# Axial Diffusivity in Acute and Isolated Optic Neuritis

**R. T. Naismith[1], J. Xu[1], A. Snyder[2], T. Benzinger[2], J. Shimony[2], K. Trinkaus[3], A. H. Cross[1], and S-K. Song[2]**

[1]Neurology, Washington University, Saint Louis, MO, United States, [2]Radiology, Washington University, Saint Louis, MO, United States, [3]Biostatistics, Washington University, Saint Louis, MO, United States

## Background

Animal studies have indicated that axial and radial diffusivities can serve as a surrogate for axonal and myelin pathologic injury.[1-8] Animal studies of acute axonal injury have found a drop in axial diffusivity. Previous human studies in *chronic* optic neuritis indicate a marginal *increase* in axial diffusivity, and clinical correlation with ADC.[9,10] We sought to determine whether directional diffusivities in the acute setting have long-term predictive value for visual function.

## Methods

Four individual nerves with acute optic neuritis and no previous neurological events were imaged within 30 days of onset and followed prospectively over 6 months. Visual measurements included Pelli-Robson contrast sensitivity, Snellen visual acuity, and Ishihara color plates. Good recovery at 6 months was defined *a priori* as visual acuity ≥ 20/25 and Pelli-Robson ≥ 1.60. Poor recovery was defined by visual acuity ≤ 20/40 and Pelli-Robson ≤ 1.50.

MR data were acquired using a 4-element phased array flexible receiver coil on a 3-tesla MR scanner (Allegra, Siemens AG). A single shot spin-echo echo planar imaging (ss-SE-EPI) diffusion sequence was employed with fat-suppression. Reduced field of view (rFOV) technique was implemented with twice refocused diffusion weighting.[11] Diffusion weighted images were acquired trans-axially (FOV 168 mm × 84 mm, matrix 128 × 64, partial Fourier 6/8, TE 65 ms) with two collated groups of 1.3 mm slices. Each slice group was comprised of five interleaved slices and was cardiac gated, yielding a TR of 4 - 6 sec. Eight to twelve image data sets, each consisting of one image with B value of 0 and twelve DW images on twelve diffusion encoding directions (two sets of six icosahedral directions with opposite gradient polarity) with b value of 600 s/mm$^2$, were acquired for each slice group.[12] Each DTI data set (thirteen volumes with twelve diffusion weighted images and one with no diffusion weighting was motion corrected using an iterative procedure.[13] During the processing stage, excessive movement (≥ 3 mm translation in either direction) was identified, and those diffusion images were excluded from the averaging.

The region of interest (ROI) included voxels at the center of the nerve, selected manually on the $b_0$ image to include 15-20 voxels longitudinally starting 12-15 voxels posterior from the retina. Voxels having sRA greater than 2SD from the mean control value were discarded, along with voxels with signal intensity lower than an equivalent SNR of 32.

## Results

**Table 1.** Diffusion Parameters in Optic Nerve from Healthy Volunteers (n=12).

| | Mean | SD | Interscan SD | Intrascan SD |
|---|---|---|---|---|
| Axial Diffusion | 1.66 | 0.18 | 0.12 | 0.13 |
| Radial Diffusion | 0.81 | 0.26 | 0.17 | 0.10 |
| Mean Diffusion | 1.09 | 0.21 | 0.15 | 0.08 |
| Scaled Relative Anisotropy | 0.29 | 0.09 | 0.07 | 0.07 |

Axial, Radial, and Mean Diffusivities are given in μm$^2$/ms. sRA is without units.

**Table 2.** Initial Diffusion Parameters in Acute Optic Neuritis with long term outcome.

| | ON 1 | ON 2 | ON 3 | ON 4 |
|---|---|---|---|---|
| **Onset Severity** | Mild PR 1.05, VA 20/25 | Mild PR 1.05, VA 20/40 | Severe PR 0, VA Motion | Severe PR 0, VA Motion |
| **Axial** | 1.53 | 1.81 | 1.34 | 1.04† |
| **Radial** | 0.70 | 0.85 | 0.76 | 0.68 |
| **ADC** | 0.97 | 1.17 | 0.95 | 0.80 |
| **RA** | 0.29 | 0.28 | 0.21 | 0.16 |
| **Six Month Recovery‡** | Good | Good | Good | Poor* |
| **OCT** | NA | 104 m | 68.3 m | 49.8 m |
| **VEP (P100)** | NA | 120 ms | 124 ms | 158 ms |

Visual evoked potentials (VEP), Ocular Coherence Tomography (OCT)
† Value is ≥ 2 SD from the normative mean.
* PR 1.15, VA 20/40, 0/14 color plates

## Interpretation

Axial diffusivity in acute and isolated optic neuritis may decrease in some individuals. Of the four diffusion parameters, axial diffusivity was the only parameter to differentiate diseased from healthy optic nerves in the acute setting. The subject with the lowest value for axial diffusivity also had the poorest recovery by contrast sensitivity, visual acuity, OCT, and VEP. Additional studies are underway to elucidate (1) whether the early drop in axial diffusivity can predict recovery, and (2) the dynamics of DTI measurements over time.

**References**: [1] Sun SW et al. Magn Res Med 2006;55(2):302-8. [2] Kim JH et al. Neurobiol of Disease 2006;21(3):626-32. [3] Song SK et al. Neuroimage 2006;26(1):132-40. [4] Song SK et al. Neuroimage 2003;20(3):1714-22. [5] Song SK et al. Neuroimage 2002;17(3):1429-36. [6] Harsan LA et al. J of Neurosci Res 2006;83(3):392-402. [7] Tyszka JM et al. Neuroimage 2006;29(4):1058-65. [8] Deboy CA et al. Brain 2007;130:2199-2210. [9] Trip SA et al. Neuroimage 2006;30(2):498-505. [10] Hickman SJ et al. Am Journal of Neurorad. 26(4):951-6, 2005. [11] Jeong EK et al. Magne Resin Med 2005;54(6):1575-9. 2005.[12] Hasan KM et al. J Magn Res Imag 2001;13:769-80. [13] Shimony JS et al. Cerebral Cortex 2006;16(11):1653-61.