

## The Effect of Electroacupuncture on the Heart Rate Variability of Stroke Patients under Mental Arithmetic Stress

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**Objectives:** This study aimed to compare the effects of high frequency electroacupuncture, low frequency electroacupuncture and manual acupuncture on the autonomic nervous system in stroke patients by using a heart rate variability measuring device.

**Methods:** Thirty-nine participants were recruited and each participated in the high frequency electroacupuncture group, low frequency electroacupuncture group, manual acupuncture group and non-acupuncture group. Some participants received needle insertion with 100 Hz stimulation, with 2Hz stimulation and manual stimulation under mental arithmetic stress during 2 sections. Other participants maintained in the supine position without acupuncture under mental arithmetic stress during the 2 sections. Acupuncture needles were directly inserted perpendicularly to the right Liv 3 acupoint followed by delivery of electric pulses to these points for 8 minutes. Heart rate variability was measured 8 minutes before and 16 minutes after acupuncture stimulation by a heart rate variability measuring system.

**Results:** We found a significant elevated HF total power between 1 section and 2 section and between 1 section and 4 section in the non-acupuncture group, between 3 section and 4 section in the 100Hz electroacupuncture group, and between 1 section and 2 section in the manual acupuncture group and with no change in the 2Hz electroacupuncture group. We also found a significant VLF total power between 2 section and 3 section in the 2Hz electroacupuncture group and between 1 section and 4 section and between 2 section and 4 section in the 100Hz electroacupuncture group.

All four groups showed no significant differences in other parameters including heart rate mean, low-frequency power, and the ratio of low-frequency power to high-frequency power.

**Conclusions:** This study may be a basis for research about effects of acupuncture and electroacupuncture because the parameters measured, heart rate variability, showed differences according to acupuncture.

**Key Words** : Heart rate variability (HRV), arithmetic stress, electroacupuncture, frequency, stroke

### Introduction

Acupuncture is widely used in the treatment of disease in China, Japan and Korea and it is increasingly requested by patients in some Western countries. It has specific effects on insomnia<sup>1</sup>,

allergic rhinitis<sup>2</sup>), premenstrual syndrome<sup>3</sup>), frozen shoulder pain<sup>4</sup>), chronic low back pain<sup>5</sup>), chronic headache<sup>6</sup>), primary dysmenorrhea<sup>7,8</sup>) and depression<sup>9</sup>). There have been many studies about autonomic nervous system and acupuncture. Acupuncture is known to affect various autonomic

• Received : 22 October 2012

• Revised : 10 December 2012

• Accepted : 10 December 2012

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functions such as blood pressure regulation, immune modulation, and the improvement of disorders concerning autonomic functions<sup>10</sup>.

Some methods have been used to study autonomic responses following acupuncture. Sympathetic nervous system activity has been evaluated indirectly by implementation of measures for skin sympathetic nervous activity<sup>11,12</sup>, microneurography<sup>13,14</sup>, skin temperature<sup>15</sup>, and thermography<sup>16</sup>.

In contrast, heart rate variability has been developed as a quantitative noninvasive marker calculated from the electrocardiogram, and it is usually used to assess the role of autonomic nervous system fluctuations with various cardiovascular and noncardiovascular disorders.

The present study aimed to investigate whether autonomic nervous system activity could change in accordance with EA frequency and manual acupuncture using a heart rate variability (HRV) measuring system in stroke patients.

**Materials and Methods**

**A. Participants**

Participants aged 66.41±11.09 years were recruited from inpatients at the Gwangju Wonkwang University Oriental medical center and were composed of 15 females and 24 males. All procedures were performed in accordance with the Institutional Review Board (IRB) and approved by the Institutional Review Board at Gwangju Wonkwang University Oriental medical center. The subjects for the current study have been recruited according to the inclusion and exclusion criteria as below.

