

Optic Radiation Abnormalities after Optic Neuritis

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Introduction

The identification of magnetic resonance imaging (MRI) measures which are sensitive and specific to neuronal injury in the context of multiple sclerosis (MS) could improve clinical patient monitoring. Postacute optic neuritis, a common presentation of MS, is associated with visual dysfunction indicative of axonal degeneration¹. Optic nerve axonal degeneration has been shown to cause injury to neurons in the lateral geniculate nuclei (LGN)². Diffusion tensor imaging (DTI) has been shown to be sensitive to neuronal injury³. Therefore DTI of the optic radiations could reveal correlates of neuronal injuries associated with trans-synaptic degeneration. We aimed to compare DTI measures in the normal-appearing white matter (NAWM) of the optic radiations of patients with a history of unilateral optic neuritis, and identify the correlates of NAWM abnormalities.

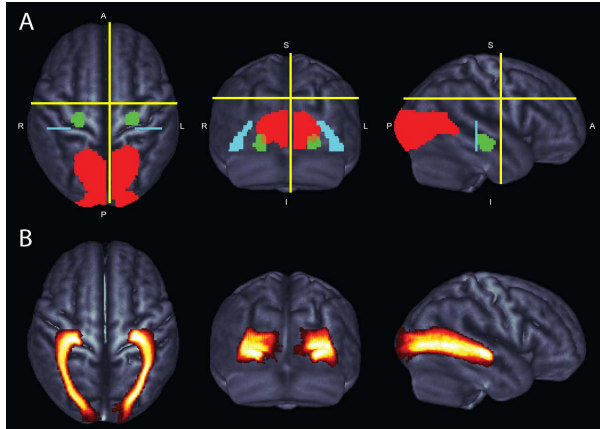


Figure 1. (A) Standard MNI152 space images of (A) seed (green) waypoint (blue) and termination (red) masks used for probabilistic tractography. (B) The optic radiation probability map calculated from 21 control subjects.

Methods

Subjects and MR Imaging: Twenty-one healthy subjects and 15 patients who had suffered acute unilateral optic neuritis four years previously were scanned using whole brain DWI (TE=85ms; $b = 1000\text{s}^2/\text{mm}$; 54-64 non-collinear diffusion gradients; matrix = 128×128 ; FOV = $220 \times 220\text{mm}^2$) using a 3 Tesla MRI system (Trio, Siemens, Erlangen, Germany). In addition, each patient was scanned with a 3D T2-weighted FLAIR sequence for lesion identification, and each had multifocal visual evoked potentials (mfVEP) recorded using Accumap (ObjectiVision, Sydney, Australia).

Probabilistic Mapping and DTI Analysis of the Optic Radiations: DWI data was eddy-current corrected and the diffusion tensor was calculated for all subjects using the FSL Diffusion Toolbox (Oxford, UK). The FSL non-linear registration tool was used to calculate deformation fields for registration of each subject's fractional anisotropy (FA) image to a standard template FA image. The inverse of this deformation field was used to transform standard space seed, waypoint and termination masks (Figure 1A) to each control subject's native space for tractography. Tractography was performed in each control subject using BEDPOSTX and PROBTRACKX⁴. The resulting tracts were thresholded at 10% of the total tracts passing through the waypoints, then were binarised and transformed to standard space. The final probabilistic map of the tracts was the average of the binary masks (Figure 1B). The probability map was transformed to each control and patient's native space. In patients, lesions were identified on FLAIR and the probability maps were parcellated into lesion and normal-appearing white matter (NAWM). Weighted averages were calculated for mean diffusivity (MD), fractional anisotropy (FA), axial diffusivity (λ_{\parallel}) and radial diffusivity (λ_{\perp}) within the optic radiations for controls, and within NAWM and lesions separately for patients.

mfVEP: In patients, mfVEP were recorded simultaneously from 56 visual field sectors. The mfVEP amplitudes were averaged for each eye and asymmetry coefficients were calculated using the formula: $[(\text{Amp}_{\text{unaff}} - \text{Amp}_{\text{aff}}) / \text{Amp}_{\text{unaff}}]$. We used correlation analyses to determine the relationships between NAWM DTI indices and affected side mfVEP amplitude reduction.

Results

All DTI indices in optic radiation lesions were abnormal compared to NAWM or control (Figure 2A-D). In NAWM, FA was reduced, λ_{\perp} was increased, and there was a trend towards a decrease in λ_{\parallel} compared to controls. We found that NAWM λ_{\parallel} was significantly negatively correlated with affected side mfVEP amplitude reduction ($R = -0.65$, $p = 0.009$) (Figure 3).

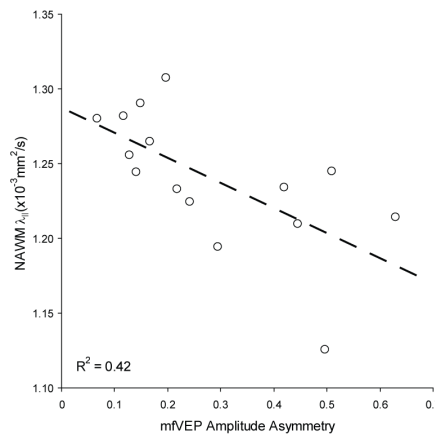


Figure 3. Scatterplot of optic radiation NAWM λ_{\parallel} as a function of mfVEP amplitude asymmetry.

Conclusions

There are detectable abnormalities in the optic radiations of patients with postacute optic neuritis. A specific abnormality in NAWM, reduced λ_{\parallel} , was found to be associated with visual dysfunction in the affected optic nerve indicative of axonal degeneration. These results show that reduced λ_{\parallel} could be a marker of neuronal injury associated with trans-synaptic degeneration in the context of MS.

References

- ¹Klistorner et al., 2008, Ann Neurol.
- ²Evangelou et al. 2002, Brain.
- ³Wu et al. 2007, NeuroImage.
- ⁴Behrens et al. 2007, NeuroImage.

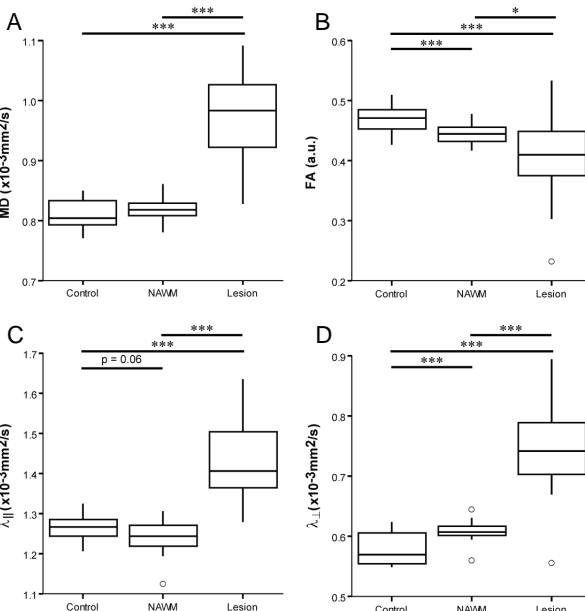


Figure 2. Group differences in (A) mean diffusivity (MD), (B) fractional anisotropy (FA), (C) parallel diffusivity (λ_{\parallel}) and (D) perpendicular diffusivity (λ_{\perp}) between control, patient normal-appearing white matter (NAWM) and T2-hyperintense (lesion) white matter.

* = ($p < 0.05$); ** = ($p < 0.01$); *** = ($p < 0.001$).