Integration of Magnetoencephalography and Q-ball Tractography in the Visual Function

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Introduction

Plenty of studies have involved in exploring anatomical and functional connectivity in brains. Recent advances in magnetic resonance imaging (MRI) tools have given new opportunities for combining those two kinds of brain information. The development of diffusion magnetic resonance imaging (dMRI) has an important application in anatomic fiber tracking (FT), which is based on the water diffusivity within brain tissue. On the contrary, the technique of magnetoencephalography (MEG) offers functional brain imaging in real time, which records the magnetic fields due to neuronal activity. Therefore, the aim of this study is to integrate these two noninvasive approaches, visual evoked dipole sources by MEG and q-ball (QBI) tracking fibers by dMRI, in order to complement each other for an in-depth exploration of neuroscience issues. The combinative mapping provides more accurate navigational tools to answer whether the tractographic path actually conveys functional information and whether the MEG dipole location has an anatomic connection.

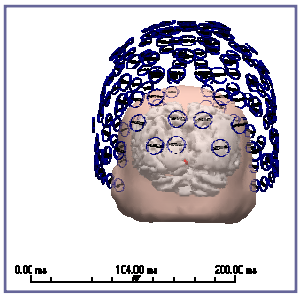
Materials and Methods

In order to make sure the track was found out exactly, the conventional early visual pathway was used as an important identification. For the visual stimulation, the wedge pattern placed in right hemifield was presented binocularly in an "on" and "off" mode. Subjects were instructed to fixate on a small red cross present in the central field so as to minimize eye movement during the test without giving other tasks. Visual evoked fields were recorded with a whole-head 160-channel coaxial gradiometer (PQ1160C, Yokogawa Electric Corp., Tokyo, Japan). One hundred epochs were averaged for each test session. Subject's head shape and position with respect to the MEG sensor were measured from a three-dimensional digitizer and five markers. Co-registration procedures of MEG and MRI are published elsewhere [1]. In the source analysis, a single equivalent current dipole (ECD) model in a spherical volume was applied to estimate the cortical sources of the measured magnetic fields. Further steps involved in source modeling were performed using Curry 5.0.8 software (Neuroscan, Inc.). All ECDs with more than 85% of the goodness-of-fit (GOF) value were selected.

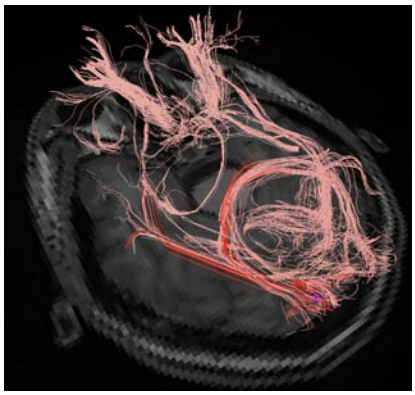
On another side, in vivo human brain QBI were acquired in a GE Healthcare Signa 1.5T Excite scanner in Taipei Veterans General Hospital by using spin echo EPI sequence with 162 icosahedral diffusion-encoding directions, matrix size=128×128, slice number=46, voxel size=2.0×2.0×2.2 mm^3,TR/TE = 13600/91.2 ms and b_{max} =3000 s mm^{-2}. For each MR voxel, the orientation distribution function (ODF) was reconstructed by the Funk-Radon transformation [2]. MFACT (multiple fiber assignment by continue tracking), the tracking algorithm applied in this research, which is similar to FACT proposed by Mori [3] but could be applied in propagating fiber spread on high angular resolution diffusion data [4]. Tracking terminated when the local maximum of ODF was lower than 0.7 or when the diffusion direction in consecutive steps differed by more than 50 degree. Reconstruction of QBI, fiber tracking, and visualization were developed in-house by using Borland C++ Builder 6 and OpenGL API.

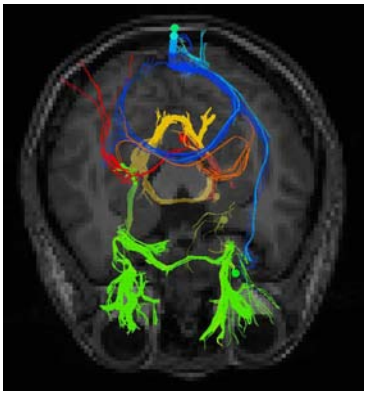
Results

The location of ECD at 104 ms (Fig. 1) with the highest GOF value (95%) was used to be a seed point for the tractography with QBI. Those fibers shown in red in Fig. 2 were superposed on the visual pathways (fiber bundles coded by pink) which were propagated from the whole V1 area by using MFACT. MEG dipoles in the diffusion-based T2 images are presented over a time course of 62 to 106 ms with 2 ms interval in Fig. 3. The latency from short to long is indicated with colors from red to blue. In the fiber tracking, each time point dipole was selected independently as a volume of interesting (VOI) in the QBI. All color lines are tracking fibers corresponding to their dipole points. According to the Brodmann template, those tracks passed forward through BA 18, 19, 30, 36, 28, 35, 38 and 11, and then turned back to BA 17.



▲Fig.1. A rear view of the segmented cortex on which the red ECD of M100 was placed.





◄◄Fig.2. Tracking fibers from the dipole at 104 ms are superposed on the early visual pathway. The red fibers are the tracking result from the blue seed point dipole fitted around the calcarine fissure with a GOF value of 95%. The pink fibers are the early visual pathway tracking from the whole V1 area.

◄Fig.3. Fiber tracking for each time point dipole. The colors of fibers correspond to the dipoles.

Conclusions

This report is the first study in integrating high temporal resolution MEG and high spatial resolution dMRI. Fibers generated from an ECD appearing near the calcarine fissure could be successfully tracked to the lateral geniculate nucleus (LGN) and corpus callosum (CC). Although the tracking of different time points did not show a consistent path, the situation could be explained as sophisticated processing in human brain. In this neural network, not only an early visual sensation but also attention and emotion were involved. In short, our present study opens a new window for further exploration of complex brain mechanisms.

Acknowledgement

This study was supported in part by Taiwan National Science Council grant NSC 95-2752-H-010-004-PAE

References

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