Brain-changes During Transition from Awake to Sleep: (MEG) study

Gumenyuk Valentina[1,2], Robinson Stephen[2], Jefferson Catherine[1], Roth Thomas[1], Tepley Norman[2] and Drake L.Christopher[1]

[1]Henry Ford Hospital Sleep Disorders & Research Center, Detroit, MI

[2]MEG laboratory, Neurology Department, Henry Ford Hospital, 48202,

Detroit, Michigan, USA

vgumenyu@neurnis.neuro.hfh.edu

ABSTRACT

During the sleep onset process the multisource alpha and sigma rhythms change dramatically. In order to begin to understand the functional role of these changes during the sleep transition, the spatial and temporal changes in alpha (8-11 HZ) and sigma (12-15 HZ) were investigated, using MEG method. The results reveal that broad regions alpha MEG activity declined in active neural sources with sleep progression from wake to sleep, however occipital-parietal generators remain be active during stage 1 and 2 sleep. The sigma activity showed strong pattern in frontal lobe predominant cortical distribution with sleep progression, specifically in stage 2 sleep across all subjects. This finding suggests that sigma activity play important role in brain regional changes, especially in frontal lobe during sleep onset in healthy normally sleeping individuals.

KEYWORDS: MEG, alpha and sigma activity, sleep onset.

INTRODUCTION

The sleep onset period is characterized by continuous changes in several measures: eye movements, muscle activity, respiration, including changes in global rhythms across brain regions [1]. During sleep onset period the global rhythms such as alpha (8-11Hz) and sigma (12-15Hz) change dramatically in temporal domain [2], whereas the evolutions of topographical changes remain unclear, especially for sigma activity. The sigma frequency is underlying the sleep spindle activity, the hallmark of the stage 2 sleep. The evolution of temporal and topographical brain changes during sleep onset period can be studded by Magnetoencephalography (MEG).

The aim of this study was to determine uncorrelated (unique) magnetic neural sources associated with alpha and sigma activity during the transition to sleep in normal subjects.

METHODS

Four healthy subjects between 19-35 years old were studied (Mean age: 24.7 ± 11.2; 3 females; right handed). All participants were free of sleep complaints as assessed by a board certified sleep specialist and had no objective signs of sleep disturbance determined from a standard overnight polysomnogram (PSG) including respiratory measurement and anterior tibialis electromyograph (apnea-hypopnea index < 10 per hr and periodic limb movements < 10 per hr). The subjects had no history of any medical or psychiatric disorder. Subjects were free of all CNS acting medications at least 2 weeks prior to the laboratory assessment. All subjects were free of alcohol and nicotine at least 24 hrs prior to the study. Each participant kept a sleep diary 2 weeks

prior to the MEG study. All subjects were paid for participation and the study was approved by the Internal Review Board of Henry Ford Hospital, Detroit MI.

Both the MEG (148 MEG sensors, 4D-Neuroimaging WH2500 Neuromagnetomer System and EEG (NeuroScan) activity of sleep spindles were recorded simultaneously. Four EEG electrodes were applied to the subject's scalp (C3, C4, O1, O2), two electrodes were applied to earlobes (A1 and A2) and used as contralateral reference sites for EEG data. Vertical/horizontal eye movement was recorded using 2 electrooculogram electrodes (left and right EOG) placed on the canthi of each eye and one electrode placed on the chin for electromyogramrecording. The electrocardiogram (ECG) was recorded using a standard V5 lead.
The whole-head neuromagnetometer detector array (148 sensors) was placed over the subject's head. After a short (1-2 min) biocalibration (eyes and muscle movement), subjects were asked to "try to fall asleep" and data acquisition began. This morning nap started at 0730 and ended at approximately 0830 depending on each individual's sleep onset. In order to maintain accurate head positioning during the MEG recording, the nap session was divided into separate 15 minute experimental runs. Each subject performed 3 runs of 15 min each. Data acquisition was monitored online and an experienced technician (CF) detected sleep stages in real time on the computer screen. If a given subject did not reach stage 2 sleep, a forth run was performed in order to ensure an adequate sample of stage 2 sleep was obtained. Sleep stages were determined on 30 sec long EEG segments during sleep scoring standard procedures (Rechtschaffen & Kales, 1968). The continuous EEG and their MEG counterpart was classified as being either wakefulness (W), stage 1 (S1), or stage 2 (S2) sleep. MEG images of alpha and sigma activity and their difference were computed using a constrained minimum-variance beamformer [3]. The results of subtraction (8-11 Hz minus 12-15 Hz) were mapped to each subject's individual MRI for multiple 30 sec time window of MEG data segment.

RESULTS

Results indicate a similar pattern of topographical changes in brain organization for magnetic cortical sources sigma activity and its relative frequency power across all subjects during the sleep onset process (Fig.1). The uncorrelated cortical magnetic sources for 8-11Hz were dominant in the occipital and temporal lobe (Fig.2), whereas 12-15Hz sources localized more predominantly in the frontal lobe during the transition to sleep. Changes from alpha with posterior predominance to sigma with anterior predominance coincided with sleep onset (R&K's rules). Changes in alpha were easily seen in both the MEG and EEG whereas the pattern of increased frontal predominance in sigma during sleep onset was observed with MEG brain mapping, but was not visually apparent in the EEG.

The statistical comparison of sigma activity across W, S1 and S2 revealed that maxima relative power for sigma was in stage 1 sleep ($P<0.009$) and stage 2 sleep ($P<0.01$) with respect to Wakefulness (Fig.3).

