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Sleep EEG

Activation of visual cortex in REM sleep measured by 24-channel NIRS imaging

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Abstract To visualize dreaming brain functions we studied hemodynamic changes in the visual cortex during the transition from non-rapid eye movement (NREM) to rapid eye movement (REM) sleep, using a 24-channel Near-Infrared Spectroscopy (NIRS) imaging method. Results were compared to the activation in visual cortex by visual stimulation during wakefulness. Subjects were four healthy males between 25 and 49 years of age. Five all-night polysomnographic and NIRS recordings were made. Increases in the oxygenated hemoglobin concentration in visual cortex were observed from nine of 14 REM periods. The activated areas were broader during REM sleep than during visual stimulation. These findings suggest that activation of visual cortex in REM sleep might represent dream-related brain activity.

Key words dreaming, EEG, mapping, NIRS, occipital, REM sleep, visual cortex.

INTRODUCTION

As a method for measuring the functions of cerebral cortex during sleep, Near-Infrared Spectroscopy (NIRS) has the advantages of being able to measure hemodynamic changes non-invasively, continuously and silently. The NIRS method measures changes in the relative amounts of total hemoglobin (total-Hb), oxygenated hemoglobin (oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb), respectively. It has been established that the increase of oxy-Hb and total-Hb is coupled with regional activation of the brain.

Dreams during rapid eye movement (REM) sleep typically include lucid visual images, suggesting the involvement of visual cortex.[1] Therefore, we investigated the hemodynamic changes in visual cortex during the periods of transition from non-rapid eye movement (NREM) to REM sleep using a 24-channel NIRS imaging method (developed by the Central Research Laboratory, Hitachi Ltd, Tokyo, Japan[2]) to investigate brain functioning during REM sleep.

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METHOD

A set of 16 optical fibers was affixed to the hemi-occipital scalp with a 9 cm^2 moulded thermoplastic support that enabled the transcranial measurement of total-Hb, oxy-Hb and deoxy-Hb at 24 points. A NIRS contour map was generated to visualize the local hemoglobin-concentration changes in the underlying hemi-occipital cortex.

Subjects were four healthy males between 25 and 49 years old. Five all-night NIRS and polysomnographic sleep recordings were made. Sleep stages were judged using standard Rechtschaffen and Kales' criteria.[3] A computerized polysomnography analyzer[4] calculated the electroencephalograhic (EEG) power density and electro-oculographic (EOG) eye movement activity (REM).

To map the activation of visual cortex during REM sleep the average concentrations of oxy-Hb, deoxy-Hb and total-Hb in the 5 min of NREM sleep just prior to each REM period were subtracted from those during the REM periods. The increase or decrease of each form of hemoglobin was plotted using linear interpolation to produce Hb concentration gradients. The subjects were also exposed to visual stimulation by a circular checker-

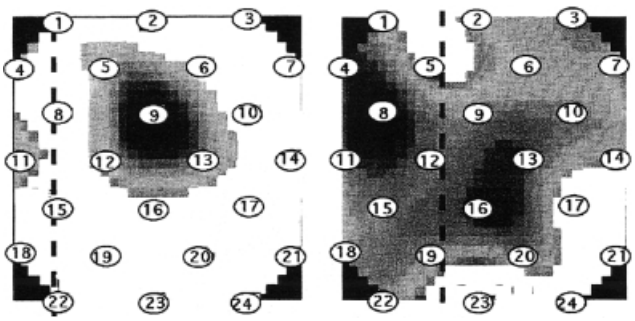

Figure 1. Map of oxygenated hemoglobin (oxy-Hb) change in the right visual cortex during wakefulness (left side) and REM period (right side) in a typical case. The midline of the brain is shown as vertical dotted lines and numbered open circles indicate the measuring points. Darker areas represent increased oxy-Hb.

board while awake, for comparison with sleep activation levels.

RESULTS

There were 14 REM periods among the five nights of sleep for these four subjects. Increased oxy-Hb concentration was found in NIRS channels monitoring the primary visual cortex during nine of the 14 REM episodes. The REM periods which showed increases in oxy-Hb shared the following two features: (i) the duration of these REM periods exceeded 10 min, and (ii) the NREM sleep preceding the REM period was stable and had no waking time. There were 10 long REM periods that continued for more than 10 min. In nine of these, increased oxy-Hb in visual cortex was observed.

The maps of oxy-Hb changes during REM period were compared to those during visual stimulation in arousal state. The activated areas during REM periods were broader, but overlapped with those found during visual stimulation. However, there were differences in the relative levels of activation. A map for a typical subject is shown in Fig. 1.

The level of oxy-Hb and EEG alpha band (8–9 Hz) power density tended to fluctuate inversely. But there was no apparent relation between oxy-Hb and the power of REM eye movements (REM frequency × REM amplitude).

DISCUSSION

It was found that oxy-Hb increased during longer (10 min or more) REM periods that followed stable NREM sleep. Comparison of the REM activated brain areas with those activated during wakefulness by visual stimulation revealed overlaps in the NIRS gradient contours, although the areas were broader during REM periods than while awake. These findings suggest that activation of visual cortex in REM sleep might reflect brain activities involved in the visual dream experiences.

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