Chinese Journal of Physiology 52(1): 1-7, 2009
DOI: 10.4077/CJP.2009.AMG070

Effects of Acupuncture at Neiguan (PC 6) on Electroencephalogram

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Abstract

The aim of this study was to investigate if there were any effects on the electroencephalogram (EEG) of human brain by the manual stimulation of Neiguan (PC 6) acupuncture site. In this paper, two groups of six healthy male volunteers of ages 27.6 ± 14.2 (mean ± SD) and 28.5 ± 13.0 (mean ± SD) and no neurological disease participated in this study. A digital storage of 12-channel EEG recorder was used and spectral analyses of the data set of 18 trials were obtained before, during, and after sham/manual acupuncture. To minimize artefacts, all data were collected with the subjects alert but eyes closed. No significant changes ($P > 0.05$) were obtained for the sham acupuncture group. As for the manual acupuncture group, the needle was inserted perpendicularly into the PC 6 acupuncture site and manually stimulated about 15 to 30 seconds to achieve De Qi sensation. Needles were left in place for 30 min and then removed. Analysis of the EEG data due to acupuncture was compared to the baseline data and changes were obtained. First, all trials had an increase in the amplitude and power of the alpha band during manual acupuncture ($P < 0.05$) when compared with the baseline data. Secondly, in the mean time, the frequency peaks in alpha band of 12-channels were all synchronized with much smaller standard deviation ($P < 0.01$). Thirdly, the manual acupuncture effects of higher power and synchronized frequencies persisted for at least 10 minutes after the experiment ($P < 0.05$) and did not disappear immediately for all 18 experiments. Finally, we hypothesized that the higher power and synchronized rhythms in brain oscillations may have to do with autonomic nervous system.

Key Words: acupuncture, EEG, synchronization of rhythms, brain oscillation

Introduction

In traditional Chinese medicine (TCM), acupuncture is a useful tool for the doctors to treat a range of diseases and relieve pain (3, 6, 14, 19, 25, 26). In the past, various useful studies on the biochemical basis of acupuncture have been reported (21). However, the results on the changes of electroencephalogram (EEG) during or after needle stimulation of an acupuncture site are relatively few. The data in these reports are derived from rather different protocols. Hence, it is difficult to draw conclusion on many contradictory

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Received: October 8, 2007; Revised: December 27, 2007; Accepted: March 6, 2008.
 ISSN : 0304-4920. http://www.cps.org.tw

findings.

The electroencephalogram data have been used to study the effects of acupuncture on the human brain activities (3, 15, 17, 22, 23). One of the main reasons to use EEG is that in the clinical situation, it is useful in accessing epilepsy, dementia and brain death (2, 3, 12, 13). On the other hand, it can also be used to find out the effects of acupuncture on pain control and autonomic nervous functions in the central nervous system (1, 6, 7, 8, 11, 14-16, 18, 24-26). In either case, it is imperative to study a normal group of people before we attempt any treatment on the neurological patients. Recently, Rosted *et al*. (22) have studied the effects of manual stimulation of Hegu (LI 4) on EEG and obtained negative results. Based only on this acupuncture site, they then concluded that *no* changes were brought about by acupuncture in the frequency range of 2-30 Hz and the changes below 2 Hz were not necessarily due to acupuncture. Furthermore, the only changes they have observed would disappear immediately afterwards. Hence, it is imperative to investigate further to see if the acupuncture has any effects on EEG at other acupuncture sites.

In this paper, we selected Neiguan (PC 6) of the pericardial meridian as the acupoint of acupuncture simulation. This point was chosen because, according to TCM, it is associated with the meridian concerning the circulatory system and has been used in the treatment of hypertension and coronary heart disease (4, 19, 26). Furthermore, in clinical reports, simulation of PC 6 can usually relieve the pain of the patients who have angina pectoris. Our aim in this paper was to investigate if there were any effects on the EEG of human brain by the manual stimulation of the PC 6 acupuncture site.

Materials and Methods

Subjects and Experimental Protocols

Protocol 1: Time control and sham acupuncture. Eighteen experiments were performed on six healthy male subjects with three experiments for each person. The age ranges from 20 to 56 with the distribution 27.6 ± 14.2 (mean ± SD) years. The experiments were conformed to the regulations of the University Ethical Committee. Each subject was healthy and had no known neurological disease.

