Short Notes

Study on the Pulse Spectrum Change before Deep Sleep and its Possible Relation to EEG

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Abstract

Our previous studies have shown that the blood distribution can be frequency modulated. After the subject lied down and relaxed, a systematic change in the spectrum of pulse waves could be observed. The high frequency components (usually above the sixth harmonic of the heart beat) became enriched. Usually there were one or two large increments around the 9th harmonic. Although the detailed pattern was different for different subjects, the same pattern was repeated for the same subject.

The brain wave of the subject was studied simultaneously. The percentage of sleeping spindles (12.4-14.6Hz) in the EEG (Electroencephalogram) was calculated. It was found that the change of pulse spectrum is a necessary condition for the change of brain wave.

Key Words : Pulse, Spectrum, EEG, Chi

Introduction

Blood is the source of oxygen and nutrient for the tissue. During our everyday activities, the blood flows to the parts of the body that need supplies and the amount is determined by the demand. To study the blood distribution during different activities, we can study the pulse spectrum of normal subject to see if there is a systematic change. This will be an indirect evidence that blood distributes according to the frequency of pulse pressure.

The relaxation process was studied for several reasons. It is one of the most convenient states that blood may change it's distribution significantly. In addition, the transition stages of the brain wave from excitation to relaxation and to sleep are well defined. Since it is known that the appearing of sleeping spindle (12.4-14.6Hz, description follows the Report of the Committee on Terminology of the International Federation of Societies for Electroencephalography and Clinical Neurophysiology) is an important indicator that the brain transited from relaxation stage into the sleeping stage[5], it is interesting to find out whether this transition is related to the changes of the pulse pressure wave.

Method

Fifteen normal subjects aged between 23 to 43 were chosen to be the experimental subjects. Before the experiment started, the subject was asked to be quiet for about 6 minutes to eliminate the possible side effects caused by nervousness or excitement. The subject was then asked to lie down and relax with their eyes closed in a dark room. Sleeping during the experiment was encouraged.

The pulse pressure on the right hand radial artery of the subject was then recorded with a pressure transducer (PSL-200GL, Kyowa Electronic Instrument Co. Ltd. Japan) which was fixed on the skin by scotch tape and an adjustable belt with a samll button to give the suitable pressure on the transducer. Our criterion of a good measurement is to seek the largest amplitude of the pulse. The transducer was at the same spot with the same pressure throughout the experiment. The output of the transducer was connected to an IBM PC via an A/D converter with sampling rate = 430 data points/sec . Pulse spectrum was analyzed with Fourier transform using T (period) = 1 pulse as described previously [1,2,3].

The pulse spectra took at different experimental durations were compared with the pulse spectrum took at the beginning of the experiment. The variations of pulse spectra of two compared measures were expressed as the percentage differences of the first 12 harmonic proportions which were defined as :

% Difference of the nth harmonic proportion

$$= \frac{C_n(T_t)-C_n(T_0)}{C_n(T_0)} \times 100\%$$

T_t : experimental time t   To : experimental time 0

$$C_n = \frac{A_n}{A_0} \times 100\%$$ C_n : nth harmonic proportion

A_n : The amplitude of the nth harmonic of pulse spectrum.

Three silver electrodes (positive, negative, and ground) (SEE-101, NEC SAN-EI Instruments, Ltd. Japan) were placed separately at about 4cm above the right eye, 2cm above the nose and the front end of the left ear. The amplifier (Gould Universal amplifier, 13-4615-55, Instrument sysrem Div. U.S.A.) with cutoff frequencies at 3 Hz and 30 Hz, full scale sensitivity at 0.5mV, was connected to another amplifier (x10, Chemlab, R.O.C.), and via an A/D converter to an IBM PC with sampling rate = 480 data point/sec. During the experiment the subject's EEG was monitored continuously from the PC monitor. 5-second of EEG epochs were taken in a rate about 10 epochs/2 minutes. The percentage power spectrum of EEG was analyzed with Fourier transform in frequency range 3 Hz to 20 Hz of 0.2 Hz sensitivity. The power spectra were averaged by 10 epochs, and the percentage of sleeping spindle contented in the averaged spectrum was calculated by summing the power percentage in frequency range 12.4-14.6Hz. Using the power spectrum averaged from the first 10 epochs as control, the variation of the sleeping spindle contented was expressed as percent difference of sleeping spindle which was defined as:

% Difference of sleeping spindle

$$= \frac{\%SP(Duration\ n)_{ave} - \%SP(Duration\ 1)_{ave}}{\%SP(Duration\ 1)_{ave}} \times 100\%$$

$\%SP(Durationn)_{ave}$: The percentage content of sleeping spindle calculated from the power spectrum averaged by 10 epochs at the nth experiment duration.

