Functional anatomy of human sleep spindles using simultaneous EEG-fMRI recording

T. Mori[1], K. Anami[1], F. Tanaka[1], T. Ohnishi[1], H. Matsuda[1], O. Saitoh[1]

[1]National Center Hospital for Mental, Nervous, and Muscular Disorders, NCNP, Kodaira, Tokyo, Japan

Introduction:

Sleep spindles appear in the thalamus and cortex during early stages of sleep. They are generated by thalamic neurons and carried to neurons in the widespread cortical regions according to the animal experiments to date. Anderer et al. estimated cortical spindle sources using low-resolution electromagnetic tomography (LORETA) [1], and demonstrated a widely distributed spindle source over the medial areas of cerebral hemispheres. However, a commonly accepted theory has not been established whether or not specific cortical regions are related to sleep spindles. In the present study, we attempted to identify cortical regions correlated to sleep spindles using simultaneous EEG-fMRI recording in the living human brain.

Methods:

Three healthy subjects (two 28-year-old male and a 25-year-old female) participated in the study. EEG was monitored from 8 scalp electrodes (F3, F4, C3, C4, Cz, Pz, O1 and O2) and referenced to linked-mastoid electrode. Neuroscan SynAmps and Scan 4.2.1 software programs were used for EEG recording combined with stepping-stone sampling method [2]. For fMRI image acquisition, Siemens Vision Plus scanner (1.5T) was used. Simultaneous recording was performed when subjects reached stage 2 sleep [3]. Imaging parameters were 6 mm slice thickness; TR = 2,000ms; TE = 40ms; TA = 1932ms; and 21 slices. 420 scans were acquired. fMRI images were analyzed with SPM99. A statistical test with general linear model was conducted using a regressor consisting of the power values of EEG in the range of 12-14 Hz.

Results:

The areas of spindle-related BOLD signal change included, almost symmetrically, primary somatosensory-motor area, primary auditory area and anterior cingulate gyrus ($p<0.01$, uncorrected).

Discussion:

Spindle-related BOLD signal changes had widespread distribution over the brain, but dominated the specific cortical areas. Activated areas were localized in primary and paralimbic areas. Though the results were preliminary, the present study provided novel insight to understand the physiological role of sleep spindles.

References:

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