The EEG baseline data for the first 10 min without acupuncture were used as the time control (27). After 10 min, the acupuncture needle was then inserted in a slanting direction at a neutral point near the PC 6 site. The depth was only 3-5 mm and would be used as sham acupuncture to evaluate the possibility that simple insertion of needles could cause any acupuncture response (27). Following the insertion, 30 min of EEG data was documented. The reason for using 30 min here was that the acupuncture effects may be more prominent after retaining the needle for a period of time (20). Afterwards, the needle was pulled out and 10 min of data was again recorded for our examination of the after-effects of sham acupuncture.

Protocol 2: Time control and manual acupuncture. Eighteen experiments were performed on six healthy male subjects with three experiments for each person. The age ranges from 20 to 55 with the distribution of 28.5 ± 13.0 (mean ± SD) years. This group of subjects was age- and gender-matched with the group under protocol 1. Each subject was again healthy and had no known neurological disease. To avoid the influence of lasting or residual effects after acupuncture, the time span between two consecutive recordings on the same subject was *one* week for both protocols.

The EEG baseline data for the first 10 min without acupuncture were also taken and used as the time control. After 10 min, the acupuncture needle was then inserted into the PC 6 site situated between the tendons of the palmaris longus and carpi radialis muscles. The stimulation was performed by manually manipulating the needle for 15 s to 30 s until De Qi. Following the manual acupuncture, 30 min of EEG data was documented. Afterwards, the needle was pulled out and 10 min of data was again recorded to let us study the after-effects of manual acupuncture. However, in the analysis of both sets of data, only the data of last 10 min during stimulation was used for comparison so that the time scales were the same for all three stages.

Data Acquisition

Needles were standard disposables with 0.30 mm in diameter. During the entire experiments, each subject was in a relaxed and comfortable situation with eyes closed on a chaise lounge in the laboratory. The 12-channel EEG cap was then connected and data sets were recorded by A1-A2 montage. The digital equipment used was the MP150 system (BIOPAC Systems, Inc., Santa Barbara, CA, USA) fixed at 200 Hz sampling rate with notch filter at the 60 Hz power line frequency. The personal computer was equipped with the Acqknowlege 3.8.1 software. The electrode impedances were kept below 5 kΩ for low-noise 12-channel EEG recordings.

EEGLAB Analysis

The software package EEGLAB was an interactive Matlab toolbox for processing continuous and event-related EEG data using independent component analysis,