At the end of experiment, the subject was awakened and asked to say a few words. The subject's pulse and brain wave were then collected for 6 six more minutes.

Results

In the relaxation process, we found that the harmonic proportions of the pulse pressure were varied. Figure 1 (A), (B), (C), (D) show four typical patterns of the pulse spectra change of four different subjects. Two peaks at the 6th and 10th harmonics are shown in figure 1 (A). Two peaks at the 7th and 11th harmonics were shown in figure 1(B). Only one huge peak at the 10th harmonic is shown in figure 1(C). In figure 1(D), one peak at 9th harmonics was shown. In summary, the higher frequency components became enriched and all the large increments appear at 6th harmonic and above. Usually one or two increment peaks appeared around the 9th harmonics. Although the detailed pattern was different for different subjects, the peak or peaks of increment was repeated for testing the same subject.

Figures 2, 3, 4, and 5 each presents the percentage differences of the harmonic proportions of the harmonics at the increment peak and the percentage differences of the sleeping spindle of four different subjects. In these figures the 6 minutes pre-experiment data and the 6 minutes post-experiment data are also shown. In figure

2, the percentage change of sleeping spindle is varied in large scale and the pace is same as the variation of peak harmonics. In figure 3, the percentage differences of sleeping spindle are kept in low level until 10 minutes. It follows the pulse variation since then. In figure 4, large variations of pulse spectrum but small variations of brain wave are shown. No large scale sleeping spindle had ever been found for this subject when we repeated the tests. It is interesting to point out that this subject snored aloud in every tests, but he claimed that he had never fallen into sleep. In figure 5, the large variations of brain wave are not appeared until 21 mintutes. For this subject, long delay time for brain wave variations were always found when we repeated the tests.

It was also noticed that the subject's heart rate lowered when the pulse spectrum variation was large. (Data are not shown.)

Discussion

Since the distribution of the blood can be frequency modulated, it becomes evident that the change of pulse spectrum can change the blood distribution.

Our previous reports suggested that "Chi" could be related to the blood pressure wave[1,2,3,4], Liu[6] has found that the "Chi" could change the EEG.

Recently, there are arguments that the EEG synchronization may cause the change of the pulse. From these studies, we have shown that a person's pulse and EEG both were changed during the relaxation process. In addition, the EEG synchronization (increasing of the sleeping spindle content) follows the change of the pulse with or without some delay.

It was suggested that EEG synchronization comes from several different sites in the brain. Some cortical oscillations are clearly driven by periodic input from the thalamus[7]; however others may arise within the cortex itself independent of the thalamus[8,9,10]. Since different pace controlling cells may dominate the frequency generating machine when the blood distribution is changed, the change of pulse spectrum may change the dominant frequency or frequencies of the EEG.

All these evidences support the hypothesis "The change of pulse spectrum may be related to the change of blood distribution. If this change is very large, it may therefore influence the EEG."

