Detection of Motor Thalamus by Probabilistic Diffusion Density : verification by motor BOLD-based fMRI

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Introduction

Functional MR studies of human brain include two major aspects, structural and functional approaches, respectively. In this project, establishment of the structural maps of thalamus is proposed by utilizing multimodal integration of these two approaches. And clinical potential of the thalamus maps will be tested for clinical approaches (e.g. functional neurosurgery). Structural MR approach applied both conventional high-resolution structural MRI and diffusion tensor images (DTI) for estimating probabilistic diffusion density tractography (PDD, Johansen-Berg et al 2005). Functional MR approach utilized the functional motor paradigms to validate the location of motor thamalus as compared to the thalamus maps derived from structural approach.

Structural MRI and functional MR data with motor task of right index were obtained from fourteen normal subjects. PDD-based thalamal parcellation was performed with two protocols. Protocol I applied the volume of interest (VOI) of Brodmann areas 1-6 as targets by spatial normalization. And protocol II used the central correlates of motor fMRI as target. Two similarity indices of thalamus parcellation were calculated as SI(BA1-6) = 0.56±0.18 and SI(motor-fMRI) = 0.96±0.06 regarding to protocol I and II, respectively. We concluded the PDD-based parcellation of motor thalamus can be validated by using the fMRI of a simple motor task.

Subjects and Methods

(1) Subject and FMRI of a go/no-go task

Fifteen right-handed subjects (gender- and age-matched, age: 36 +/- 8 years old) were recruited for the fMRI and DTI studies. FMRI studies were conducted at a 3T system (MedSpec 300, Bruker GmbH, Ettlingen, Germany). For mapping motor areas of right index involved in button response during the go/no-go task, an event-type functional paradigm was applied for fMRI examination (BLIP echo planar imaging (EPI) sequence, 64x64 matrix, slice thickness/ gap = 5/1 mm, 20 slices covering whole brain, field of view (FOV)= 230x230 mm, a flip angle = 90 degree, echo time (TE) = 50 ms, repetition time (TR) = 2000 ms, dummy scan (DS) = 5, and repetition number (NR) = 288). Analyses of fMRI data were analyzed with Statistical Parametric Mapping (SPM2, Wellcome Department of Cognitive Neurology, London, UK) with a Gaussian spatial smooth kernel of 8-mm FWHM. Regional activations were significant at $p < 0.001$, uncorrected for multiple comparisons and cluster size > 0 voxel.

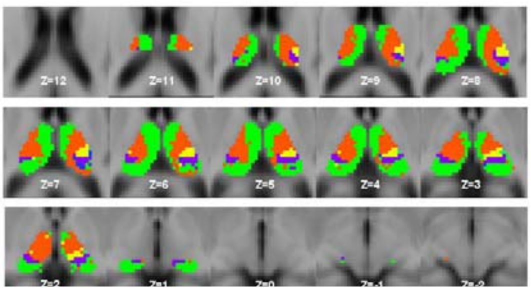
(2) DTI acquisition and analyses

All subjects also received structural studies using a 1.5T MRI system (Signa Excite, General Electronics, Milwaukee, Wisconsin, USA.). DTI studies were obtained using spin-echo-based diffusion-weighted echo-planar-image (EPI) sequence (TR=17000 milliseconds, minimal TE, matrix size = 128x128, NE = 6, b=1000, 13 or upto 55 directions, voxel size = 2.03x2.03x2.2 mm) in a 1.5T MRI system (Signa Excite, General Electronics, Milwaukee, Wisconsin, USA.) High-resolution T1-weighted anatomical images were also acquired using the 3D spoiled gradient echo sequence (TR= 2000 milliseconds, TE=53 millisceonds, voxel size = 1.02x1.02x1.5 mm). After EPI reconstruction, realignment and eddy current correction was performed using the image of B0 (without diffusion weighting). Reconstruction of diffusion tensor was obtained with conventional algorithm for diffusion tensor calculation. With Bayesian Estimation of Diffusion Parameters Obtained using Sampling Techniques, the probabilistic estimation of major diffusion density was obtained. By co-registration of DTI and high-resolution T1-weighted image and normalization of the high-resolution T1-weighted image to ICBM-152 T1 template, the maps of probabilistic diffusion density (PDD) were normalized. And parcellation of thalamus was obtained using constrains of PDD and prior knowledge of normalized areas (e.g. thalamus).

