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Sleep EEG

Topographic mapping of electroencephalography coherence in hypnagogic state

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Abstract The present study examined the topographic characteristics of hypnagogic electroencephalography (EEG), using topographic mapping of EEG power and coherence corresponding to nine EEG stages (Hori's hypnagogic EEG stages). EEG stages 1 and 2, the EEG stages 3–8, and the EEG stage 9 each correspond with standard sleep stage W, 1 and 2, respectively. The dominant topographic components of delta and theta activities increased clearly from the vertex sharp-wave stage (the EEG stages 6 and 7) in the anterior-central areas. The dominant topographic component of alpha 3 activities increased clearly from the EEG stage 9 in the anterior-central areas. The dominant topographic component of sigma activities increased clearly from the EEG stage 8 in the central–parietal area. These results suggested basic sleep process might start before the onset of sleep stage 2 or of the manually scored spindles.

Key words alpha activity, principal component analysis, sleep onset period, sleep spindles, slow wave activity.

INTRODUCTION

The sleep onset period (SOP) is neurophysiologically complex.[1] Topographical analysis of EEG have been used to examine changes in brain activity in SOP.[2,3] 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,[1,5] developed for analysis of the SOP. The present study used topographic mapping of spectral power and coherence for each of the nine EEG stages in order to examine the spatio-temporal behavior of the EEG activity in the SOP. In addition, the structural laws of complicated changes of EEG coherence data were examined by a principal component analysis (PCA).

METHODS

Somnography of nocturnal sleep was recorded in 10 male students (aged 20–25 years). Spectral analysis of the 12 scalp EEGs (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,[1,5] (i) alpha wave train, (ii) alpha wave intermittent A ($\alpha \geq 50\%$), (iii) alpha wave intermittent B ($\alpha < 50\%$), (iv) EEG flattening, (v) ripples, (vi) vertex sharp wave solitary, (vii) vertex sharp wave burst, (viii) vertex sharp wave with incomplete spindles, and (ix) spindles. Topographic maps of EEG power from the samples of 30 (5×6) speriod for six frequency bands (delta: 2.0–3.4 Hz; theta: 3.6–7.4 Hz; alpha 1: 7.6–9.4 Hz; alpha 2: 9.6–11.4 Hz; alpha 3: 11.6–13.4 Hz; sigma: 13.0–14.8 Hz) were computed for 12 EEG channels for each of the nine stages. The 66 paired single coherence values among 12 areas were computed for six frequency bands for the same EEG samples. Coherence measures of the EEG are used to compare a linear correlation between two brain sites.

RESULTS AND DISCUSSION

Topographic maps of EEG power and coherence were made for six frequency bands for the nine EEG stages. Topographic maps of coherence in delta and theta band activities demonstrated that the synchronous component in anterior–central areas of scalp appeared, which corresponded with increasing power. For the alpha 3 band, the topographic maps of coherence demonstrated that a synchronous component appeared

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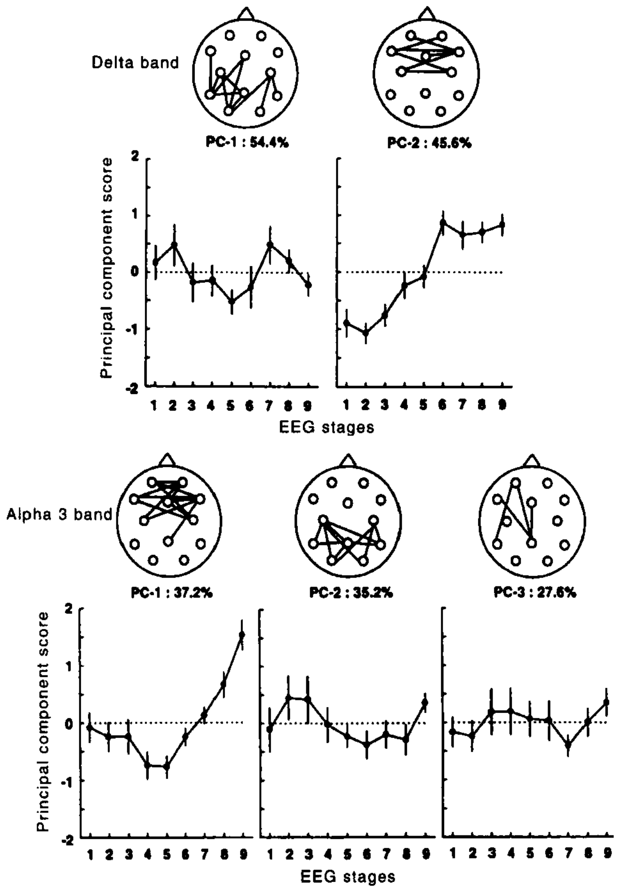

Figure 1. Topographical distributions and variations in averaged component scores for each electroencephalogram stage for delta and alpha 3 bands. The solid lines in the upper panel (topographic map) show the above 0.7 level of factor loading show the electrode pairs extracted by principal component analysis.

on the anterior–central areas of scalp, which corresponded with increasing power. For the sigma band, high coherence pairs appeared after EEG stage 8, which focused on the central area, and spread throughout the scalp with the development of EEG stages.

In order to identify the dominant topographic components of coherence, PCA was applied. Figure 1 shows the topographic features of synchronous components and the variations in averaged component scores for each EEG stage. The dominant synchronous component of delta and theta band activities clearly increased 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 vertex sharp wave is related with behavioral sleep onset.[6] For alpha 2 band activity, principal components consisted of the anterior areas and the posterior areas. One component is the widespread alpha activity in frontal pole (occipital chain) and the other is local alpha activity in the posterior regions. Both of the alpha 2 band components (PC-1, PC-2) showed high scores during waking. These suggest that these band activities could reflect fluctuation of the arousal level. The dominant synchronous component of alpha 3 band activity appeared from EEG stage 6 and developed sharply from the EEG stage 9 (spindles) in the anterior–central areas. By visual inspection, it is confirmed that this increase of coherence value is associated with the development of the activities of 12 Hz slow spindles. In sigma band activity, the dominant synchronous component appeared clearly on the parietal area from the EEG stage 8. This increase of coherence value reflected the development of the activities of 14 Hz sleep spindles. These results indicate that anterior synchronous components are related to the sleep EEG activities and that posterior components are related to the waking EEG activities, with the exception of components related to 14 Hz sleep spindles which has a focus at the parietal area. These findings suggest that the sleep onset processes start in anterior areas.

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