White Matter Pathway Asymmetry Corresponds to Auditory Spatial and Language Lateralisation

T. R. Barrick[1], I. N. Lawes[2], C. A. Clark[1]

[1]Clinical Neuroscience, St George's Hospital Medical School, London, United Kingdom, [2]Anatomy & Developmental Biology, St George's Hospital Medical School, London, United Kingdom

Introduction

The planum temporale, a region of auditory cortex known to sub-serve language is located on the posterior part of the superior surface of the temporal lobe. Typically in right-handed subjects the planum temporale is larger in the left hemisphere (1,2), language function is left lateralised (3) and auditory spatial localisation is lateralised to the right hemisphere (4,5). Here we investigate the asymmetry of white matter pathways beneath the planum temporale by application of a reflection based asymmetry technique (2,6) to diffusion tensor images (DTI). Asymmetries are identified by a voxel-based morphometry (VBM) style analysis (2,6) and fibre tracking is performed such that white matter pathways are retained if they pass through significantly asymmetric regions. This is the first investigation of DTIs to combine VBM and fibre tracking techniques and demonstrates that regions detected by VBM DTI analyses may be localised to specific white matter pathways which correspond to known functional differences between the hemispheres.

Methods

MRI Data Acquisition

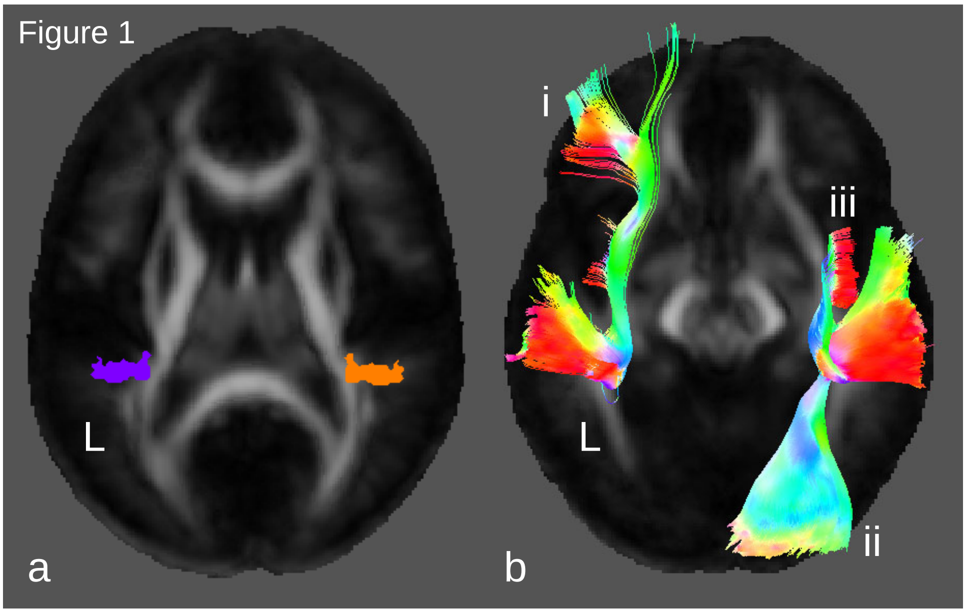
Thirty healthy right-handed subjects (15 male and 15 female: mean age 27.2±5.2) were scanned on a 1.5T General Electric Signa MRI system with maximum field gradient strength of $22mTm^{-1}$. Diffusion tensor imaging (DTI) was achieved using a single shot echo planar sequence with 12 diffusion sensitised directions as described previously (7). Whole brain coverage was achieved with two interleaved acquisitions comprising 25 slices each. In plane resolution was 2.5mm and through plane resolution was 2.8mm, providing near isotropic voxels. Each subject's DTI was normalised by affine transformation using the method of Alexander et al., (8), thus preserving the orientation of the tensor field. Normalised fractional anisotropy (FA) maps were then computed for each subject and a normalised mean DTI was computed across the data set (9).

Computation of Asymmetry Images and VBM Statistical Analysis

Asymmetry images were computed from each subject's FA map. Each normalised FA map was reflected in the mid-sagittal plane (x=0) and was subtracted from the unreflected FA map to quantify a reflection measure of structural asymmetry. These images were then smoothed by a 6mm full width at half maximum isotropic Gaussian filter and were statistically analysed in SPM2b (Department of Cognitive Neurology, Institute of Neurology, London, UK). Results were considered significant at $p < 0.05$ corrected for peak height over the whole volume analysed.

Fibre Tracking

Significant clusters found by the statistical analysis were used as regions of interest (ROIs) for fibre tracking experiments. This allowed significant asymmetries to be localised to specific white matter pathways. Subvoxel principal direction tracking was performed by interpolation of the tensor field as described previously (10). Tracking was initiated from the centre of every voxel in the normalised mean DTI for an FA of above 0.05, vector step length 0.8mm with no angular threshold. Only tracks passing through significant clusters found by the statistical analysis were retained. Resulting fibre tracks were coloured according to their orientation (left to right: red, anterior to posterior: green, inferior to superior: blue).



Results

Statistical analysis revealed a significant rightward asymmetry of the white matter below the planum temporale. In Figure 1 the significant asymmetry is shown rendered on an axial FA slice computed from the mean DTI (Figure 1a). The orange surface represents greater FA values in the right hemisphere and the purple cluster represents smaller values in the left hemisphere (L in Figure 1). Rightward FA asymmetry below the planum temporale is consistent with a larger planum temporale displacing white matter immediately below it in the left hemisphere (2). Fibre tracking results from the significant cluster below the planum temporale revealed striking differences in pathway morphology between the hemispheres. Left hemisphere pathways passing beneath the planum temporale terminate in the insular cortex and the inferior frontal gyrus close to Broca's area (Figure 1b, i). However, right hemisphere pathways passing beneath the planum temporale terminate in cortices of the parietal and occipital lobe (Figure 1b, ii) and the insular cortex (Figure 1b, iii). The right sided termination in the insula was more extensive than on the left. Fibre tracks in the left hemisphere link auditory cortex to regions in close proximity to language areas in the frontal lobe. Pathways on the right correspond to visual (11) and spatial (4,5) aspects of auditory function attributed to the right hemisphere.

Discussion

White matter asymmetry of the human brain has been investigated by application of VBM DTI and fibre tracking techniques to a data set of right-handed healthy subjects. This study shows for the first time the underlying white matter tract asymmetry that is the substrate of functional lateralisation of auditory spatial (4,5), auditory visual (11) and language (3) processes in the human brain.

References

[1] Steinmetz H, 1996. *Neuroscience and Biobehavioural Reviews*, **20(4):** 587-591.
[2] Barrick TR, 2003. PhD Thesis, University of Liverpool, UK.
[3] Josse G et al., 2003. *Cognitive Brain Research*, in press.
[4] Thiran AB and Clarke S, 2003. *Neuropsychologia*, **41:** 1254-1261.
[5] Griffiths TD et al., 1998. Nature Neuroscience, **1(1):** 74-79.
[6] Watkins KE et al., 2001. *Cerebral Cortex*, **11:** 868-877.
[7] Clark CA, Barrick TR, et al., 2003. *Neuroimage*, in press.
[8] Alexander DC et al., 2001. *IEEE Trans Med Imaging*, **20(11):** 1131-1139.
[9] Jones DK et al., 2002. *Neuroimage*, **17:** 592-617.
[10] Barrick TR and Clark CA, 2003. ISMRM, Toronto, #2159.
[11] Bamiou DE et al., 2003. *Brain Research Reviews*, **42:** 143-154.