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Sleep EEG

Topographic mapping of EEG spectral power and coherence in delta activity during the transition from wakefulness to sleep

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Abstract The present study examined the topographic characteristics in delta band activity during the transition from wakefulness to sleep, using topographic mapping of electroencephalogram (EEG) power and coherence corresponding to nine EEG stages. The dominant topographic components of delta band activity increased clearly from the vertex sharp-wave stage EEG stage 6) in the anterior-central area. Principal component maps revealed the scalp distribution of EEG. Delta activity in the sleep onset period were composed of two covariant components. One is a diffuse component widely distributed on the scalp and the other is a local component at the temporo-occipital area.

Key words coherence, delta activity, principal component analysis, topographic maps, sleep onset period.

INTRODUCTION

Topographical analyses of electroencephalograms have been used to examine changes in brain activity in the sleep onset period (SOP).[1,2] The SOP is neurophysiologically complex.[3] When the topographical behavior of EEG in SOP is of interest, however, the standard sleep stage criteria[4] are somewhat vague, especially for stage 1. Therefore, the present authors have used nine EEG stage criteria[3,5] developed for the analysis of the SOP. Recently, we examined the topographical characteristics of nine EEG stages during the hypnagogic state.[6,7] These results suggest that the topographical structure of slow wave activities in the SOP starts to develop clearly from the vertex sharp wave stage. However, in these studies typically only one quantitative EEG technique was used. Therefore, it would be necessary to examine coherence analyses of hypnagogic EEG, which is a measure of the linear correlation between two EEG derivations. The present study used topographic mapping of spectral power and coherence for each of the nine EEG stages to examine the spatio-temporal behavior of the EEG activity in the SOP. Furthermore, the EEG power in the delta band activity is an indicator of a progressively declining process during sleep,[8] and it is suggested that the slow wave band activity could be used as the parameter to describe the transition process from wakefulness to sleep. The present study focused on the delta band activity, the structural laws of complicated changes of EEG power and coherence data were examined by principal component analysis (PCA).

METHODS

Somnography of nocturnal sleep was recorded on 10 male students (20–25 years). Spectral analysis of the 12 scalp EEG (Fp1, Fp2, F7, F8, Fz, C3, C4, Pz, T5, T6, O1 and O2) was carried out. The typical EEG patterns during hypnagogic state were classified into nine stages:[3,5] (1) alpha wave train; (2) alpha wave intermittent A ($\alpha \geq 50\%$); (3) alpha wave intermittent B ($\alpha < 50\%$); (4) EEG flattening; (5) ripples; (6) vertex sharp wave solitary; (7) vertex

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sharp wave burst; (8) vertex sharp wave with incomplete spindles; (9) spindles. Topographic maps of EEG power from the samples of 30 (5×6) s period (0.2 Hz resolution) for delta band (2.0–3.4 Hz)[7] were computed for 12 EEG channels for each of the nine stages. The 66 paired single coherence values among 12 areas were computed for the delta band for the same EEG samples. Coherence measures of the EEG are used to compare a linear correlation between two brain sites. The average 12×12 (electrode sites) matrixes across all subjects were made from 66 paired coherence values for the delta band and EEG stages. The diagonal of the matrixes represent power data transformed from zero to one range correspond to coherence range. The PCA was carried out on these matrixes for nine EEG stages. The factor loading patterns of the initial two values accounting for 70% of the trace were illustrated on a topography map. Factor loading is the correlation coefficient between the principal component (PC) and EEG activity of the electrode site. These values of the factor loading pattern were plotted on 12 scalp areas of the topogram. After the average interpolation was performed, the contour map of the PC was displayed.

RESULTS

As shown in Fig. 1, the dominant area of the delta power was observed on the frontal region at first and then extended across the scalp, from the central to the temporal region. Topographic maps of coherence in delta activity demonstrated that the synchronous component in the anterior-central area of scalp appeared, which corresponded with increasing power. Therefore the dominant synchronous component of delta band activity increased clearly from EEG stage 6 in the anterior-central area. To identify the dominant topographic components of delta band activity, PCA was applied. As shown in Fig. 2, PC maps revealed the scalp distribution of EEG delta activity in the SOP were composed of two covariant components. One is a diffuse component widely distributed on the scalp focus on the anterior-central area (communality also increased clearly from EEG stage 6) and the other one is a local component at the temporo-occipital area. These two components did not show any interhemispheric differences.

