 0.04	0.02	✱	#	✱	#	✱
λ⊥/λ‖	Cervical	0.12 ± 0.01	0.15 ± 0.02	0.38 ± 0.05	0.62 ± 0.01	0.01	✱	#	✱	#	✱
	Thoracic	0.12 ± 0.01	0.15 ± 0.00	0.31 ± 0.02	0.59 ± 0.03	0.01	✱	#	✱	#	✱
	Lumbar	0.14 ± 0.01	0.17 ± 0.02	0.36 ± 0.02	0.65 ± 0.02	0.01	✱	#	✱	#	✱
	Sacral	0.14 ± 0.03	0.19 ± 0.02	0.47 ± 0.06	0.62 ± 0.03	0.01	✱	#	✱	#	✱
# of Pixels	Cervical	89 ± 8	390 ± 32	80 ± 10	230 ± 32						
	Thoracic	50 ± 7	300 ± 28	50 ± 13	180 ± 15	Note: ✱: $P < 1.0 \times 10^{-4}$, #: $P < 1.0 \times 10^{-8}$, and $: $P > 0.3$					
	Lumbar	48 ± 9	250 ± 29	34 ± 11	400 ± 23						
	Sacral	17 ± 4	128 ± 34	38 ± 12	229 ± 43						

Results and Conclusions: All *in vivo* DTI maps had a signal-to-noise ratio (SNR) of ~40. FA and λ⊥ maps provided clear tissue contrast and spinal cord structure enabling accurate localization and quantification on a pixel by pixel basis (Fig. 1). Region of interest (ROI) analyses were performed on dorsal white matter (DWM), ventrolateral white matter (VLWM), dorsal gray matter (DGM), and ventrolateral gray matter (VLGm). The DTI parameters are shown with statistical analysis in Fig. 2 and Table 1. In general, white matter λ‖ was six times greater than white matter λ⊥ originating from long cylindrical axon structures. In contrast, values for λ‖ were relatively similar to λ⊥ in VLGM that is mainly composed of cell bodies. Intermediate values for DGM λ‖ and λ⊥ were determined reflecting the complex micro structural environment (i.e, mixtures of axons and cell bodies). Consequently, elevated anisotropy values were observed with an increase in axonal fraction in tissue. Interestingly, λ‖ demonstrated significant longitudinal variance from lumbar to sacral cord, which was not observed in other tissues or DTI parameters. These rat spinal cord DTI parameters may serve as reference for future inter-lab comparison of rat spinal cord diffusion measurements.