Figure 1

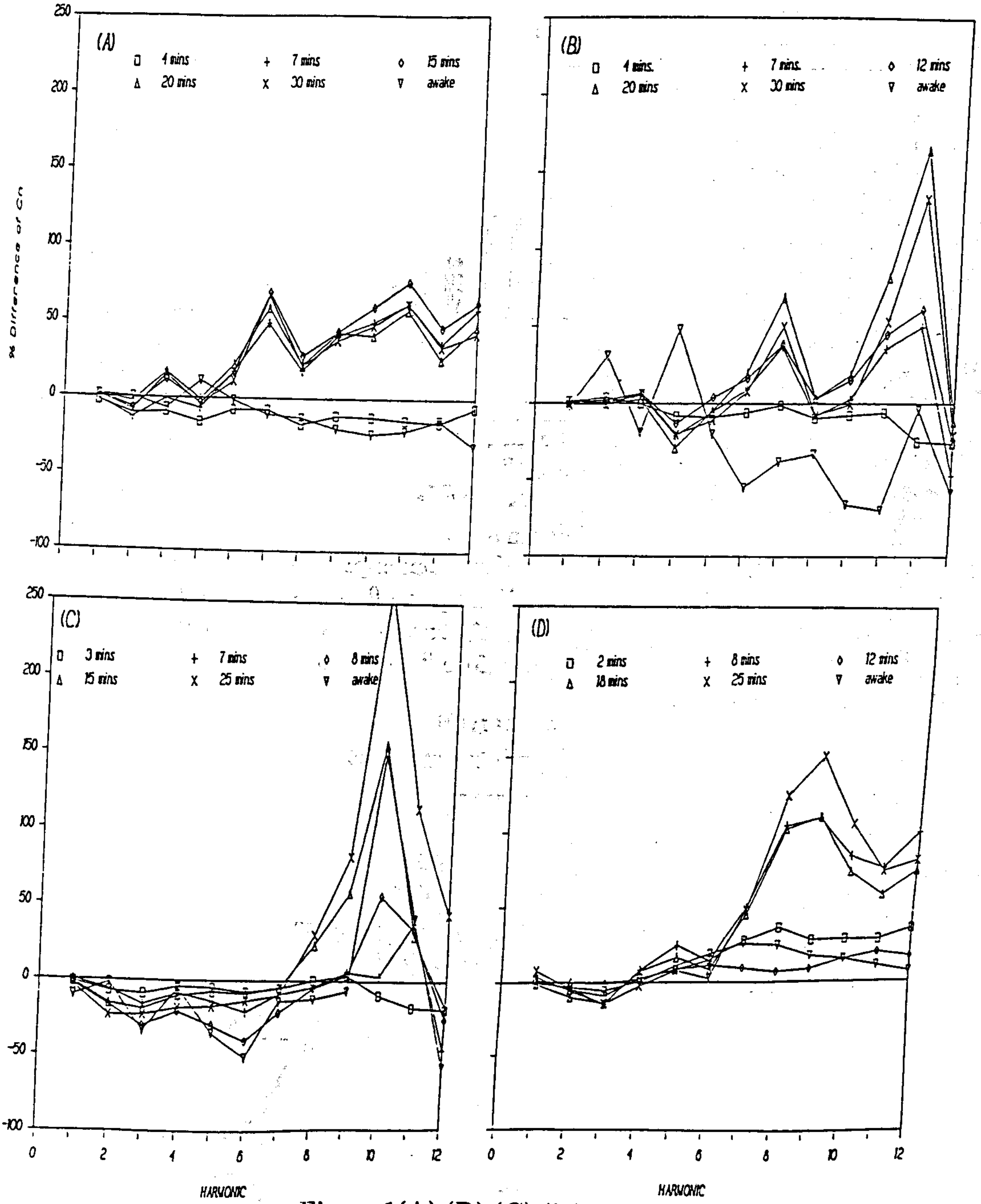
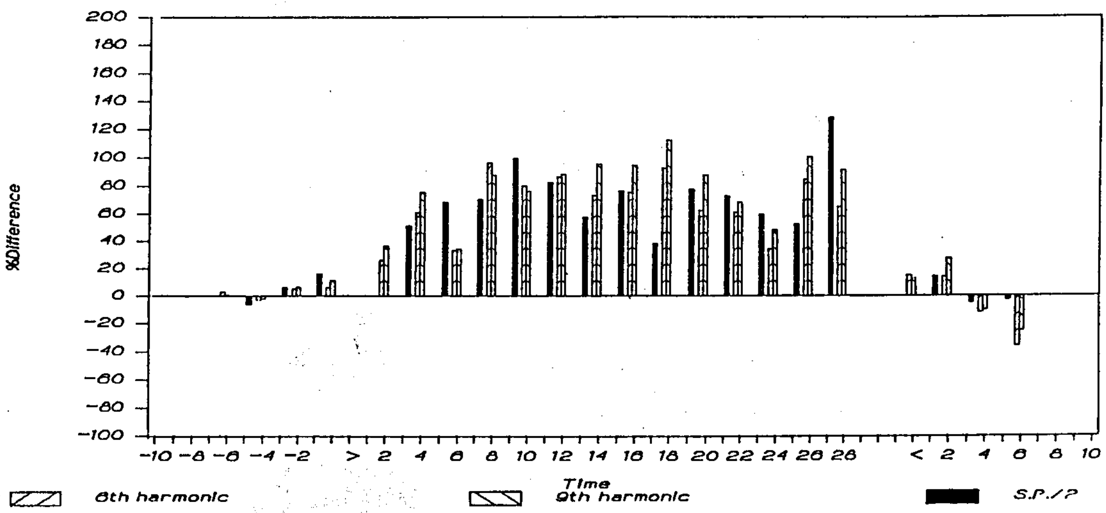


