The reproducibility of diffusion tensor imaging on brain connectivity measures between cortical regions using probabilistic tractography

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Introduction

Diffusion Tensor Imaging (DTI) associated with tractographic method has been used to investigate the structural or anatomical connectivity in the brain, which can be linked to dynamic behavior (functional connectivity) of the brain[1,2]. Recently, small world model in network analysis have been widely used to study the structural networks accessed by connectivity between spatially isolated grey matter (GM) regions[1,3]. Although streamline tractography has been used to track the continuity of fiber orientation along the principle diffusion tensor, the ambiguity of principle diffusion direction in GM regions make tractography strongly affected by noise[1]. Probabilistic tractography is an extension of streamline method that calculates the probability of connectivity between regions with consideration of the uncertainty of major diffusion direction. Therefore, this method should be more robust and suitable for study the structural connectivity between GM regions. In this study, we investigate the test-retest reliability of structural connectivity among cortical regions parcellated in automatic anatomic labeling (AAL) template using probabilistic tractography.

Methods

Fourteen healthy subjects, 7 male and 7 female, with ages raging from 20 to 25 years old (21.8± 2.1), were recruited. Data were collected on a 3T MR system (Skyra, SIEMENS Medical Solutions, Erlangen, Germany) with a 32-channel head coil array. All subjects were scanned twice for the assessment of test-retest reproducibility. For each subject, a high-solution 3D T1 images were performed for the anatomical information. DTI protocols were performed using spin echo EPI sequence. We used 30 gradient directions with b-value 1000 s/mm^2 and five additional images with minimum diffusion weighting. Experiment parameters were TR = 8800 ms, TE = 90 ms, FOV=256x256 mm^2, MAT=128x128, slice thickness = 2 mm, slice = 61, NEX = 2, acceleration factor = 2. The total acquisition time were 15 minutes including T1 and DTI scans.

The image preprocessing, estimation of diffusion parameters and tractoraphy for DTI was carried out using FSL (www.fmrib.ox.ac.uk/fsl/). Preprocessing includes motion correction, eddy current correction and brain extraction. Then we estimate the transformation matrix between standard MNI space and DTI space for each subject. A total of 78 cortical regions (39 in each hemisphere) in AAL template can be warped from MNI space into native DTI space. The local probability distribution of fiber orientation for each voxel in brain was estimated. Then probabilistic tractography was applied by sampling 5000 streamlines fibers per voxel within regions to estimate the connectivity probability between seed GM region to target GM region. Connectivity between two GM regions was displayed as number of streamlines passing target regions divided by total streamlines from seed region. Structural connectivity matrix in the order of 78 by 78 can be generated for each subject for each scan. Coefficient of variance (CV) and intra class coefficient (ICC) were calculated to characterize the inter-scan reproducibility.

Results and Discussion

Structural connectivity matrix of 78 GM regions from average of all subjects is shown in figure1. The connectivity is low between most of GM regions, which is in agreement with previous reports[3]. Connectivity probability among all regions is summarized by separating connectivity into groups according to the probability. Inter-subject CV range from 33% to 13% and Inter-scan CV range from 22% to 9% for groups with connectivity strength over 0.05. Better reproducibility and less variability between subjects is found in regions with higher connectivity. For connectivity over 0.2, inter-scan CVs are at level of 10% and inter-subject CV at 13%. This implies that the DTI with probabilistic tractography can provide stable estimation on connectivity between GM regions with higher connectivity. Further, structural connectivity network of brain can be similar across subjects because network analysis is constructed majorly based on regions with higher connectivity strength. ICCs for all groups range between 0.7 to 0.8. In conclusion, we have investigated the inter-scan reproducibility of DTI on the estimation of structural connectivity between AAL cortical regions. Probabilistic tractography can be successfully applied to calculate the connectivity between GM regions at the presence of the ambiguity of principle diffusion direction in GM regions. Thus network analysis based on DTI and probabilistic tractography can be feasible.

Reference

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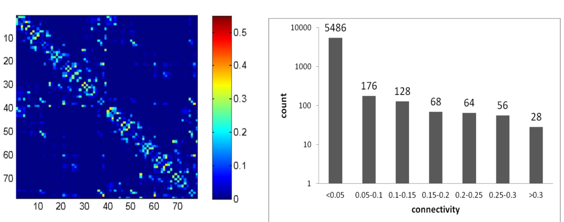

Figure 1. (Top) Averaged structural connectivity among 78 GM regions from all subjects. (Bottom) number of elements in groups with different connectivity probability

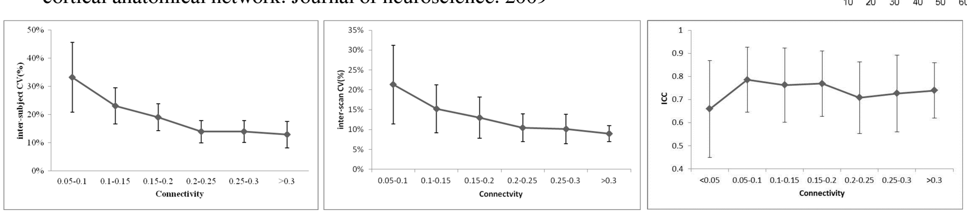

Figure 2. inter-subject CV, inter-scan CV and ICC for groups with different connectivity probability.