Subdivisions of Mid-sagittal Corpus Callosum by Cortico-cortical Connectivity with QBI Tractography

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Introduction

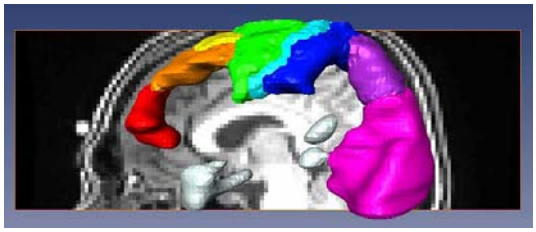
The corpus callosum (CC), the largest white matter tract of brain, is responsible for integrating information between two cerebral hemispheres. The location in the mid-sagittal cross-session of fibers within CC could be parcellated in correspondence with cortical region. The analysis of regional neuroanatomy and callosal morphology are key elements not only to the radiological assessment of neurological disorders such as dyslexia, schizophrenia and HIV/AIDS, but also to the research of brain development and degeneration [1]. Recently, tractography technique with diffusion tensor magnetic resonance imaging (DTMRI) has been employed for distinguishing vertical segments of CC and for revealing the topographical distribution of fiber connections to the cortex [2, 3]. However, the limitation of DTMRI model of single fiber mapping and low anisotropy might influence the outcomes despite the adoption of multiple ROI selection. In this study, we adopt a novel fiber tacking algorithm for propagating from multiple fiber dispersals within a voxel that is derived from q-ball imaging (QBI) of human brain. Incorporated with Brodmann template, seed regions of tractography were placed in the specific Brodmann's areas (BAs) within the cerebral cortex for tracing the related neural tracts that pass through CC and for forming the function-based subdivisions of CC.

Materials and Methods

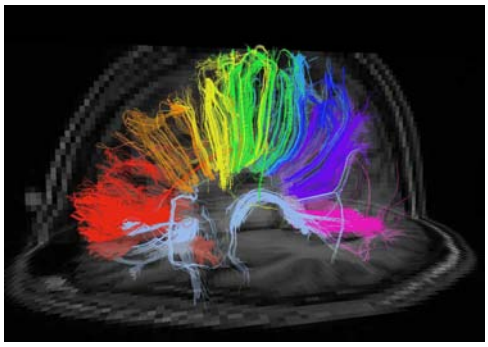
In vivo human QBI data were acquired in a GE Healthcare Signa 1.5T Excite scanner in Taipei Veterans General Hospital by spin echo EPI sequence with 162 icosahedral diffusion-encoding directions, matrix size=128×128, slice number=46, voxel size=2.0×2.0×2.2 mm^3, TR/TE = 13600/91.2 ms and b_{max} =3000 s mm^{-2}. For each MR voxel, the orientation distribution function (ODF) was reconstructed by Funk-Radon transformation [4]. MFACT (multiple fiber assignment by continue tracking), the tracking algorithm applied in this research, which is similar to FACT implemented by Mori [5] but could be applied for tracing trajectories with multiple fiber incoherence within a voxel [6]. As to the selection of volume of interesting (VOI), all VOIs were defined manually in the sagittal view of T1 image. The first VOI was marked in the mid-sagittal plane with the width of 7 sagittal slices and others were placed in the corresponding BAs in the cortex for the cortico-cortical tractography. All tracts would be initialized to spread from the cortical region of BAs and be constrained by CC via simple Boolean function. In addition, fiber bundles were encoded by various colors for distinguishing the "inverse-parcellation" from different BAs to CC. The fiber tracking algorithm and visualization relied on softwares that were developed in-house by Borland C++ Builder 6 and OpenGL API.

Results

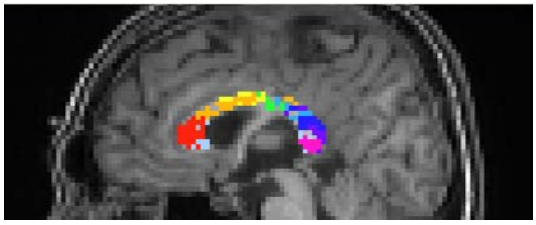
Fig.1 showed nine groups of BAs selected as the target VOIs for tracing the cortico-cortical fiber bundles. After the inverse parcellation of trajectories from the different BAs to the CC, the presentation of 3D fiber reconstruction was shown in Fig.2. And the oblique view of a 3D fiber reconstruction which passed through CC comprised bundles from the seed VOI in BA 10 (coded in Red), BA9 (orange), BA8 (yellow), BA6 (light green), BA4 (light blue), BA1, 2, 3 and 5 (deep blue), BA 7(violet), BA 17,18 and 19 (Pink) and BA27, 34, 38, and 41(gray). According to the results of tractography, each pixel of CC would be assigned as one of nine departures with the majority of fibers that passed though CC. By the same color scheme, the segmentation of mid-sagittal slice of CC based on BAs was displayed in Fig.3.



◄*Fig.1 Nine groups of BAs were selected with different color coded, including BA10, 9, 8, 6, 4, 1, 2, 3, 5, 7, 17, 18, 19, 27, 34, 38, and 41.*



◄*Fig.2 The presentation of 3D fiber reconstruction by QBI tractography from the selected BAs. The color scheme follows the assignment in Fig.1. All tracts were restricted by the initiation from the cerebral cortical regions and pass through the corpus callosum.*



▲*Fig.3 The subdivisions of mid-sagittal plane of corpus callosum. This slice is the center sagittal slice, which presents different geometric distribution of anatomic clusters from neural projections.*

Conclusions

CC was subdivided into nine clusters based on the connectivity via high angular resolution diffusion (HARD) tractgraphy. The multiple fiber reconstruction technique, such as QBI, could map the complex fiber distribution within a voxel and provide the potential for tracing the cortico-cortical fiber bundles. Moreover, VOI assignment in Brodmann's areas with mid-sagittal plane of CC could not only avoid the lack of labeling which is caused by low anisotropy in DTI but also furnish the intuitive connection. The result of distinct callosal areas is dissimilar to the new scheme of CC partitions proposed by Hofer [2], while BA 10 and 9 are assigned as the prefrontal, BA 8 and 6 as the pre-motor and supplementary motor, BA 4 as the motor, BA 1, 2, 3, 5 and 7 as the sensory and others as the partial, temporal and occipital regions. The reason might be due to the lack of subject number. Nevertheless, more detailed distinctions in CC and validation of geometric partitioning schemes would be advantageous to provide evidence in neuroscience and clinical diagnosis.

Acknowledgement

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