Correlation between Eyelid Microvibration and Electroencephalogram at Various Sleep Stages in Man

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The mechanism for generating microvibration (MV) or minor tremor has been proposed by many investigators. Rohrachner (1955) postulated the thermoregulatory autonomic nervous system, Sugano and Inanaga (1960) proposed the reflex of spinal cord by γ motor system, and Ozaki *et al.* (1962) insisted the ballistocardiogram by heart beat. The contribution of the upper central nervous system (CNS) to MV was also reported (Sugano and Inanaga, 1960; Itoh, 1967). We have considered that the CNS contributes much effect upon three factors stated above. The uniform interpretation of the mechanism of MV, however, has not been given yet. The aim of this investigation is to give the relationship between eyelid MV and electroencephalogram (EEG) in order to study the contribution of the CNS on MV.

METHODS

EEG between C_3 and T_3 and between F_{p1} and left ear lobe were led with the use of disc electrodes as bipolar leading and referential one, respectively, where the position C_z was employed as the ground. EMG on m. mentalis and EOG between the upper and outer right canthus and the lower and outer left canthus were measured in order to determine sleep stage REM (SREM). MV on left eyelid was detected by MV sensor (MT-3T, Nihon Kohden), which the acceleration of 0.01 G generated the electric output of 1mV. ECG was measured at chest to show the effect of R wave on MV amplitude. Subjects were four normal males aged 21 to 27 years. Sleep stage

was determined by the criterion of Rechtschaffen and Kales (1968). The power spectra of MV and EEG for each one minute were calculated till the second sleep cycle, using sampling time of 10 msec, where the data contaminated by the body movement at any sleep stage or the rapid eye movement at RSEM were removed. The maximum power spectrum and the peak frequency which was defined as the frequency at the maximum power spectrum were evaluated. From these, the mean values of the maximum power spectrum and of the peak frequency were obtained at wakefulness (eye closure) and each sleep stage. The principal component analysis was performed to study the correlation between the change of MV and EEG for each conscious level like wakefulness or sleep.

RESULTS AND DISCUSSION

The typical examples of MV and EEG etc. are presented in Fig. 1. MV generates after the appearance of R wave in ECG at wakefulness and any sleep stage. The peak frequency of MV was not significant between sleep stages, but the fluctuation of MV and EEG decreased as sleep stage proceeded from non-REM sleep stages 1 (S1) to 4 (S4) (Fig. 2(a)). The change of MV amplitudes was different from the change of EEG's at various sleep stages as shown in Fig. 2(b). Especially, during the rapid eye movement at SREM, MV amplitude increased extraordinarily. Even at SREM without rapid eye movement, the maximum power spectrum showed twice value at other stages (Fig. 2(b)). The heart rate at S4

Fig. 1. Polygraph of EEG (C₃-T₃), EMG (m. mentalis), EOG (the upper and outer right canthus and the lower and outer left one), MV (left eyelid), and ECG (chest) at wakefulness (eye closure) and various sleep stages of a subject (S.Y.). Calibration levels (bar in left upper) are 50 μ V for EEG, EMG, and EOG, 0.01G for MV, and 1mV for ECG.

decreased by about 5 beats/min. and the value at SREM increased by at most 7 beats/min. (10.9%), as compared with S1. The heart rates at wakefulness in supine position and S1 gave almost similar value. Although the effect of heart beat on MV was predominant as shown in Fig. 1 or as Ozaki *et al.* (1962) stated, the much increase of MV amplitude at SREM could not be explained by only the change of heart beat. It was considered that the cause was the lowering of tonus of skeletal muscle at SREM, so that the ballistocardiogram's component augmented. Furthermore, the result of the principal component analysis, which the accumulated proportion till the third principal component presented 61 to 74 % for various sleep stages, showed that a good

Fig. 2. (a) Mean peak frequency and (b) mean relative amplitude of maximum power spectrum at wakefulness and sleep stages. The calibration level was shown by the value of maximum power spectrum for the calibration signal (see Fig. 1.) with time constant 0.3sec. The standard deviation is shown by upper side line at each mark.

correlation between MV and EEG at the higher conscious level in not only wakefulness and S1 but also SREM which stage in man was known to be close to S2 in conscious level (Okuma *et al.*, 1966) was recognized in amplitude, while there existed no relation at other sleep stages like S2, S3, and S4. The result denoted the contribution of the CNS to MV at higher level of consciousness. In the response experiment by flash stimulus, Ozaki *et al.* (1966) and Itoh (1967) reported the synchronization of MV and EEG at S1. Ozaki *et al.* (1962) stated that MV was influenced from ballistocardiogram and the CNS, but they did not find the close relation at SREM. The discrepancy at SREM seemed to be due to the reason that the extra stimulus was generally incorporated to dream and could not be recognized itself. The conclusion, on the basis of these discussion, was that eyelid MV was generated predominantly by ballistocardiogram, but that it was also influenced by the CNS at higher level of consciousness.

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