DISCUSSION

The dominant synchronous component of delta band activity increased clearly from EEG stage 6 in the anterior-central areas. These results suggest that the topographical structure of slow wave activities in the hypnagogic state starts to develop rapidly from the vertex sharp wave stage. These findings support Broughton's suggestion that the appearance of the vertex sharp wave is related to behavioral sleep onset.[9] On the other hand, the PC map revealed the scalp distribution of EEG delta activity in the SOP was composed of two covariant components. One is a diffuse component widely distributed on the scalp and the other one is a local component at temporo-occipital areas. Additionally, these two components

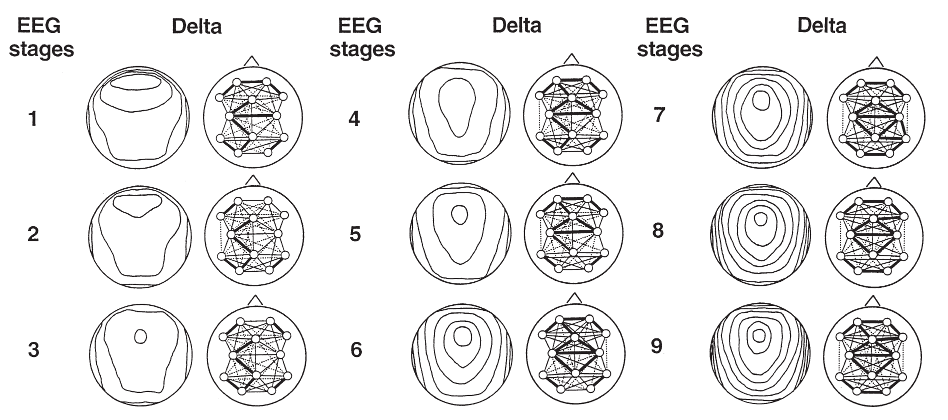

Figure 1. Typical patterns of topographic maps of power (left panel) and coherence (right panel) for delta band corresponding to EEG stages. Upper portion of each map shows the nasal and lower side shows the occipital side. The numerals on the left side of this panel indicate the nine EEG stages. Each topographic map of power (left panel) was sliced in equal steps of amplitude (delta, 1 step = 3.0 μV/Hz; Theta, 1 step = 1.6 μV/Hz). Thick lines (**—**) of topographic maps of coherence (right panel) show above 0.9 coherence level, thin lines (—) show the level from 0.8 to 0.9, and broken lines (...) show the level from 0.7 to 0.8.

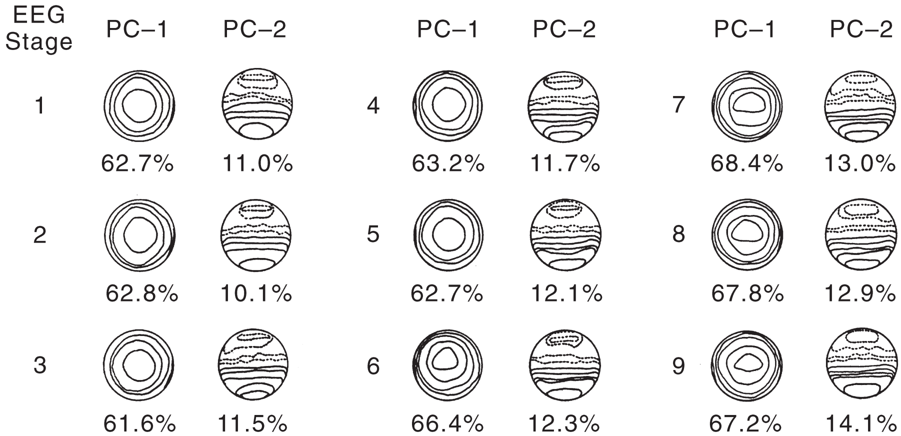

Figure 2. Principal component maps for delta band activity in a waking–sleeping transition period. Upper side of each map shows the nasal side and lower side shows the occipital side. The numbers on the left side of this panel show the EEG stages.[3]

did not show any interhemispheric differences. These results suggest that the origin or pacemaker system of delta activities would be inferred in the subcortical level as noted by dipole analysis.[10]

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