Journal of Magnetics 17(2), 133-137 (2012) http://dx.doi.org/10.4283/JMAG.2012.17.2.133

Analysis of Electroencephalogram and Electrocardiogram at an Acupoint PC9 during Pulsed Magnetic Field Stimulus

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(Received 22 December 2011, Received in final form 24 April 2012, Accepted 25 April 2012)

We investigated the effects of pulsed magnetic fields (PMF) stimulus on electroencephalogram (EEG) alpha activity and heart rate variability (HRV) from electrocardiogram (ECG) measurements with various stimulus durations at acupoint PC9. The alpha activity in the EEG and the ratio of low frequency power and high frequency power (LHR) in the HRV, a reflection of sympathovagal activity, were increased and decreased, respectively, after PMF stimulus of 3 min. Our spectral analysis quantitatively proved that the changes in the EEG alpha activity were consistent with an autonomic function in the ECG. These findings suggest that appropriate PMF stimulus results in the same effect as that of acupuncture applied to the acupoint PC9, which is closely related to the parasympathetic activity of the autonomic nervous system.

Keywords : pulsed magnetic field stimulus, electroencephalogram, alpha activity, heart rate variability, autonomic nervous system

1. Introduction

Stimulation of the human body using pulsed magnetic fields (PMF) can be non-invasive alternative to acupuncture as a medical treatment for influencing human physiology because PMF induces electric fields and flows of current in tissues that conduct impulses toward the deep tissues [1, 2]. The effects on the autonomic nervous system (ANS) and microvascular blood system under pulsed and static electromagnetic fields have been elucidated in many studies [1, 3-5]. Also the effect of electromagnetic fields on stress has been evaluated in many papers [6]. The physiological underpinning of the link between stress and hypertension may involve excessive sympathetic nervous system activation of ANS.

It is known that the change of electroencephalogram (EEG) and heart rate variability (HRV) are closely correlated [7]. There are several papers that have studied the effects of acupuncture stimulus on the relationship between EEG and HRV. Some looked into the effect of acupuncture stimulus on ANS in patients with a normal physiological status, and others investigated it with their HRV in a stress condition [8, 9].

The EEG activity that shows oscillations at a variety of frequencies, with the alpha rhythm in a frequency range of 8 Hz to 13 Hz, has been associated with mental relaxation and with the closing of the eyes. Since an increase in alpha activity is a reflection of a state of peace, relaxation and diminishing stress and tension, it is expected that the activation of the parasympathetic nervous system of ANS is also increased.

It has been reported that the HRV is strictly regulated by brain activity [10], and is changed by general anesthesia [11]. Electrocardiogram (ECG) signal results from activity in the ANS and HRV, and it is an important measure used to estimate brain activities such as stress, anxiety, hypertension, and relaxation. The findings of some studies suggest that HRV spectral analysis is also a powerful non-invasive tool for quantifying autonomic nervous system activity [12]. Therefore it is expected that monitoring autonomic nerve activity can be quantitatively measured with EEG and ECG.

In this study an acupoint, PC9, is chosen for the application of PMF stimulus to investigate the correlation between EEG alpha activity in the human brain and ECG. In addition, we wish to understand its specific effects on cerebral function and the ANS. PC9 (Zhongchong) is a point, at the center of the tip of the distal phalanx of the middle finger and is usually stimulated for pacifying

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emotion and calming the mind. The aim of this study was, by using power spectral analysis of EEG and HRV, to investigate the effect of PMF stimulus on sympathetic and parasympathetic activity of the ANS.

2. Method

The effect of PMF stimulus on the EEG and HRV was investigated in one subject with 6 repetitions for reliability. A subject was instructed not to eat, drink alcohol, coffee or smoke two hours prior to experiment and data recordings were done six times at the same time every morning on six different days.

Fig. 1(a) shows schematic diagrams of the measurement system. The PMF waveforms generated from magnetic stimulator and a photograph of the experimental setup for EEG and ECG measurement are shown in Fig. 1(b) and (c), respectively. Fig. 1(d) is a continuous and simultaneous recording of EEG, its alpha wave, ECG and R-R interval, which is the time elapsing between two consecutive R waves in the ECG.

