Impacts of diffusion MRI spatial resolution on the short-range structural connectivity estimation

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Introduction

White matter (WM) demyelination and degeneration are significant indicators of various brain diseases. However, short-range fibers (SAFs), which connect adjacent cortical regions within a range of 3 to 30 mm, have received less attention and are still mostly unknown despite their contribution to 90% of all structural connections and their important role in mediating cortico-cortical connectivity. Diffusion MRI is the only non-invasive method capable of mapping WM fibers throughout the human brain and estimating structural connectivity. This study aims to optimize diffusion MRI acquisition for accurately estimating short-range connectivity. Since SAFs are located in the ~1.5 mm thick superficial WM, which is thinner than most cortices, we focus on studying the impacts of diffusion image spatial resolution on the short-range connectivity estimation.

Methods

Fiber orientation distribution functions were estimated using the state-of-the-art multi-shell multi-tissue constrained spherical deconvolution (MSMT-CSD) method. Probabilistic tractography was performed using the anatomically constrained tractography (ACT), which is more biologically accurate. The ratio between the number of fibers connecting a cortical area and its direct neighbors and the number of all fibers connecting to this cortical area was proposed to quantify the short-range connectivity. The cortical parcellation was performed on the T_1-weighted MRI data using the FreeSurfer software to identify 34 cortices in each hemisphere (i.e., Desikan-Killiany atlas).

To evaluate the impacts of image resolution on the short-range connectivity estimation, the diffusion data at 1.25 mm isotropic resolution of 20 healthy subjects from the Human Connectome Project (HCP) were downs-sampled to widely adopted 1.5, 2, and 2.5 mm isotropic resolution.

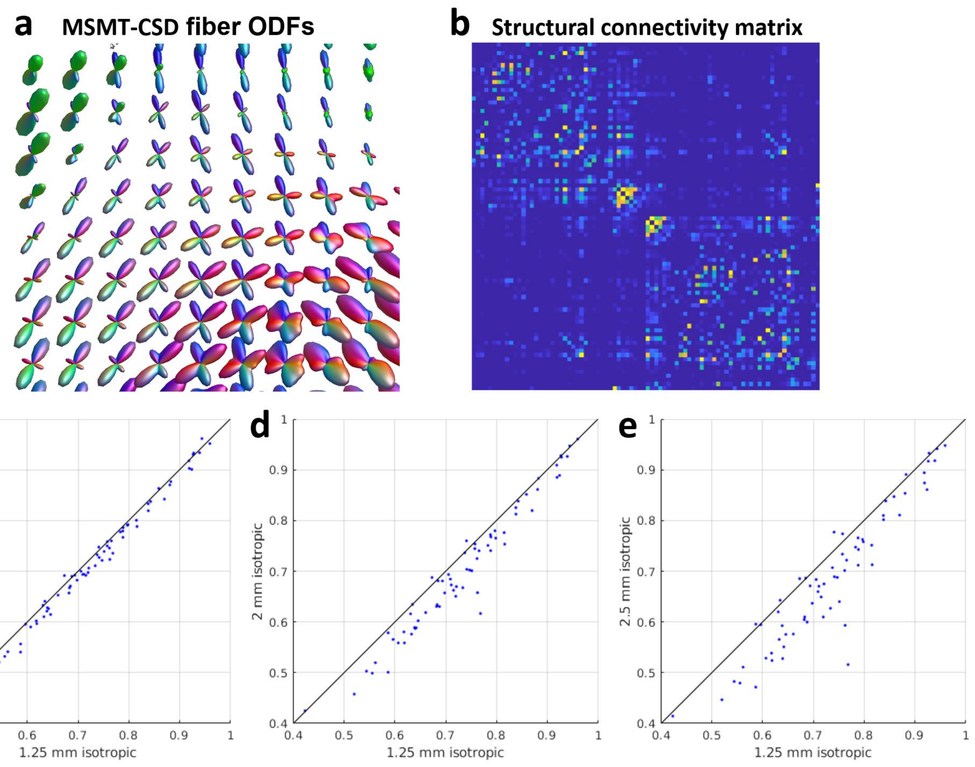
Results

Scatter plots for the 20-subject-averaged short-range structural connectivity values for all 68 cortices at 1.25 mm versus at 1.5, 2, 2.5 mm isotropic resolution are displayed. The 20-subject-averaged and 68-cortice-averaged short-range structural connectivity values at 1.25 mm, 1.5 mm, 2 mm, and 2.5 mm were 0.7483, 0.7363, 0.7199, and 0.7067, respectively, demonstrating a decrease in values as the image spatial resolution decreases.

Conclusions and Discussions

Lower image spatial resolution leads to under-estimated short-range connectivity for most cortical areas.

Clinicians have to consider the impacts of diffusion MRI spatial resolution on structural connectivity estimation. High-resolution diffusion MRI data should be collected preferentially if the signal-to-noise ratio is sufficient.



(a) Fiber orientation distribution functions.

(b) The estimated structural connectivity matrix.

(c,d,e) Scatter plots at 1.25 mm versus at 1.5, 2, 2.5 mm isotropic resolution.

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