Reconstruction and Visualization of White Matter Tracts Based on Clinical Diffusion Spectrum Imaging

L-W. Kuo[1], V. J. Wedeen[2], J-C. Weng[1], T. G. Reese[2], J-H. Chen[1], W-Y. I. Tseng[3]

[1]Interdisciplinary MRI/MRS Lab, Department of electrical engineering, National Taiwan University, Taipei, Taiwan, [2]MGH Martinos Center for Biomedical Imaging, Harvard Medical School, Charlestown, MA, United States, [3]Center for Optoelectronic Biomedicine, National Taiwan University College of Medicine, Taipei, Taiwan

Abstract

This abstract reported our recent progress in white matter fiber tractography based on diffusion spectrum imaging (DSI) data. Isotropic DSI images (2.3 mm^3) were acquired on a 3T scanner with 203 diffusion-encoding gradients reaching the maximal b-value of 4000 s/mm^2. The scan time was within 30 min. An automated tractography algorithm using pixels in the whole brain as seed points was applied. An interactive visualization tool was developed to view interested tracts. The tractography showed major white matter tracts including association fibers, commissural fibers and projection fibers. The results were consistent with the findings obtained from white matter dissection.

Introduction

Diffusion spectrum imaging (DSI) has been proved to reveal local fiber orientations, especially in the regions of complex fiber intersections [1,2]. Reconstruction of tractography from DSI data clearly showed distinct axonal fiber tracts at the criss-cross regions [3,4]. Although potentially useful, this technique cannot be realized in the clinical settings until the following goals are achieved. First, DSI data of the whole brain at adequate isotropic resolution have to be acquired in a clinically acceptable scan time, typically 30 min. Second, the reconstruction algorithm for DSI tractography should be as automated as possible in order to avoid subjective intervention. Third, an interactive 3D visualization tool is required to show specific fiber tracts according to viewer's preference. In this abstract, we reported our recent progress toward the above goals. The tractography showed major white matter tracts including association fibers, commissural fibers and projection fibers. The results were consistent with the findings obtained from white matter dissection.

Materials and Methods

DSI data were obtained from three healthy volunteers with a 3T MRI system (Trio, Siemens, Erlangen, Germany). A twice-refocused balanced echo diffusion EPI sequence was used to acquire MR diffusion images. In order to implement the tractography, isotropic voxels were obtained by setting in-plane resolution and slice thickness to be 2.3 mm. Approximately 45 to 50 slices were acquired compassing the whole brain. Images of DSI were acquired with 203 diffusion-encodings comprising isotropic 3D grid points over the q-space. The maximum diffusion sensitivity bmax = 4000 s/mm^2, and TR/TE = 6500/150 ms. DSI analysis was based on the relationship that the echo signal $S(\mathbf{q})$ and the diffusion probability density function $P(\mathbf{r})$ were a Fourier pair, i.e., $S(\mathbf{q}) = FT\{P(\mathbf{r})\}$ [5]. The integration of $P(\mathbf{r})$ r^2 along each radial direction was used to calculate the orientation density function (ODF). The main orientations of the water diffusion were then determined by the local maximum vectors of the ODF. The fiber tracking was based on an automated algorithm that was adapted for DSI data. The first three DSI vectors of each voxel over the whole brain were used to be the seed points. All fiber orientations of the nearest voxels were used to decide the proceeding orientation for the next step. The most coincident orientation less than 22° was chosen. The proceeding length of each step was 0.5 voxel. The tracking would stop if there was no coincident orientation in the nearest voxels. To visualize interested white matter tracts, an interactive visualization tool was developed. Region-of-interests (ROIs) of any shape and orientation could be specified and the tracts passing through the ROIs could be selected.