**1. Inclusion criteria**

- a. Korean over fifty years and under eighty five years old

- b. People that underwent an acupuncture procedure

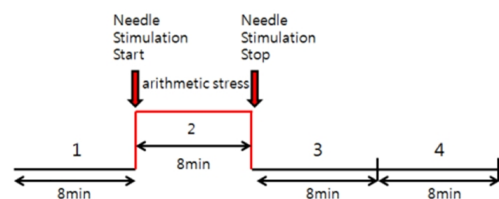
**2. Exclusion criteria**

- a. People with excessive fear of acupuncture
- b. People that have difficulty staying in the same (supine) posture longer than 30 minutes
- c. People having sleeping hours within 4 hours on the day of the test
- d. People taking antipsychotic drugs
- e. People taking β-blockers among antihypertensive drugs
- f. People with previous cardiac or pulmonary disease (dynamic behavior of heart rate in ischemic stroke)
- g. People with acute congestive cardiac failure

Participants were randomly divided into 4 groups. The non-acupuncture group had 11 (4 female, 7 male; mean age±SD 69.64±10.81; range 57-85). The 2Hz electroacupuncture group had 9 (3 female, 6 male; mean age± SD 63.89±12.59; range 50-76). The 100Hz electroacupuncture group had 10 (4 female, 6 male; mean age± SD 65.40±10.30; range 50-73). The manual acupuncture group had 9 (4 female, 5 male; mean age± SD 66.33±11.32; range 50-80).

**B. Experimental design**

Each subject participated in four sections.



**Fig. 1.** Measurement procedure.

The data before (measurement 1 section), during (2), and after (3,4) needle acupuncture were measured and statistically analyzed. In 2 section, all participants had arithmetic stress.

Figure 1 shows the experimental procedure. For each section, the participants first had a 5-minute rest in the supine position. This was followed by the measurement of HRV for 8 minutes in 1 section. Acupuncture needles were then inserted into two acupoints or 1 acupoint, right LR 3 (*Taechung*) under mental arithmetic stress. Electroacupuncture or manual acupuncture was administered for 8 minutes and then needles were removed in 2 section. Then the participants remained for 8 minutes in the same supine position without acupuncture under arithmetic stress in 2 section. The participants rested for 8 minutes in the same supine position in 3 section and rested for 8 minutes in the same supine position during which HRV was measured again in 4 section. The participants remained in supine positions throughout the periods of resting, measurement of HRV, arithmetic stress and acupuncture stimulation. This experiment was conducted in a calm room indoors. The room temperature was maintained at 24-25°C.

### C. Acupuncture

All the acupuncture insertions were performed by the same acupuncturist, licensed in Oriental medicine. The skin was cleaned with alcohol before each insertion. Acupuncture needles (0.30 mm×40 mm length; DongBang Acupuncture, Inc., Korea) were inserted perpendicularly into Liv 3 of the right foot. Their locations were decided that Liv 3 is located on the proximal end of the 1st interosseous metatarsal space, where the pulsation of the dorsal artery is palpable. We selected two right Liv 3 points as close as possible for the two electric poles of EA. Manual acupuncture was inserted at one point on right Liv 3 and stimulated by turning once per second. Liv 3 has the effect of blood and circulation regulation<sup>17)</sup>. So Liv 3 may have the effects of reducing the stress

responses.

### D. Electroacupuncture

Electric pulses of either 2Hz (low) or 100Hz (high) EA were delivered to the two needles for 8 minutes with an electrical stimulator of a brand (ES-160; ITO Co., Japan) that has been used clinically in Korea. Electric pulse duration and width were 1 ms, electro current was 3 mA and electro waveform was rectangular. The electrical stimulator was placed in a location where the participants could not see the frequency being administered, and the acupuncturist was instructed only to insert needles and was blinded to the administration of the EA frequencies.

### E. Measurement of heart rate variability

Participants were connected to a HRV measuring device (ProComp Infiniti and BioGraph Infiniti 5.0; Thought Technology Co., Canada). This device collects signals on a 3rd finger tip. To calculate the HRV indices, the system analyzes the changes in heart rate using the methods of time domain and frequency domain.

### F. Statistical analysis

The differences between the HRV indices measured before acupuncture stimulation and arithmetic stress and those measured after acupuncture stimulation and arithmetic stress were evaluated by using Wilcoxon signed ranks test. A value of  $p < 0.05$  was considered to be the level of statistical significance.

## Results

HRV analysis uses time or frequency domain analysis. This study used both. The first method was the HR mean of time domain analysis. Comparison of sections was checked for

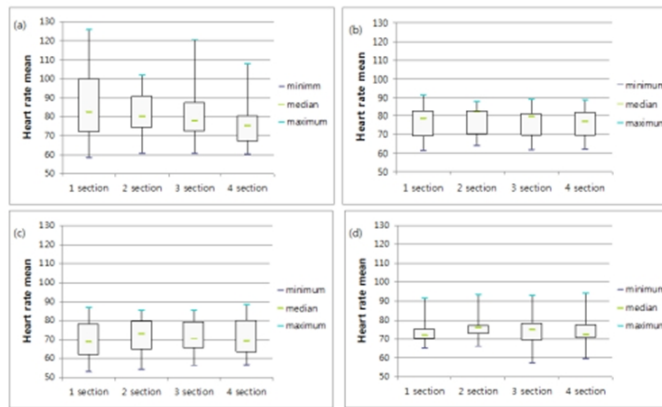


Fig. 2. Change of heart rate mean.

