# *in vivo* Anisotropy and Diffusivity of the Optic Nerve: pilot study

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**Introduction:** Quantitative MRI of the optic nerve (ON) is challenging due to its small size, the motion and susceptibility artefacts and the high signal from orbital fat and CSF that surrounds the ON. Diffusion weighted (DW) ZOOM-EPI (ZOnal Oblique Multislice - Echo Planar Imaging) has previously allowed us to acquire coronal ADC maps of the ON *in vivo* (1) and to determine ADC changes in optic neuritis patients. Our aim is now to further assess structural changes of the ON, caused by pathology, for which the full diffusion tensor (DT) needs to be sampled (2). Preliminary measurements of fractional anisotropy (FA) and mean diffusivity (MD) of the ON in 10 normal controls, obtained with ZOOM-EPI DTI (Diffusion Tensor Imaging), are presented.

**Method:** Images were acquired with a 1.5T GE Signa scanner (General Electric, Milwaukee, WI) with maximum gradient strength of 22 $mTm^{-1}$. A quadrature birdcage coil was used as transmitter and receiver. Coronal images of the ON were obtained using a single-shot ZOOM-EPI DTI sequence, with the following parameters: FOV = 80x40$mm^2$ (with only the inner volume, IV=26mm, fully excited); matrix = 64x32; pixel size = 1.25x1.25$mm^2$. To increase the efficiency of the sequence, diffusion gradients were applied at maximum strength along 6 pairs of orthogonal directions (1,1,0; 1,0,1; 0,1,1; -1,1,0; -1,0,1; 0,-1,1). The diffusion parameters were $\delta$, $\Delta$ = 20, 27ms, b=600$smm^{-2}$. The echo time TE was 83.6ms. One non-DW ($b_0$) set of images was acquired.

To reduce the partial volume effects due to CSF and fat signal, an inversion pulse was used to null signal from CSF (TI = 1400ms, TR = 3400ms) and a frequency-selective fat-saturation spectral-spatial pulse was used for excitation. ZOOM-EPI requires a spatial gap between slices acquired consecutively in time, therefore we chose: no. slices = 3; sl. thick = 4mm; sl. gap = 8mm. The motion of the ON is "frozen" during each single-shot acquisition of one image, but motion between successive acquisitions is extremely difficult to control; averaging over many images seems to be the most successful option to consistently determine the ON central position (3). Averaging is also necessary because of the low signal-to-noise ratio (SNR) which characterises the images (SNR of DW images < 5:1). For our protocol, we used 44 averages. The total acquisition time for the DT (with 3 dummy cycles) was 17'40'' for a total of 924 images.

The averaging process to obtain the final $b_0$ and 6 DW images was performed on the magnitude signal. The low SNR of the magnitude images meant that a bias could be introduced in the DT calculations. An extra scan of just noise (total scan time = 3min) was acquired and used during post-processing to perform Rayleigh noise correction of the signal intensity, before DT calculations (4, 1). Initial quantitative analysis was performed on the central slice only, in the middle portion of the ON. FA, MD, and the eigenvalues of the DT along ($\lambda_{//}$) and across ($\lambda_{\perp}$) the axis of the ON values were obtained.

**Results:** Preliminary results on 10 normal controls showed that it is possible to measure the DT successfully on a coronal slice of the ON. The left and right ON averaged parameters across subjects were MD=(1223±164)$\times 10^{-6}$ $mm^2$ $s^{-1}$; FA=0.61±0.08; $\lambda_{||}$= (2089±171)$\times 10^{-6} mm^2 s^{-1}$; $\lambda_{\perp}$=(752±195)$\times 10^{-6} mm^2 s^{-1}$. These measurements of the *eigenvalues* of the DT also indicate high alignment of fibres along the ON. A direct comparison with previously published data from other groups is not possible due to the fact previous studies all measured only the ADC, rather than the DT, and did so without CSF suppression (5, 6).

**Conclusions:** Coronal DT imaging of the ON is possible with single-shot DW ZOOM-EPI. Measuring rotationally invariant parameters, such as FA, has potentially great relevance for clinical applications (e.g. in optic neuritis) because they reflect white matter structure integrity. Dealing appropriately with technical challenges such as the ON size, its motion, partial volume from CSF and fat, SNR issues, gave results which are consistent with known white matter properties. Future developments include the possibility of using new hardware (eg higher gradient strengths; parallel imaging) to reduce acquisition time, improve coverage and resolution.

**References:** 1) Wheeler-Kingshott, *Magn Reson.Med.* 47:24-31 (2002). 2) Basser and Pierpaoli, *Magn Reson.Med.* 39:928-934 (1998). 3) Wheeler-Kingshott, Proc. XVI ESMRMB, 443 (2000). 4) Miller and Joseph, *Magn Reson Imag* 11:1051-1056 (1993). 5) Iwasawa, *MRM*, 38: 484-491, 1997. 6) Freeman, *Proc. ISMRM* 1265, 1996.

**Acknowledgements:** CWK is supported by the MS Society of Great Britain and Northern Ireland.

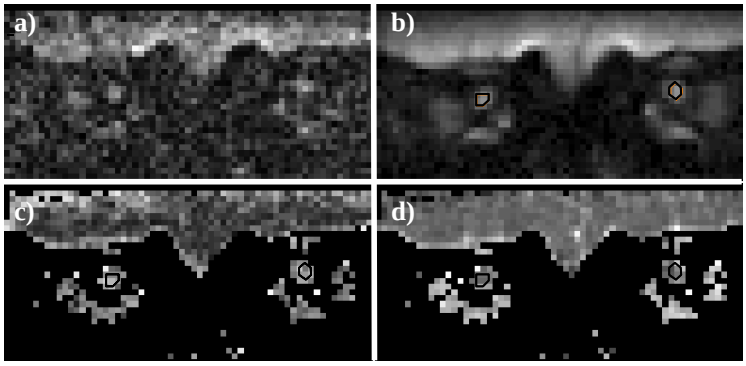


**Figure 1** – Images of the ON, acquired at 1.5T with ZOOM-EPI. **a)** $b_0$ magnitude image (as acquired); **b)** averaged $b_0$ image (after Rayleigh noise correction). **c)** MD map (MD = (1223±164) $10^{-6}$ $mm^2$ $s^{-1}$). **d)** FA map (FA = 0.61±0.08).
Contours of the ON highlight their position on b), c) and d).

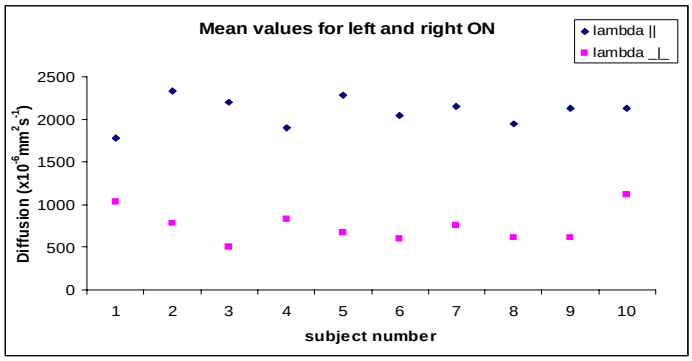


**Figure 2** – Eigenvectors of the DT. $\lambda||$ represent the highest diffusion component which is aligned with the axis of the ON. $\lambda\perp$ is the average of the other two orthogonal components, which represent the diffusivity across the optic nerve. Although there is variation across subjects, the two components are clearly distinct.