An objective tractography method using a diffusion spectrum imaging (DSI) template

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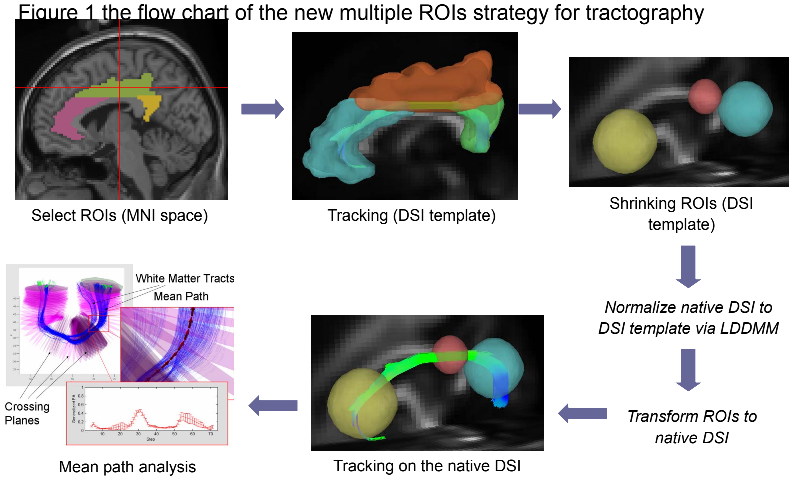
Introduction Diffusion-tensor imaging (DTI)-based tractography is one of the most remarkable advances in neuroimaging in the past decade [1]. Tractography has become a popular way which offers *in vivo* localization of fiber tracts to investigate the white matter structure of the brain. The diffusion properties, e.g. the fractional anisotropy (FA), from tractography have been found to reflect microstructural alterations in some neurological or psychiatric disorders [2]. To construct the tractography of an interested pathway, it is usually achieved by manually determining at least one region of interesting (ROI) through which the fibers would evidently pass. Fiber tracking is then performed using the streamline algorithm along with some decision criteria, such as the range of tract lengths, allowed turning angles and FA threshold etc. Although this procedure is intuitively straightforward to produce pathways of interest, it also produces pathways that are evidently wrong. Therefore, the experimenters need to apply judgments to select the reasonable fiber tracts according to anatomical and neurological information. The above method involves considerable subjective decisions. First, the ROIs are determined manually, which would be different in locations and sizes among different experimenters. Second, the fiber-tracking results require additional treatment such as selecting, trimming, or deleting, leading to poor reproducibility. Therefore, a more objective way to minimize the human intervention would be preferable. In this study, we proposed a standard procedure of tractography method for diffusion spectrum imaging (DSI) to reduce the subjective adjustment.

Materials and methods DSI was performed using a twice-refocused balanced echo diffusion echo planar imaging (EPI) sequence, TR/TE = 9600/130 ms, image matrix size = 80 x 80, spatial resolution = 2.5 x 2.5 mm^2, and slice thickness = 2.5 mm. 102 diffusion encoding gradients with the maximum diffusion sensitivity b_{max} = 4000 s/mm^2 were sampled on the grid points in the 3D q-space with $|q| \leq 3.6$ units [3]. For DSI tractography, we proposed a multiple ROIs strategy with whole brain seeding. First, we used MARINA software (Bender Institute of Neuroimaging, University of Giessen, Germany) to define cortical regions as ROIs on the Montreal Neurobiology Institute (MNI) space for each targeted tract bundle. After ROIs in the MNI space were identified, their coordinates were transformed to the DSI template using SPM8 [4]. Targeted tracts were reconstructed on the DSI template using DSI studio. In order to reduce the tracking bias of large ROIs, we shaped the ROIs in the template space to smaller and more specific ones which just covered the target tract bundle on the DSI template. For obtaining the transformation information between individual's DSI coordinates and the DSI template space, we proposed a registration method on DSI dataset by considering the fact that DSI dataset is inherently 6D: 3D image space and 3D q-space. Specifically, we generalized the conventional 3D registration to the 6D scenario by implementing Large Deformation Diffeomorphic Metric Mapping (LDDMM) method [5]. With the help of the LDDMM DSI algorithm, the modified ROIs on the DSI template could be transformed to individual's DSI space. Then, a streamline-based fiber tracking algorithm was performed based on the resolved fiber vector fields provided by DSI. A method that projected the generalized fractional anisotropy (GFA) onto a single mean path of a specific white matter tract, called mean path analysis, was used to analyze local changes in structural connectivity along individual tract bundles [6].

Results The whole procedure was shown as Figure 1. The feasibility of the new objective tractography method was demonstrated using left cingulum bundle. As shown in the figure, the tractography of the cingulum bundle on the DSI template was reproduced on the individual's native DSI with little subjective adjustment.

Discussion In this study, we develop a standard procedure of tractography that minimizes human intervention. The goal is achieved by the use of the LDDMM DSI algorithm to transform ROIs that have been determined on the DSI template to individual's native DSI. Human intervention is invoked only once on the DSI template to determine ROIs suitable for producing tractography of the targeted pathways. The rest of the procedure is virtually automatic. The proposed standardized procedure can improve the reproducibility among different experimenters and increase the speed of tractography production. This computationally-efficient approach is potentially useful in the tractography-based analysis that involves multiple pathways in a large number of subjects.

Figure 1 the flow chart of the new multiple ROIs strategy for tractography



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