Box plot illustration before (1 section), during (2 section), and after (3, 4 section) arithmetic stress and acupuncture. No significant changes were found. The horizontal line in the box gives the position of the median. The end of the box defines the 25th and 75th percentile. (a) non acupuncture Group (b) 2Hz electroacupuncture group (c) 100Hz electroacupuncture group (d) manual acupuncture group.

significance.

The second method is power spectrum analysis of frequency domain analysis. Total power was divided by HF, LF, VLF and significances were checked though comparison among the sections.

The third method is the LF/HF ratio of frequency domain analysis. Comparison of sections was checked for significance.

#### A. Time domain analysis: HR (Heart rate) mean

Results of HR mean before, during, and after arithmetic stress stimulation and non-acupuncture, 2Hz electroacupuncture, 100Hz electroacupuncture, and manual acupuncture of cerebral infarction patients are shown in Figure 2.

Boxplots show the distribution of the approximate values. The graph of cerebral infarction patients with non-acupuncture decreased in value; the graph of cerebral infarction patients with 2Hz electroacupuncture, 100Hz electroacupuncture stimulation and manual acupuncture stimulation had similar results. HR mean increased more in 2 section than 1 section and decreased more in 3 section and 4 section.

This study used the statistic method of Wilcoxon signed ranks test, but there was no significant difference ( $p > 0.05$ ).

#### B. Frequency domain analysis: power spectrum analysis

##### 1. HF total power comparison

Figure 3 shows with boxplots the change of HF

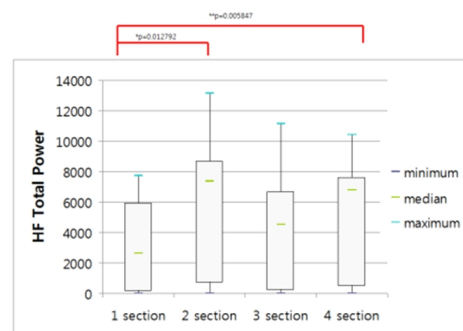


Fig. 3. Change of HF total power in non acupuncture subject.

Box plot illustration before (1 section), during (2 section), and after (3, 4 section) only arithmetic stress. The horizontal line in the box gives the position of the median. The end of the box defines the 25th and 75th percentile.

\*  $p < 0.05$  compared 1 section with 2 section.

\*\*  $p < 0.01$  compared 1 section with 4 section.

total power when arithmetic stress is given without acupuncture stimulation in 2 section. HF total power value increased more in 2 section than in 1 section, it decreased more in 3 section than in 2 section and it increased again. There was significance of results when comparing 1 section with 2 section and 1 section with 4 section. ( $p < 0.05$ )

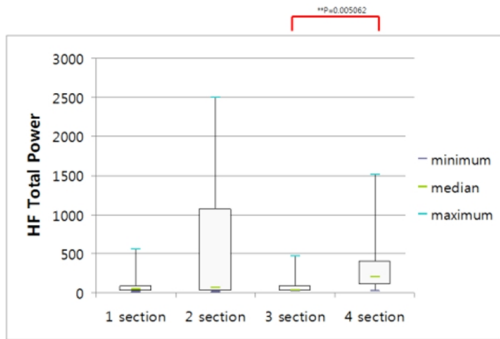


Fig. 4. Change of HF total power in 100Hz electroacupuncture subject.

Box plot illustration before (1 section), during (2 section), and after (3, 4 section) arithmetic stress and 100Hz electroacupuncture. The horizontal line in the box gives the position of the median. The end of the box defines the 25th and 75th percentile.

\*\*  $p < 0.01$  compared 3 section with 4 section.