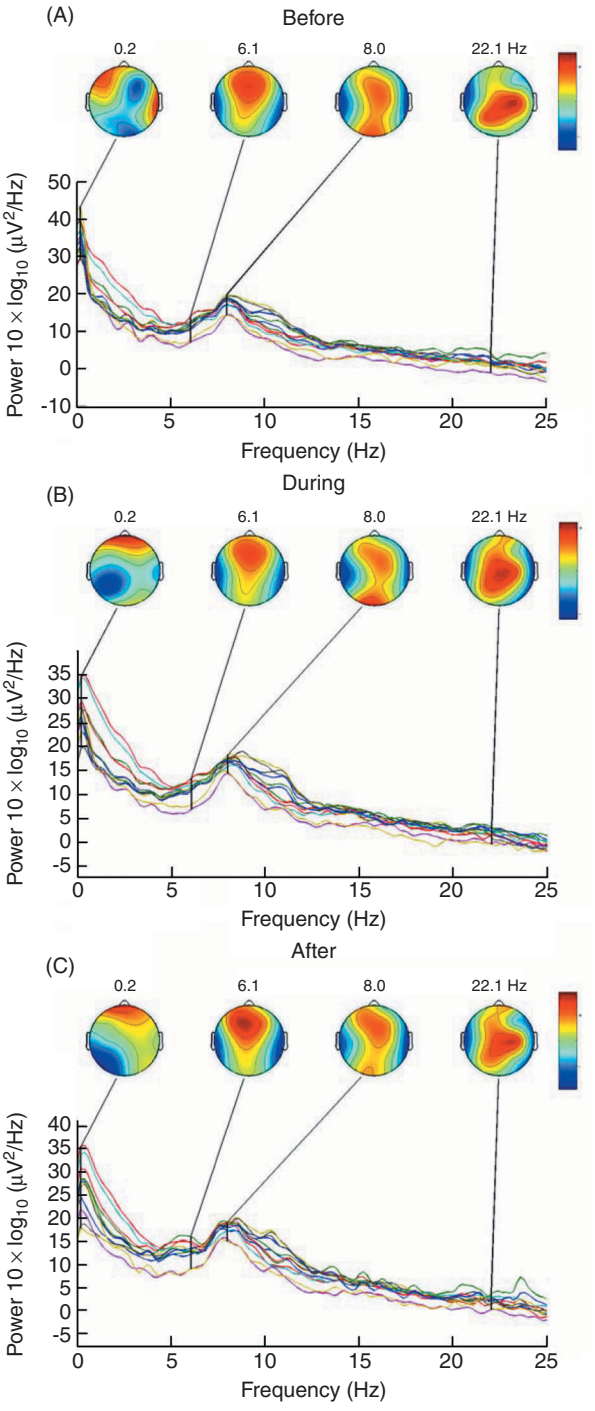

Fig. 1. Electric potentials and power spectra of all 12-channels under protocol 1: (A) In the first 10 min, the maximum frequency in alpha band of the power spectra is located around 8.008 Hz. (B) In the sham acupuncture, the maximum frequency in alpha band of the power spectra is located around 8.252 Hz with no significant change in power. (C) After sham acupuncture, the maximum frequency in alpha band of the power spectra is located around 8.089 Hz with no significant change in power. The logarithmic power intensity of electric potentials at 0.2 Hz, 6.1 Hz, 8.0 Hz and 22.1 Hz are also illustrated.

Table 1. The dominant frequency of alpha band in 12-channels under protocol 1

	Frequency (Hz)		
Channel \ Stage	Before	During	After
Fp1	8.008	8.203	7.813
F3	8.008	8.203	7.813
C3	8.008	8.203	7.813
P3	8.008	8.008	7.617
O1	8.008	8.203	8.008
T3	8.203	8.008	7.813
Fp2	8.008	8.398	8.398
F4	8.008	8.398	8.398
C4	8.008	8.398	8.398
P4	8.008	8.398	8.398
O2	8.203	8.789	8.594
T4	8.008	7.813	7.617
Mean	8.041	8.252	8.089
SD	0.076	0.251	0.367

time/frequency analysis, artifact rejection, and several modes of data visualization. It was accessible through (10).

To compare the effects of sham and manual acupuncture with baseline time control data, frequency of the EEG data in EEGLAB was also analyzed. The power spectra could be obtained by using either the fast Fourier transform (FFT) described by Cooley and Tukey (9) or the spectral distribution function proposed by Chang *et al.* (5).

Results

Protocol 1: One exemplary field electric potentials in the 12-channel EEG colored images under time control and sham acupuncture were displayed in Fig. 1. The high electric potentials were expressed by the red color code and the low potentials by the blue color code. To quantitatively compare the power of EEG in three different stages, the power spectra were also included. Significant peaks of alpha band were shown in Table 1. From the data set, the frequencies of 12 channels varied greatly with a mean value of 8.041 Hz and standard deviation 0.076 Hz in the alpha band during time control. During sham acupuncture, the frequencies of 12 channels were around mean value 8.252 Hz with standard deviation 0.251 Hz. Finally, after sham acupuncture, the frequencies were around the mean value of 8.089 Hz with standard deviation 0.367 Hz. No synchronization of rhythms was observed during and after sham acupuncture, as can been seen from Table 1.

