

White Matter Complexity for Population Studies using Q-Ball Imaging: Application to Brain Asymmetry

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Introduction: Structural and functional brain asymmetry (Hellige, 2003) is caused by a combination of genetic, environmental, and evolutionary factors, as in the case of language dominance in the left hemisphere. Functional lateralization is observed in Broca's speech area and Wernicke's comprehension area (especially in the *planum temporale*), and in motor and auditory cortices (Toga, 2003). Little is known however on white matter connectivity asymmetry (Dubois, 2009; Büchel, 2004). Here we apply, to population studies, a new method to quantify local white matter complexity, based on Q-Ball Imaging (Tuch, 2005) and stratification learning (Haro, 2008). Stratification learning generalizes manifold learning, and represents Q-ball data as unions of manifolds with different complexity and density. This can visualize the higher dimensionality of the white matter signal in regions where fibers intermix or cross (Haro, 2008). In population-based maps, prominent asymmetries emerged in the population complexity values in classical language areas, consistent with their known hemispheric specialization.

Methods: 22 young adult subjects were scanned at 4T with an optimized diffusion tensor sequence. Imaging parameters were: 55 contiguous slices (2 mm thick), TR/TE=8250/92.3 ms, FOV=230 x 230 and 1.8 x 1.8 mm² in-plane resolution. A total of 105 images were acquired: 11 with no diffusion sensitization and 94 diffusion-weighted images with $b=1159$ s/mm². 4th order orientation density functions (ODFs) were computed (Descoteaux, 2007), followed by local white matter complexity calculations for each subject (Haro, 2008). To combine such individual complexity maps and perform statistical analysis, we first rigidly aligned and then nonlinearly registered all structural images to the high-resolution *Colin27* brain template. Affine transformation parameters and deformation fields were then used to align the Q-ball derived complexity images and produce a mean complexity map (Figure 1). We then tested for hemispheric asymmetries in complexity by comparing the registered complexity maps to their reflected version in the mid-sagittal plane. Voxel-wise statistics and probability maps were computed.

Results: Statistically significant asymmetries ($p<0.05$) are presented on Figure 2. Broca's speech area is clearly detected (left panel, Fig. 2A), as is the white matter innervating the *planum temporale* (right panel, Fig. 2B). This localization is consistent with the literature, suggesting that the speech and language comprehension areas are among the most highly functionally lateralized areas of the brain.

Conclusions: We have shown how local white matter complexity can be used in population studies and applied this to brain asymmetry. Further study is needed to clarify what proportion of these asymmetries is due to hemispheric differences in shape and volume (flipped brains were not included in the structural average while creating the template), and how much is attributable to mean differences in QBI signals for homologous structures in both hemispheres.

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