Figure 4 shows via boxplots the change of HF total power when arithmetic stress is given with 100Hz electroacupuncture stimulation in 2 section. HF total power value increased in 4 section more than in 3 section. There was significance of results when comparing 3 section with 4 section. ( $p < 0.01$ )

Figure 5 shows with boxplots the change of HF total power when arithmetic stress is given with manual acupuncture stimulation in 2 section. HF total power value increased in 2 section more than in 1 section. There was significance of results when comparing 2 section with 1 section. ( $p < 0.05$ )

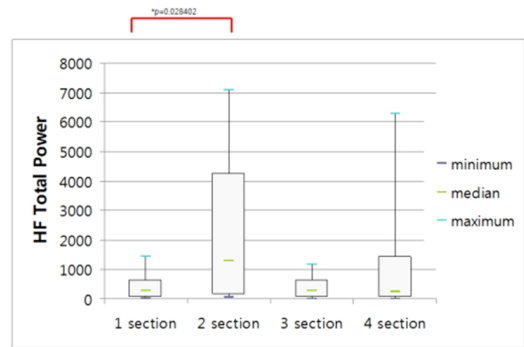


Fig. 5. Change of HF total power in manual acupuncture subject.

Box plot illustration before (1 section), during (2 section), and after (3, 4 section) arithmetic stress and manual acupuncture. The horizontal line in the box gives the position of the median. The end of the box defines the 25th and 75th percentile.

\*  $p < 0.05$  compared 1 section with 2 section.

## 2. LF total power comparison

The result of Wilcoxon signed ranks test did not show significance in any sections. This signifies that arithmetic stress as well as acupuncture stimulation can not change LF total power.

## 3. VLF total power comparison

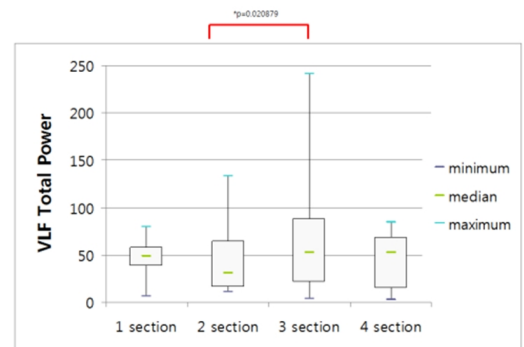
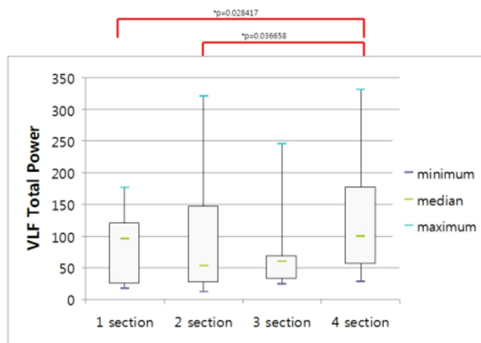


Fig. 6. Change of VLF total power in 2Hz electroacupuncture subject.

Box plot illustration before (1 section), during (2 section), and after (3, 4 section) arithmetic stress and 2Hz electroacupuncture. The horizontal line in the box defines the position of the median. The end of the box defines the 25th and 75th percentile.

\*  $p < 0.05$  compared 2 section with 3 section.



**Fig. 7.** Change of VLF total power in 100Hz electroacupuncture subject.

Box plot illustration before (1 section), during (2 section), and after (3, 4 section) arithmetic stress and 100Hz electroacupuncture. The horizontal line in the box gives the position of the median. The end of the box defines the 25th and 75th percentile.

\*  $p < 0.05$  compared 1 section with 4 section and 2 section with 4 section.

Figure 6 shows with boxplots the change of VLF total power when arithmetic stress is given with 2Hz electroacupuncture stimulation in 2 section. VLF total power value increased in 3 section more than in 2 section. There was significance of results when comparing 3 section

with 2 section. ( $p < 0.05$ )

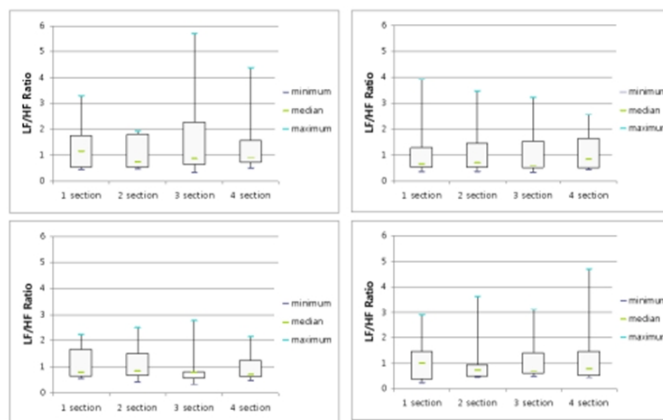
Figure 7 shows via boxplots the change of VLF total power when arithmetic stress is given with 100Hz electroacupuncture stimulation in 2 section. VLF total power value increased more in 4 section than in 2 section. There was significance of results when comparing 4 section with 2 section and 4 section with 1 section. ( $p < 0.05$ )