Table 2. The power of dominant frequencies in all 12-channels under protocol 1

Power (dB)			
Channel \ Stage	Before	During	After
Fp1	18.02	17.26	18.90
F3	18.61	17.85	19.40
C3	17.02	16.14	17.72
P3	18.01	16.55	18.47
O1	19.59	18.43	19.99
T3	14.32	14.43	15.81
Fp2	16.80	16.18	17.46
F4	18.74	17.91	19.37
C4	18.83	17.61	18.94
P4	18.33	16.92	18.44
O2	19.22	19.01	19.88
T4	14.20	14.92	15.42
Mean	17.64	16.93	18.32
SD	1.77	1.37	1.48

In Table 2, we listed the average logarithmic power of these dominant frequencies during the three different stages. For instance, the average logarithmic power around 8.041 Hz during time control was 17.64 dB, the power around 8.252 Hz during sham acupuncture was 16.93 dB, and that around 8.089 Hz after sham acupuncture was 18.32 dB. Clearly, the power were not significantly different during ($P >$ 0.05) and after ($P > 0.05$) sham acupuncture when compared with the baseline data.

Protocol 2: One exemplary field electric potentials in the 12-channel EEG colored images under manual acupuncture were displayed in Fig. 2. Notice that the peaks for all 12 channels were almost all synchronized during manual acupuncture and completely synchronized after acupuncture. The significant peaks of this experiment were exhibited in Table 3. The frequencies of 12 channels were quite varied with mean value 8.300 Hz and standard deviation 0.176 Hz in the alpha band before manual acupuncture. During acupuncture, the frequencies of all the 12 channels were almost synchronized at 8.202 Hz and rather reduced standard deviation 0.081 Hz was observed. Finally, after manual acupuncture, the frequencies were all synchronized at 8.008 Hz with very small standard deviation 2.03E-07 Hz.

Table 4 displays the average logarithmic power of these dominant frequencies during the three different stages of this exemplary test. For instance, the average logarithmic power around 8.300 Hz during time control was 16.02 dB. The power around 8.202 Hz during manual acupuncture was 18.40 dB, and the power around 8.008 Hz after acupuncture was