Figure 1(A),(B),(C),(D)

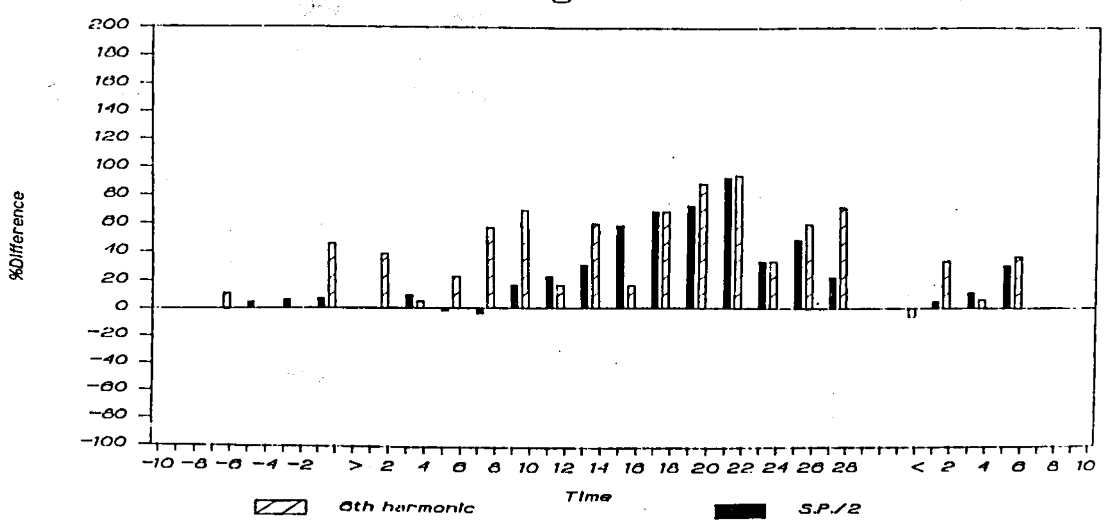
The pulses at different sleeping durations were compared with the pulse of the awaken state at the beginning. The percentage differences of the first 12 harmonic proportions of the compared pairs were presented.

Figure 2



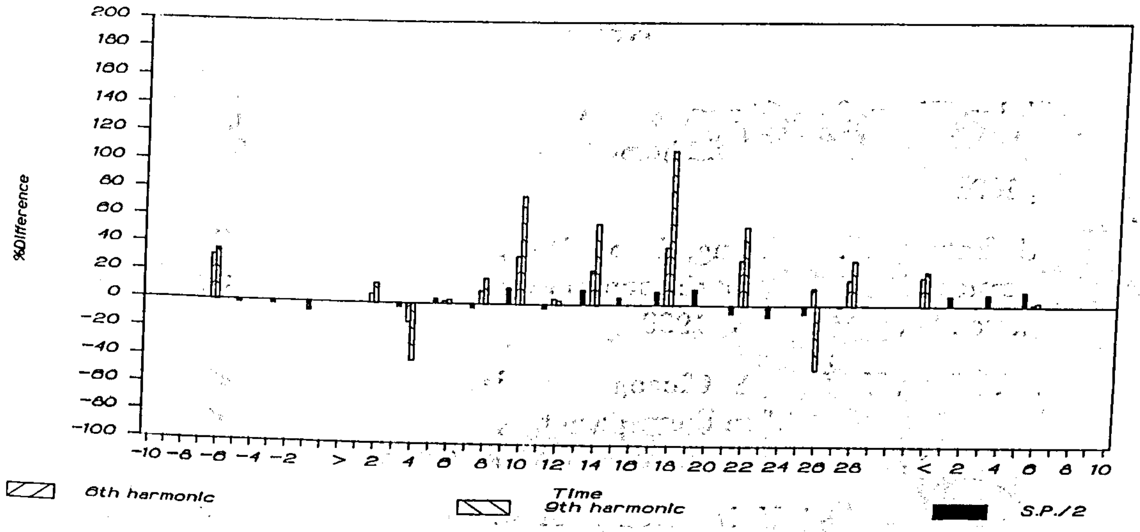
The percentage differences of the peak harmonics proportions of the pulse spectrum and the half value of the percentage differences of the sleeping spindle (S.P./2) were presented on the same time scale. Experiment were started at time" > " and ended at time" < ". Pre-experiment (time before " > ") and post-experiment (time after " < ") data were also shown.