Our PMF stimulator generated a maximum intensity variation of 0.67 T at a transition time of 0.075 ms, with pulse intervals of 2 Hz. The stimulated acupoint PC9 was selected from the acupuncture map and the International Standard Nomenclature of Acupuncture. The entire EEG and ECG data were simultaneously collected with the subject alert, but with eyes closed and recorded for 2-min resting before PMF stimulus and continuously during and after PMF stimulus. MP150 system (BIOPAC Systems, Inc., Santa Barbara, CA, USA) and Acknowledge programs were employed to analyze both the EEG and ECG data.

The EEG and ECG signals were synchronously digitized by an analog-digital converter with the same sampling rate of 200 Hz. Details regarding EEG signal acquisition and power spectral analysis have been described in our previous reports [1]. Fig. 2 represents a typical example of the changes in EEG spectra and ECG: (a) enlarged raw EEG data set, and (c) the extracted alpha band of the power spectra.

The spectrum curves of the ECG obtained from a Fast Fourier Transform (FFT) were employed to analyze the frequency domain of the HRV. Low frequency power (LFP: 0.04-0.15 Hz) and high frequency power (HFP: 0.15-0.4 Hz) represent the activities of the sympathetic and parasympathetic nerves of the ANS, respectively. Fig. 2(b) shows an enlarged raw ECG data set and (d) shows the power spectral density of ECG using FFT.

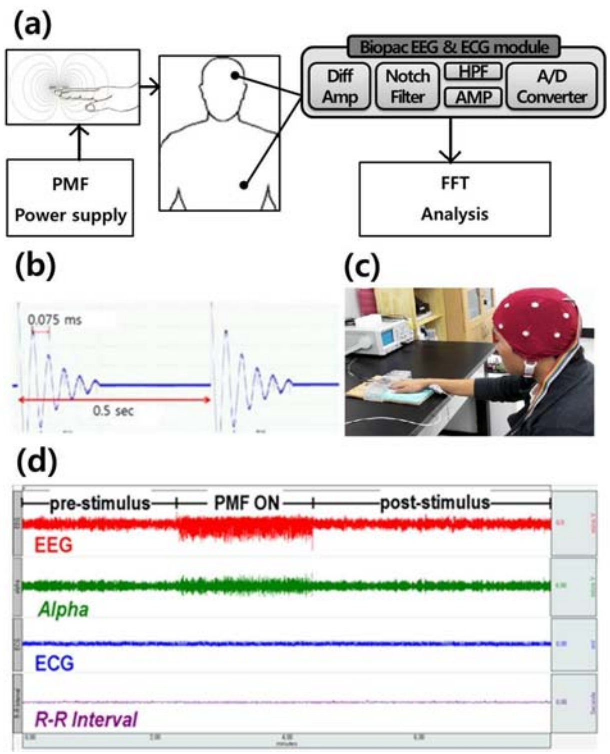

Fig. 1. (Color online) (a) Schematic diagram of measurement system, (b) pulsed magnetic field (PMF) waveforms generated from magnetic stimulator, (c) photograph of the experimental setup for EEG and ECG measurement and (d) continuous and simultaneous recordings of EEG and ECG before, during and after PMF stimulus.

3. Results and Discussion

The difference in the alpha activity before and after stimulus with PMF stimulus of various durations was computed separately, in order to evaluate the effect of PMF stimulus on EEG quantitatively. Fig. 3 presents the difference in alpha activities obtained from 4 selected data. Significant increases in alpha activity were induced following PMF stimulus for 3 mins, while changes in alpha activity were reduced following PMF stimulus for 2 mins. This result indicates that the increase in alpha activity, i.e. to obtain a relaxed mental state requires a PMF stimulus for 3mins or more. On the other hand, the difference in alpha power following a PMF stimulus for 5 mins is slightly reduced compared with that for 3-4 mins. This seems to be related to the adaptation of the central nervous system to the repetition of PMF stimulus on the acupoint. Therefore, appropriate PMF stimulus is suitable as a new noninvasive stimulus technique for this specific acupoint.