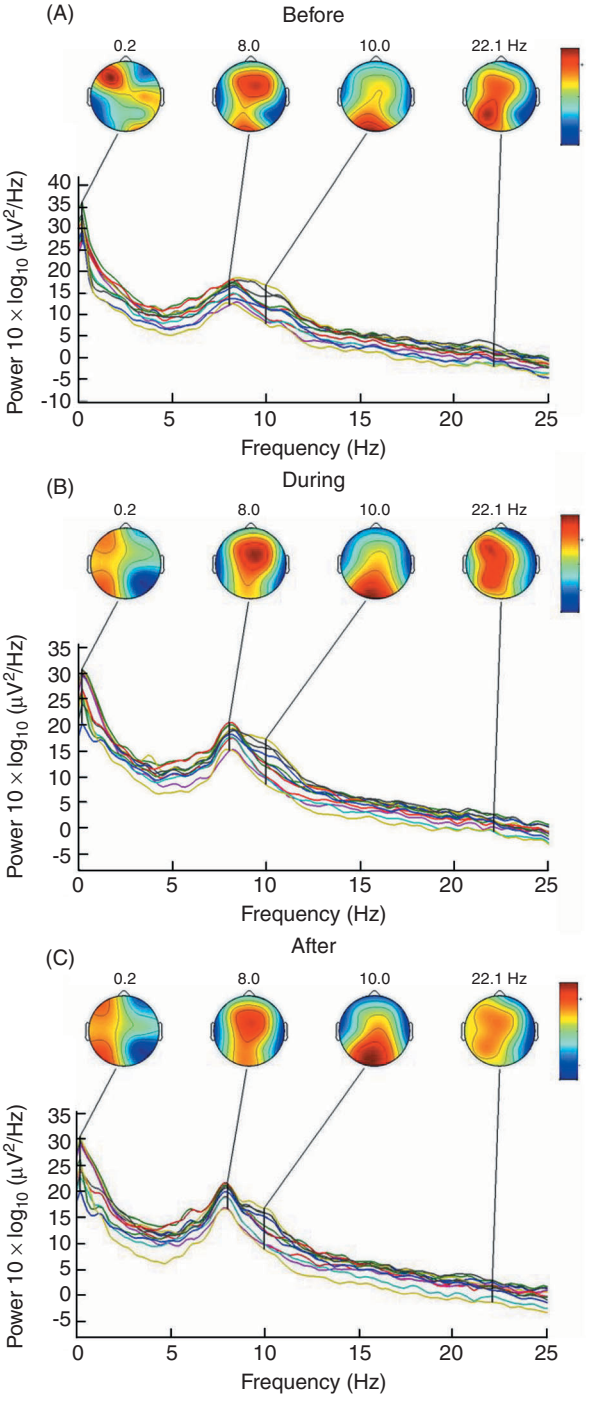

Fig. 2. Electric potentials and power spectra of all 12-channels under protocol 2: (A) During time control, the maximum frequency in alpha band of the power spectra is located around 8.300 Hz. (B) During manual acupuncture, the maximum frequency in alpha band is synchronized around 8.202 Hz and an increase in power is observed. (C) After manual acupuncture, the maximum frequency in alpha band is synchronized around 8.008 Hz and an increase in power is still observed. The logarithmic power intensity of electric potentials at 0.2 Hz, 8 Hz, 10 Hz and 22.1 Hz are also illustrated.

Table 3. The dominant frequency of alpha band in 12-channels under protocol 2

Frequency (Hz)			
Channel \ Stage	Before	During	After
Fp1	8.394	8.203	8.008
F3	8.203	8.203	8.008
C3	8.203	8.203	8.008
P3	8.203	8.203	8.008
O1	8.594	8.203	8.008
T3	8.398	8.203	8.008
Fp2	8.203	8.203	8.008
F4	8.203	8.203	8.008
C4	8.203	8.203	8.008
P4	8.398	8.203	8.008
O2	8.594	8.389	8.008
T4	8.008	8.008	8.008
Mean	8.300	8.202	8.008
SD	0.176	0.081	2.03E-07

Table 4. The power of dominant frequencies in all 12-channels under protocol 2

Power (dB)			
Channel \ Stage	Before	During	After
Fp1	14.83	17.48	18.94
F3	17.62	20.01	21.48
C3	16.45	19.14	20.64
P3	16.86	19.28	20.99
O1	18.56	19.43	21.34
T3	13.02	15.27	16.76
Fp2	15.02	17.62	18.77
F4	18.12	20.38	21.53
C4	17.34	19.96	21.16
P4	13.67	18.09	19.90
O2	18.04	18.90	20.70
T4	12.71	15.27	16.52
Mean	16.02	18.40	19.89
SD	2.09	1.72	1.78

Table 5. The power (Mean and SD) of dominant frequencies in all 12-channels of 18 experiments under protocol 2

Power (dB)						
	Before		During		After	
	Mean	SD	Mean	SD	Mean	SD
Ex1	14.992	1.506	18.378	1.493	18.494	1.307
Ex2	13.692	3.502	14.910	3.283	15.153	3.186
Ex3	16.965	1.384	16.762	1.276	17.149	1.355
Ex4	15.808	1.407	17.785	1.506	17.138	1.815
Ex5	17.188	1.399	17.371	1.624	19.123	1.510
Ex6	16.376	1.887	18.083	2.015	18.216	2.072
Ex7	16.020	2.090	18.403	1.725	19.894	1.775
Ex8	19.419	0.745	19.658	0.552	20.935	0.487
Ex9	18.843	0.741	19.682	0.881	20.858	0.779
Ex10	18.555	2.188	18.697	2.388	18.320	2.078
Ex11	16.919	0.817	19.153	1.414	18.164	1.379
Ex12	16.714	1.147	17.478	1.120	18.285	1.307
Ex13	17.197	1.893	18.636	1.733	19.369	1.857
Ex14	12.463	3.621	13.670	3.487	14.642	3.375
Ex15	8.727	1.571	12.404	1.650	12.534	1.622
Ex16	12.487	2.272	14.585	2.120	13.241	2.477
Ex17	15.008	5.239	16.384	5.615	14.618	4.757
Ex18	13.848	2.338	19.308	2.348	16.349	2.094

19.89 dB. The power during ($P = 0.003 < 0.01$) and after ($P = 0.000038 < 0.01$) manual acupuncture significantly increased when compared with the time control baseline data.