Figure 3



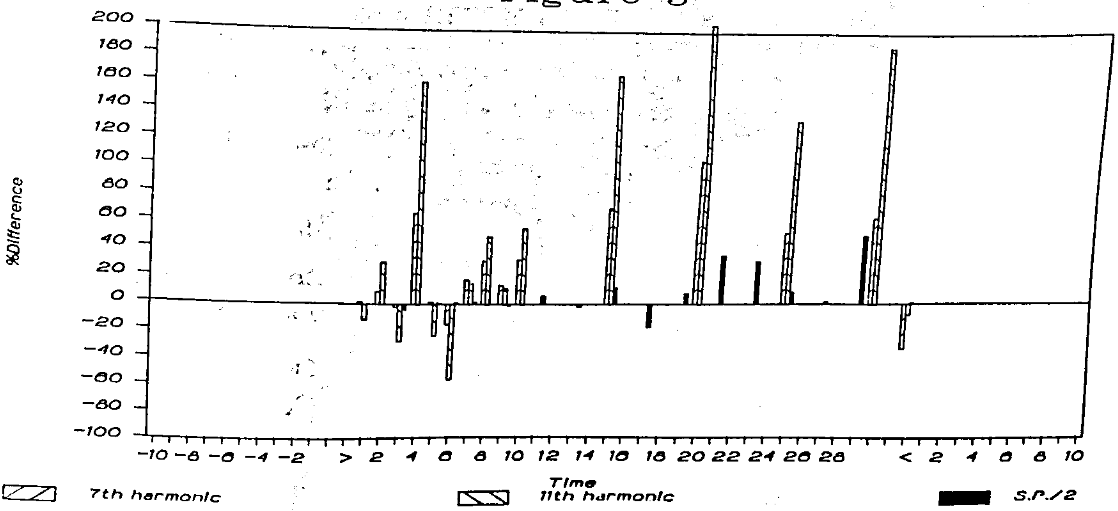
The percentage differences of the peak harmonics proportions of the pulse spectrum and the half value of the percentage differences of the sleeping spindle (S.P./2) were presented on the same time scale. Experiment were started at time" > " and ended at time" < ". Pre-experiment (time before " > ") and post-experiment (time after " < ") data were also shown.

Figure 4



The percentage differences of the peak harmonics proportions of the pulse spectrum and the half value of the percentage differences of the sleeping spindle (S.P./2) were presented on the same time scale. Experiment were started at time" > " and ended at time" < ". Pre-experiment (time before " > ") and post-experiment (time after " < ") data were also shown.

Figure 5



The percentage differences of the peak harmonics proportions of the pulse spectrum and the half value of the percentage differences of the sleeping spindle (S.P./2) were presented on the same time scale. Experiment were started at time" > " and ended at time" < ". Pre-experiment (time before " > ") and post-experiment (time after " < ") data were also shown.

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在熟睡前脈波變化之研究及其與腦波之可能關連

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摘要

以往之研究顯示，血液的分配，是由頻率來調變的，在受測試者躺下放鬆後，發現脈博頻譜會呈系統性變化，其中，高頻部份（通常高於心跳速率之第六諧頻）會增加，而在第九諧頻附近有一或二個諧波會大幅增大，雖然不同的測試者間其細部頻譜變化型式相異，但對同一測試者做重覆測試則有類似的變化型態。同時對受測者之腦波探討，計算腦波中睡眠紡錘波（頻率範圍12.4-14.6 Hz)之百分比。發現脈波頻譜的變化為腦波變化之必要條件。

關鍵詞：脈波，頻譜，腦電波圖，氣