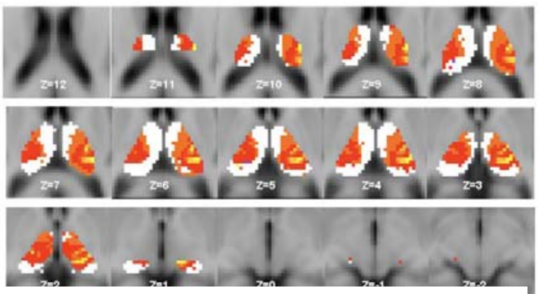
With the functional correlates identified by motor fMRI paradigms, similar strategy like the thalamic parcellation was applied for validation of motor thalamus. Correlation of two methods, normalized Brodmann area and fMRI, provided evidence for validation. A similar index (SI) was calculated by the motor thalamic parcellation identified via the two protocols using the VOIs of Brodmann areas 1-6 (BA1-6) and VOIs of motor fMRI (motor-fMRI) for left cerebrum [SI(motor-fMRI) = (BA1-6∩motor-fMRI) / motor-fMRI; and SI(BA1-6) = (BA1-6∩motor-fMRI) / BA1_6].

Results

PDD-based parcellation of thalami was demonstrated for a 32 year-old subject by thalamo-cortical projection to Brodmann areas 1-6 (**Figure 1**) and motor cortices defined by fMRI (**Figure 2**). Sensitivity of PDD-based parcellation was verified by averaged SI(motor-fMRI) = 0.96 as **Table 1**, when averaged specificity was 0.56 by SI(BA1-6).



▲**Figure 1 :** PDD-based parcellation of thalami of a 32 year-old female was demonstrated in normalized space of ICBM-152. Classification of thalamal sub-regions were created by the thalamocortical projection to Brodmann areas 1-6 (labeled as yellow-green for BA 2, blue for BA 3, yellow for BA 4, purple for BA 5 and orange for BA 6). The VOI of thalami (in green) was applied for PDD-based parcellation.



▲**Figure 2 :** PDD-based parcellation of thalami of a 32 year-old female was demonstrated in normalized space of ICBM-152. Classification of thalamal sub-regions were created by the thalamo-cortical projection to functional cortices detected by fMRI (in color scale from red to yellow as low to high probability). The VOI of thalami (in white) was applied for PDD.

Table 1 : Validation of motor thalamus

Subject No.	SI(motor-fMRI)@	SI(BA1-6)#
1	0.81	0.58
2	1	0.31
3	1	0.41
4	1	0.62
5	0.87	0.79
6	1	0.48
7	0.99	0.87
8	0.99	0.49
9	0.95	0.80
10	0.99	0.72
11	0.99	0.46
12	0.93	0.59
13	1	0.46
14	0.90	0.29
Mean±SD	0.96±0.06	0.56±0.18

@ : SI(motot-fMRI) = (BA1-6∩motor-fMRI) / motor-fMRI
# : SI(BA1-6) = (BA1-6∩motor-fMRI) / BA1_6

Discussion

Localization of motor thalamus using PDD was justified using the high-resolution structural MRI and DTI studies in human brain. With limited functional correlates of sensori-motor modality by the motor-task of right index during a Go/NoGo paradigm, SI(motor-fMRI) demonstrated 96±6% by PDD showing sensori-motor thalamus with fiber projection to sensori-motor modality of right index. And SI(BA1-6) showed less similarity of 56±18% based on PDD using VOIs of Brodmann areas 1~6 by normalization in Talairach space.

Acknowledgement

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References

Johansen-Berg et al 2005, Cerebral Cortex, 15:31-39