Results

Figure 1a shows the first 10000 long tracts over the whole brain. We can see association fibers such as superior longitudinal fasciculus (a) and inferior longitudinal fasciculus (b), and projection fibers such as corona radiate (c). A 3D color scheme was assigned to indicate tract orientations; red in left-right, green in anterior-posterior, and blue in top-bottom orientation. The morphology of these fiber tracts are consistent with those shown from white matter dissection (Fig. 1b) [6]. The white matter tracts that pass across each other could be tracked successfully. Fig. 2a shows the corpus callosum viewing from the top. Frontal forceps, occipital forceps and tapetum were shown. Consistent with the dissection results (Fig. 2b), there are some callosal fibers going laterally to cortical regions on both sides, and some bending upwards. Adjacent to the corpus callosum, Fig. 3a shows two important association fibers: cingulum (in green) and fornix (in blue).

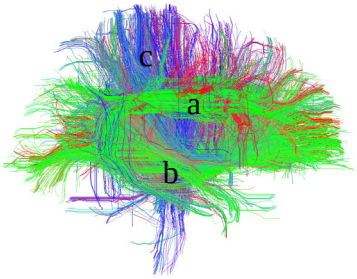

Figure 1a

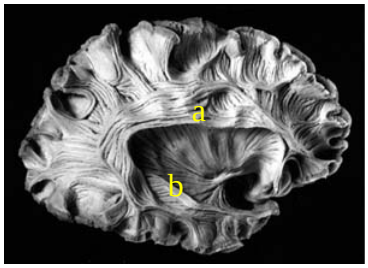

Figure 1b

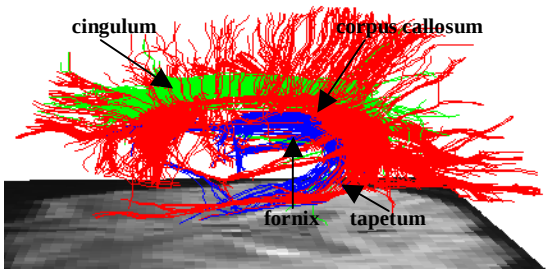

Figure 3a

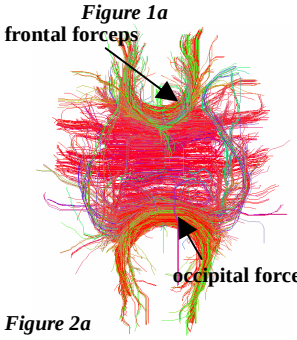

Figure 2a

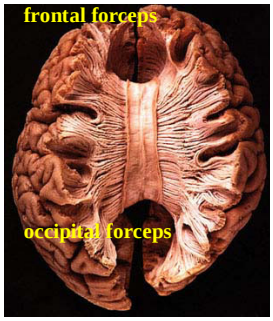

Figure 2b

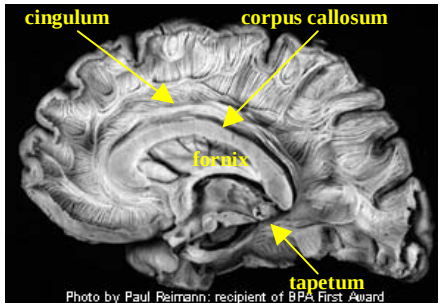

Figure 3b

Conclusions

We have developed automated and interactive software for reconstruction and visualization of DSI tractography. Tractography showed major neural axonal pathways in the brain, consistent with the findings from white matter dissection. With this technique, MRI of functional connectivity can be realized by combining selected tracks with functional activations from fMRI.

Reference

[1] Wedeen et al., ISMRM2000, p82. [2] Lin et al., NeuroImage. 19:482-95, 2003. [3] Hagmann et al., ISMRM2004, p62 [4] Kuo et al. ISMRM p1286. [5] Callaghan PT: Principles of nuclear magnetic resonance microscopy. Oxford Science Publication, 1991. [6] Williams et al., The Human Brain: Dissections of the Real Brain, http://www.vh.org/adult/provider/anatomy/BrainAnatomy/BrainAnatomy.html