Fiber Orientations from Diffusion MRI and Histology in the Macaque Brain

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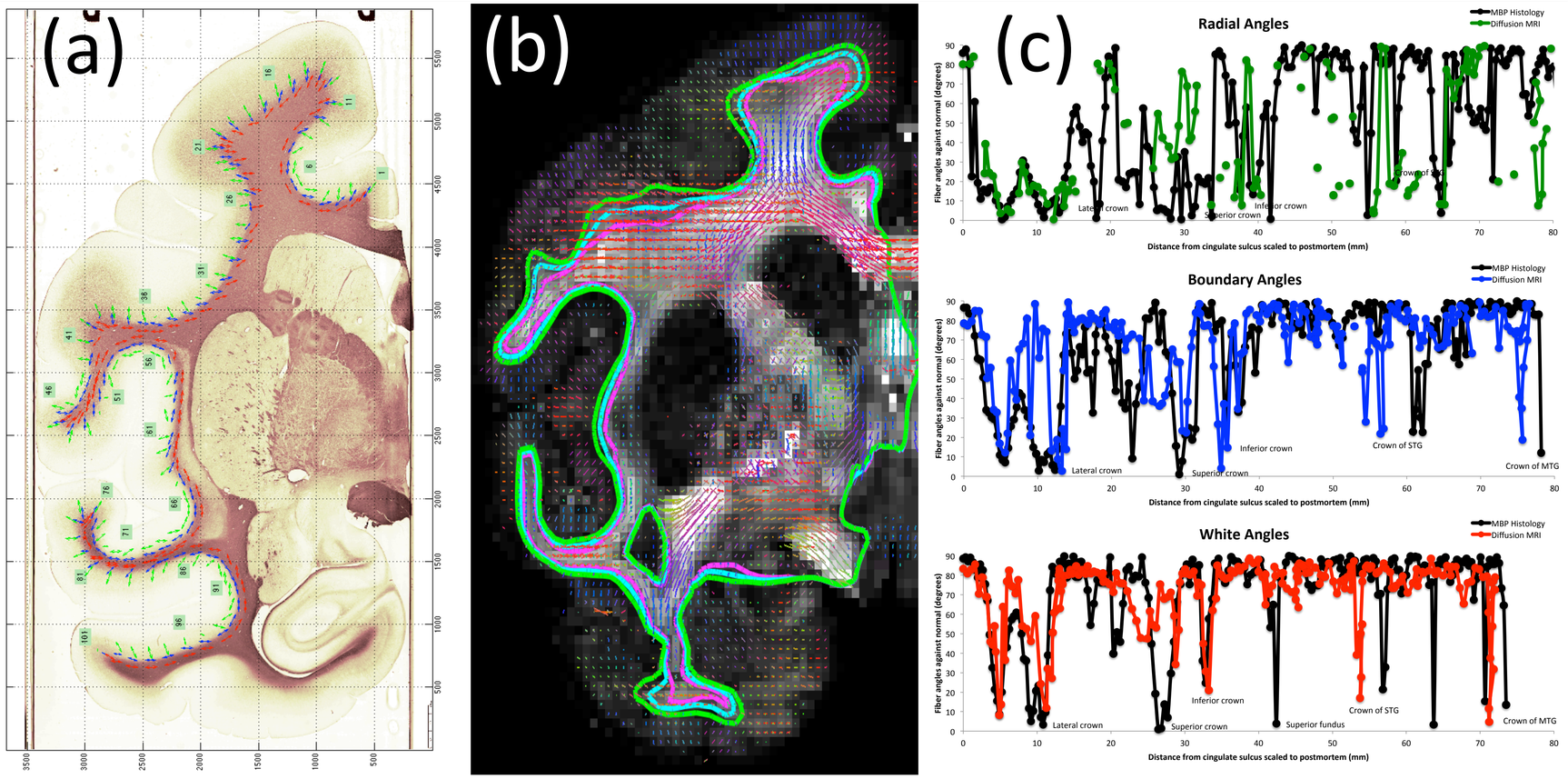
Introduction

Diffusion MRI uses the anisotropic diffusion of water in neural tissue to reveal underlying orientations of fibers in each imaging voxel. Tractography algorithms then reconstruct fiber trajectories from the orientations. However, these algorithms exhibit stronger connections to cortical gyri than to cortical sulci, which is not observed in connectivity patterns measured with invasive tracer injections in macaque monkeys [1]. Diffusion fiber orientations tend to point towards the cortical surface on gyral crowns, but tend to be tangential to the cortical surface in sulci [2]. We evaluated fiber orientations near the grey-white boundary of the cerebral cortex, comparing fiber orientations found in diffusion MRI to those in histology.

Methods

- Coronal sections from an adult macaque brain were immunostained with an antibody to myelin basic protein.
- These were scanned on a NanoZoomer microscope at 20x and downsampled to a 0.007 mm/pixel resolution.
- Structure tensor analysis was performed in MATLAB to estimate fiber orientations.
- A diffusion-weighted MRI dataset of a perfusion-fixed adult macaque brain was acquired with a 4.7 T Bruker scanner at a 0.43 mm/voxel resolution.
- The bedpostX fiber orientation modeling algorithm (FSL software) was used to reconstruct up to three fiber orientations per MRI voxel.

Results



Comparison of fiber orientations near the grey-white boundary. (a) A digitized myelin-stained coronal section used for structure tensor analysis. (b) Diffusion imaging estimates with ball-and-stick model. Fibers are colored according to orientation: medial-lateral (red), dorso-ventral (blue), and antero-posterior (green). Surface boundaries were generated from a thresholded sum of anisotropy image, manually edited in Connectome Workbench. (c) Cross-modal comparison of fiber orientations in subcortical white matter (red), grey-white boundary (blue), and deep-layer cortex (green).

Conclusions

- Histology and diffusion MRI show good agreement in white matter and near the gyral crowns.
- Discrepancies occur where structure tensor analysis correctly determines the sharp angles of terminating fibers, compared to diffusion MRI, which shows fibers running near tangential.
- This causes tractography streamlines to travel along the bank to terminate at the crown in a gyral bias.
- Where there is similarity between histology and MRI, orientation estimates of MRI are validated.

References

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