Partial volume effects in DTI

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We present a method for analysing and correcting for partial volume effects in DTI acquired with large voxels, using a high resolution MPRAGE and its corresponding SPM2 tissue segmentation. The analysis shows that voxels with mixed tissue types contribute to a broadened profile of ADC and FA values within an ROI of the splenium. Furthermore a correction scheme is devised which is robust with respect to mixed tissue voxels.

Methods: Subjects were recruited as healthy controls for another study and had no history of neuropsychiatric disease or any major medical illness. All subjects were scanned on the same 1.5 T imaging system (Magnetom Vision; Siemens Medical Solutions, Erlangen, Germany) using a standard circular-polarized head coil. For all subjects DTI and a 3D sagittal T1-weighted sequence (MPRAGE) with isotropic resolution of 1 mm were acquired. DTI was obtained using a diffusion-weighted SE single-shot EPI sequence with 6 directions and averaged over 6 datasets. The diffusion-weighted parameters were as follows: TE = 60 msec, field of view 230 mm, matrix 128 x 128, 30 axial slices, 5 mm slice thickness, b values 0 and 724 sec/mm2 consisting of a diffusion sensitizing pulse duration = 29 msec (δ), separation = 52 msec (Δ), and a gradient amplitude of 21 mT/m (G).

For each individual scan an anatomical ROI was manually drawn on the 3D T1-weighted images delineating the posterior aspect of the corpus callosum on the midsagittal slice plus 8 parasagittal slices. The anterior border was defined arbitrarily as a line perpendicular to the AC-PC line, crossing it at the midpoint. The ROI was eroded in the sagittal plane in three steps, each step eroding the outer one voxel rim of the ROI. Furthermore the MPRAGE images were segmented using SPM2[1] into the three standard tissue probability maps denoted GM, WM, and CSF

Diffusion tensor calculations were performed in native DTI space and the resulting eigenvalues (λ_1, λ_2, λ_3), ADC and FA maps were resliced to MPRAGE space using SPM2. In addition an index image of voxels in DTI space was resliced to MPRAGE space via the previously calculated reslice parameters and using nearest neighbor interpolation. The high resolution segmentation was then used to calculate a partial volume estimate for each of the original DTI voxels from its respective component tissues (see image below).

Results:A linear relation was fitted between WM and the different DTI results, and the value at 100% WM was determined. When compared to the average values within the full ROI and the eroded ROIs, this clearly shows the error of just averaging the full ROI, and also the effect of eroding the ROI in order to obtain the purer 'core' values.

Table 1: Calculated mean values	ADC/ $10^{-3}mm^2/s$	FA	λ_1/ 10^{-3}	λ_2/ 10^{-3}	λ_3/ 10^{-3}
"100 % WM"	0.807	0.775	1.76	0.401	0.254
Full ROI	1.015	0.626	1.83	0. 711	0.517
ROI eroded once	0.929	0.690	1.81	0. 586	0.407
ROI eroded twice	0.843	0.760	1.80	0. 453	0.291
ROI eroded three times	0.783	0.808	1.79	0. 366	0.214

The 3D histograms of FA and WM below show how eroding narrows the overall profile of the FA value and mainly removes voxels with mixed tissue types. Similarly a histogram of the WM shows that only voxels with a relatively high WM fraction are retained when eroding the ROI.

Conclusions:Large voxels are sometimes a necessity when doing DTI, resulting in a greater number of mixed tissue types. This can lead to difficulties in interpretation, as any apparent differences could be solely due to partial volume. We have demonstrated two techniques to analyse and correct for such potential partial volume problems.

References:

[1] Friston, et.al, 2003.