In order to obtain information on the sympathetic and parasympathetic activities of the ANS, the ratio of low frequency power and high frequency power (LHR), a reflection of sympathovagal activity, was calculated from

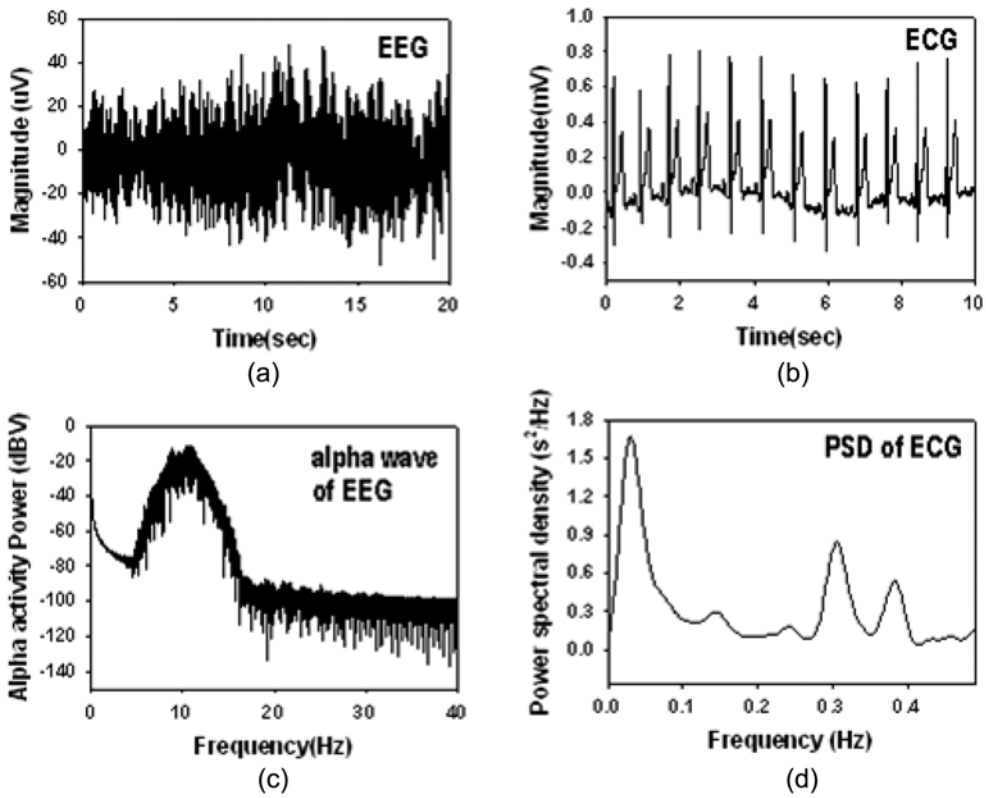

Fig. 2. (a) Enlarged raw EEG data set, (b) enlarged raw ECG data set, (c) the extracted alpha band of the power spectra and (d) power spectral density of ECG using fast Fourier transform (FFT).

the normalized high/low frequency power (nHFP and nLFP), which were divided by total power. Table 1 shows the mean values of the nLFP, nHFP and LHR before and after stimulus for various stimulus durations. In the nLFP data we can see there were slight decreases after PMF stimulus, compared to before PMF stimulus. Slight increases in nHFP were observed after PMF stimulus for 3 mins and 5 mins. Since LHR is the ratio of nLFP and nHFP, it becomes smaller with decreased nLFP, increased nHFP and even when there are no changes in nHFP. The LHR was reduced after PMF stimulus for 3 mins or more, although there was no change in nHFP after PMF stimulus for 4 mins. The calculated LHR in Table 1 showed that it increased from 3.75 to 3.85 for 2 mins of stimulus, then decreased from the range of 3.75-3.60 to 3.43-3.46 for PMF stimulus of 3 mins or more.

These results indicate that the parasympathetic nerves were activated after PMF stimulus for 3 mins or more and the sympathetic nerves were in a constrained condition. These findings might be explained by the role of acupoint PC9, which is known to pacify emotion and calm the mind following acupuncture.