Table 5 shows the average logarithmic power of dominant frequencies in three different stages for all 18 manual acupuncture experiments. Since the results for sham acupuncture were not statistically significant, they were not shown. Results in Table 5 indicated that the average logarithmic power increased during manual acupuncture ($P = 0.021 < 0.05$), when compared with baseline data except for the third experiment. In this experiment, after pulling out the needle, the residual or lasting effects of manual

acupuncture had actually increased the power from 16.762 dB to 17.149 dB, as compared to the baseline value 16.965 dB. As a result, the average power remained comparable throughout this third experiment. Notice that the increased power persisted even after manual acupuncture ($P = 0.024 < 0.05$), when compared with the baseline data.

Discussion

The experimental results in our sham acupuncture indicated that no statistically significant results were obtained. However, by analyses of EEG signals, in the manual acupuncture experiments of six subjects, we found that the average logarithmic power and frequencies of alpha band in the brain activities of each subject were all affected by acupuncture. Note that the EEG signals may vary both in power and frequency due to the physical movements and mental state of the subject. Consequently, it is most important to minimize any possible disturbance during the experiment. In addition, once reliable data have been obtained, it is also imperative to use the correct tools in the examination of the obtained data. For instance, the main reason for Rosted *et al*. to have come to the other conclusion that no changes were brought about in the EEG by acupuncture at LI 4 is perhaps that they did not use their data effectively and only one channel, *i.e.*, the Oz channel in their comparison has been adopted. Furthermore, they have compounded the effect by comparing this single channel data among all 14 subjects. That was probably why it was hard to find any change on acupuncture, since they used so little information with so many different subjects at the same time. Consequently, it is improper to claim that no effect has been produced by acupuncture merely based on the result of LI 4 site alone. On the other hand, in our case, we compared all 12 channels for the same object in three different stages. After we have obtained enough evidence for a single subject, we then extended the same procedure and carry out the experiments for each different subject. Finally, we were able to detect the effects of acupuncture on EEG for the whole group with statistical significance. Our results indicated that it would be inappropriate to jump to any conclusion without doing more tests.

Furthermore, as can be seen in Fig. 2 and Tables 3 to 4, the effects of acupuncture not only exist during manual acupuncture but also persist after pulling out the needle. This is again in direct conflict with the claim (22) that the minor spectral change in their research will return to baseline values *immediately* after acupuncture. Also, in Table 5, the acupuncture effects of higher power persisted at least 10 min after the experiment and did not disappear immediately even though the values fluctuate.

Hence, we argue that there were indeed changes on the EEG of human brain by the manual stimulation of PC 6 acupuncture site. In future studies, we will try to associate this study with another set of experiments we have done on the acupuncture mechanism in the peripheral nervous system (4). The behavior we have observed so far in EEG may be related to the sympathetic or parasympathetic system activities (1). Our studies on the peripheral nervous system have indicated that the spectra of heart rate variability have also exhibited significant changes in all 18 experiments (4). For instance, we observed the disappearance of low frequency (LF: 0.04–0.15 Hz) spectral frequencies in HRV after acupuncture. Furthermore, in very low frequency (VLF: 0.00–0.04 Hz) range, the intensities were more concentrated and synchronized. Comparing with the more synchronized brain oscillations around 8.202 and 8.008 Hz, we hypothesized in this paper that the effect of autonomous nervous control of heart could also be exhibited in the EEG alpha band of the central nervous system. This topic is certainly worth studying in the future. Various useful studies on the biochemical basis of acupuncture have been reported. Here, in this paper, the synchronization of brain oscillations may also have a positive correlation with the chemical or hormone release. Further studies are needed to validate these claims.

In conclusion, we have reported the effects on human brain EEG by the manual stimulation of the PC 6 acupuncture site. The results indicated that in all trials increases were found in the amplitude and average logarithmic power of the alpha band during manual acupuncture. In addition, the frequency peaks in alpha band of 12-channels were more synchronized during and after acupuncture. It is believed that the power and synchronized rhythms in brain oscillation may have to do with autonomic nervous system. Further studies on this conjecture will be conducted in the future.

Acknowledgments

This work was supported in part under the Grant number NSC 97-2221-E-007-072 from National Science Council, Taiwan, R.O.C.

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