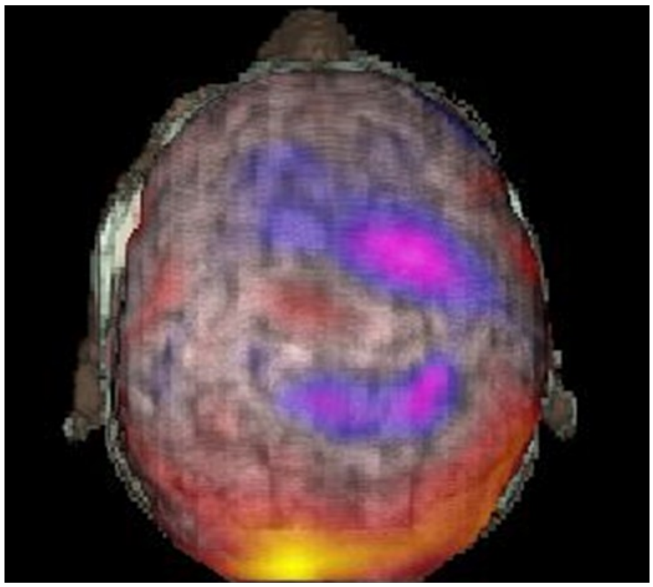

Fig 1. MEG Alpha (orange color) minus Sigma (magenta color) activity in one of the 4 subjects during stage 2 sleep. Note, there was robust pattern in spatial distribution for sigma activity across all subjects, showing that frontal lobe predominance is associate with sigma activation during stages 1 and 2 sleep.

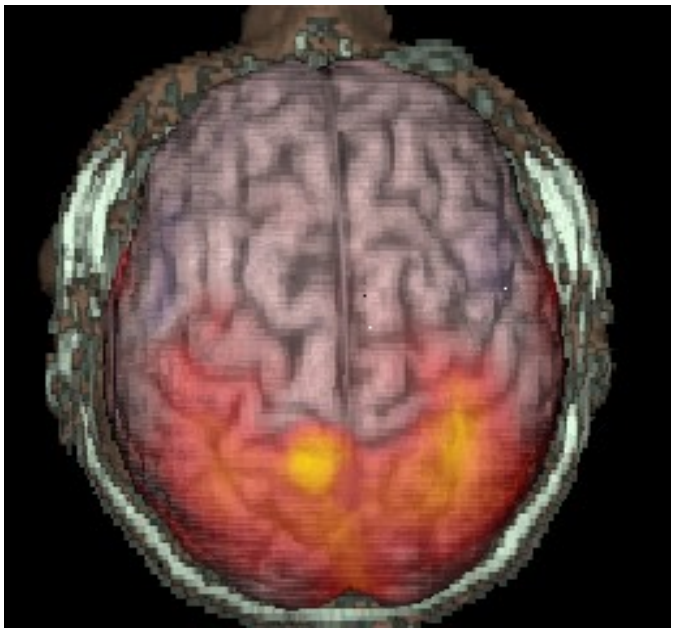

Fig 2. Alpha (orange color) minus Sigma difference for stage Wake. Alpha predominance was topographically distributed in occipital and temporal lobes during wakefulness across all subjects.

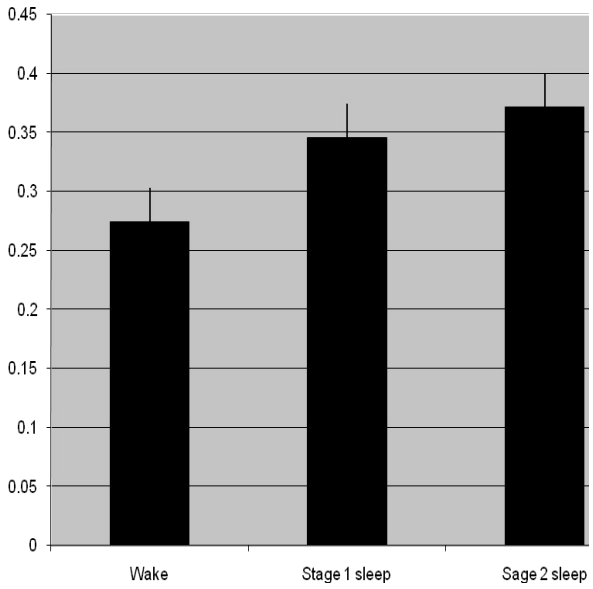

Fig.3. Relative power of Sigma frequency across stages wake, stage 1 sleep and stage 2 sleep in one individual subject. A statistical analysis (t-test) of relative sigma frequency power revealed increase Sigma from wake- to- sleep transition. (Wake= 9 segs., Stage1=7segs., Stage2=14 segs.)

DISCUSSION

Brain micro-changes in MEG alpha-sigma activity during transition to sleep reflect spatial and temporal changes. Alpha activity was generated by a multiregional neuronal network, declining in number of active generators with sleep progression. Thus, the neural generator of the alpha in occipital region remains active during stage 1 and 2 sleep. However sigma activity showed unique frontally distributed neural generators, activated during the transition to sleep specifically stage 1 and with more strength in stage 2 sleep across all our subjects.

This study suggest that sigma activity may show unique spatial distribution of the activity related with sleep onset and can be used for study sleep-onset-dysfunction in individuals with sleep disorder (e.g. Insomnia).

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