Spatial resolution dependence of DTI tractography in human occipito-callosal region

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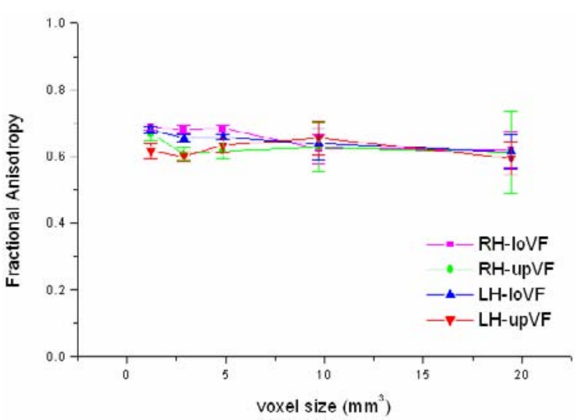
Introduction

Diffusion tensor magnetic resonance imaging (DT-MRI), coupled with fiber-tracking algorithms, promises to provide substantial information about both animal and human fiber tracts (FTs). There are, however, technical limitations in DTI that must be considered when inferring connectivity. In particular, a detailed knowledge about the precise correlation for spatial resolution remains elusive. Here we studied the effect of differential spatial resolutions of DTI data by systematically re-sampling the acquired data into a variety of nominal resolutions. To quantitatively measure the variation from DTI data, we studied the pattern of human occipito-callsosal connections.

Methods

The functional retinotopic areas of the both hemispheres (8 subjects) on the human visual cortices were obtained using standard flickering checkerboard stimuli. We used 3T whole body scanner (Intera, Philips). Typical MR parameters for fMRI: gradient-echo Echo-Planar Imaging (GE-EPI); 2000 ms; 128×128 in a FOV of 230×230 mm^2, 30 slices, 2 mm of slice thickness, native resolution: 1.8×1.8×2 mm^3/voxel. Parameters for DT-MRI: spin-echo EPI; TE=91 ms; TR=10.6 s; 256×256 in a FOV of 230×230 mm^2, native resolution: 0.9×0.9×1.5 mm^3/voxel with b=1000s/mm^2. Diffusion-weighted images were obtained for 15 gradient encoding directions. fMRI data was analyzed with BrainVoyager (Brain Innovation, Netherlands) and the areas identified using fMRI were used as seeding ROIs for DTI based axonal fiber reconstructions. High-resolution DTI raw data in image space was rescaled into four different data sets by using bi-cubic interpolation. The down-sampled DT data sets were used for fiber tracing, and the separate FTs were identified in a different spatial resolution by using custom-written Matlab (Mathworks) software.

Results



The amount of FTs between identical ROIs was strongly correlated with the spatial resolution of the DTI data: the lower the resolution of the native DTI data was, the lower was the number of FTs generated. It is also consistent with the reduction of number of seeding ROIs, however the number of seed ROIs did not always correlate with number of FTs. Figure shows that decreasing spatial resolution results in an increase of the standard error of the FA estimation.

Figure legend: The average and the standard error of FA on the cortico-splenium FTs through all subjects. All FA values are high around in between 0.6 and 0.7, and the average FA values through all different spatial resolution were not significantly different at the 0.05 level with one-way ANOVA. However, the variation of each FA value at different VOI gets smaller while standard error becomes larger, as the spatial resolution increases (color labeled as blue for LH-lower visual field (loVF), red for LH-upper VF (upVF), magenta for RH-loVF, and green for RH-upVF).

Conclusion

Our results demonstrate the impact that spatial resolution has on DTI and fiber tracking results that stem from DTI data sets with different spatial resolution. Increasing voxel size induces higher SNR, partial volume effects, and reduction on the number of fiber tracts. Partial volume effects particularly correspond to the accuracy of FA estimation, resulting increased FA variation and erroneous fiber connections. The optimal native resolution will strongly depend on the average thickness of the expected fiber tract, the SNR of the data sets, the size and shape of the ROIs used as starting regions for fiber tracking and the number of seeding point used in each ROI. Consequently, the application of such resolution may further improve tissue characterization through the quantification of FA and apparent diffusion coefficient indices. Additionally, systematic models of diffusion in biological tissues could be considered to maximize the accuracy of diffusion measurements.

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