A significant change in LHR following PMF stimulus of various durations concurs with observations from EEG alpha activity. PMF stimulus for 2 mins does not seem to be sufficient to regulate cerebral nervous system consider-

Table 1. Values of heart rate variability components of normalized low frequency power (nLFP) and high frequency power (nHFP) and the ratio of low frequency power and high frequency power (LHR) before and after PMF stimulus for various stimulus durations.

	nLFP		nHFP		LHR	
	before	after	before	after	before	after
2 min	0.648 ± 0.007	0.647 ± 0.005	0.173 ± 0.007	0.171 ± 0.003	3.75 ± 0.053	3.84 ± 0.031
3 min	0.642 ± 0.004	0.638 ± 0.008	0.174 ± 0.003	0.179 ± 0.008	3.75 ± 0.044	3.46 ± 0.060
4 min	0.645 ± 0.006	0.643 ± 0.004	0.174 ± 0.004	0.174 ± 0.004	3.77 ± 0.059	3.57 ± 0.034
5 min	0.644 ± 0.003	0.637 ± 0.014	0.175 ± 0.003	0.183 ± 0.013	3.60 ± 0.035	3.43 ± 0.074

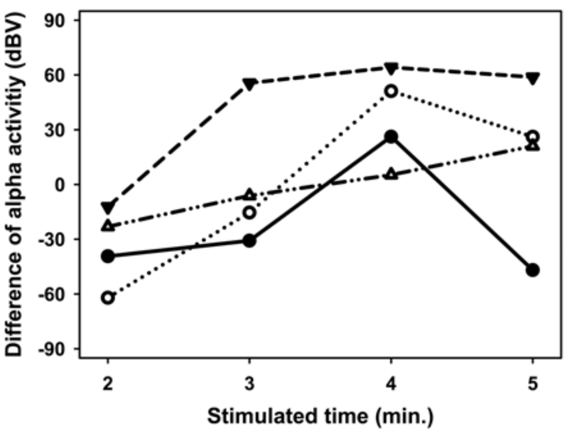

Fig. 3. Changes in alpha activity before and after stimulus with various PMF stimulus durations. The results presented are alpha activity obtained from 4 selected subjects when the PC9 acupoint was stimulated. It is shown that increases in alpha activity occurred after PMF stimulus for 3 mins or more, whereas the alpha power is reduced after PMF stimulus for 2 mins.

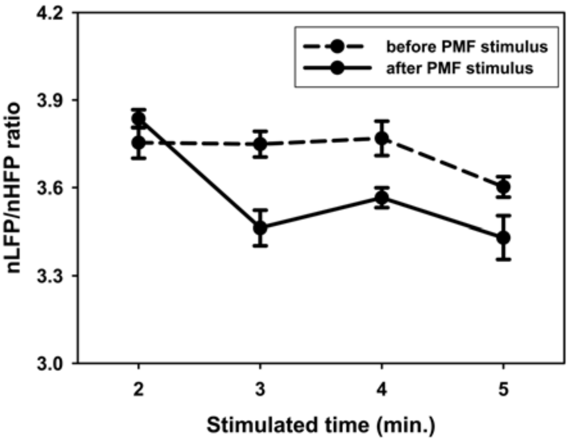

Fig. 4. Ratio of low frequency power and high frequency power (LHR) before and after PMF stimulus for various stimulus durations.

ing the change in alpha activity in Fig. 3, and it does not provide enough of a boost to the parasympathetic nerves of ANS function considering the LHR after PMF stimulus for 2 mins is higher than before PMF stimulus in Fig. 4. On the other hand, the difference in LHR following PMF stimulus for 5 mins is slightly reduced compared with that of 3-4 min. This phenomenon can be explained again by the tendency of adaptation of the ANS according to the repetition of PMF stimulus.

Therefore our results for spectral analysis of EEG alpha activity and HRV provide scientific evidence for the effect of PMF on acupoint related to brain activity. Also we proved that PMF can be an alternative non-invasive medical treatment for influencing human physiology. Since our work is a preliminary study with just one subject using 6 repetitions for reliability, additional studies need to be performed with a large number of subjects with diverse conditions to confirm our findings.

4. Conclusions

This study suggests that PMF stimulus on PC9 results in significant changes in EEG alpha activity and the spectral power of HRV; leading to relaxation, calmness and reduction of tense feelings. It was proved that an appropriate PMF stimulus duration is needed to evoke cerebral nerve activity and autonomic nervous activity that can be measured by EEG and ECG, respectively. Therefore, our result can be used as a foundation of future studies to prove the correlation between PMF stimulus and brain activity.

Acknowledgement

This research was financially supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2011-0025231). Special thanks to J.Y. Seo, J.H. Kim, S.H. Kim, and T.S. Jang for giving technical assistance.

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