### C. Frequency domain analysis: LF/HF ratio

Figure 8 shows using boxplots the change of LF/HF ratio. We measured significance of comparison with each subject. There were no significant results. ( $p > 0.05$ )

## Discussion

Despite a lot of use and research in clinical settings, HRV analysis is still poorly supported by rigorous reliability studies<sup>15</sup>). The purpose of the present study was to examine the effect of acupuncture on the HRV of stroke patients under



**Fig. 8.** Change of LF/HF ratio.

Box plot illustration before (1 section), during (2 section), and after (3, 4 section) arithmetic stress and acupuncture. No significant changes were found. The horizontal line in the box gives the position of the median. The end of the box defines the 25th and 75th percentile.

- (a) non acupuncture Group
- (b) 2Hz electroacupuncture group
- (c) 100Hz electroacupuncture group
- (d) manual acupuncture group

mental arithmetic stress.

In the present study, we did not observe a difference in effects on the heart rate mean under mental arithmetic stress with non-acupuncture, manual acupuncture, high frequency electroacupuncture or low frequency electroacupuncture. It is generally accepted that mental arithmetic stress tests have been shown to cause increases in heart rate and mean blood pressure<sup>18)</sup> and increased urinary excretion of adrenaline and noradrenaline<sup>19)</sup>. However, more research will be needed in stroke patients.

The present study showed a significant elevated HF total power between 1 section and 2 section and between 1 section and 4 section in the non-acupuncture group, between 3 section and 4 section in 100Hz electroacupuncture group, between 1 section and 2 section in the manual acupuncture group and with no change in the 2Hz electroacupuncture group. HF represents the area from 0.15 to 0.4Hz<sup>20)</sup>. In a previous study, HF was a major contributor of efferent vagal activity, as well as an index that reflects parasympathetic activation<sup>21)</sup>, and stroke patients show a typical suppression of all the power spectral components of HR variability<sup>20)</sup> and mental stress increases LF activities but decreases HF activities<sup>22)</sup>. However, the present study's result was the reverse.

The present study showed a significant VLF total power between 2 section and 3 section in the 2Hz electroacupuncture group and between 1 section and 4 section and between 2 section and 4 section in the 100Hz electroacupuncture group. A VLF component was suggested by several physiological interpretations, but was not clearly conclusive<sup>23,24)</sup>.

Low frequency electroacupuncture stimulation has the effects of cerebral blood flow increase<sup>25)</sup> and ovarian blood flow intensity<sup>26)</sup>. On the other hand, high frequency electroacupuncture stimulation has the effects of bowel movement

hyperactivity suppression<sup>27)</sup> and blood pressure elevation<sup>28)</sup>. Both low and high frequency electroacupuncture have effects of sweating rate reduction<sup>29)</sup>.

The present study showed the LF/HF ratio. During experiment, there was no significant result. LF/HF ratio is generally accepted as a measure of sympatho-vagal balance<sup>30)</sup>. In previous studies, LF/HF ratio correctly present sympatho-vagal balance in healthy subjects, while LF/HF ratio was useless in patients with seriously decreased overall HRV and sympathetic overactivity<sup>31,32)</sup>. Furthermore, the possible explanation for limited benefit from LF/HF ratio in the analysis of sympatho-vagal balance in stroke patients is that disease progression shifts HRV spectra leftward<sup>33)</sup>. These findings explain why we didn't find significant changes between stroke patients when LF/HF ratio was analyzed.

The present study had limitations about small number of recruited subjects and wide age distribution. Nevertheless, the measured values will be useful for more future research which will be needed.

## Conclusions

Cerebral infarction subjects were divided into 4 groups: arithmetic stressed, 2Hz electroacupuncture stimulated, 100Hz electroacupuncture stimulated, and manual acupuncture. HRV change was observed depending on arithmetic stress and acupuncture stimulation as time passed.

According to measured values, we saw the following results.

First, we saw a change of HR (heart rate) mean between sections. The HR mean without acupuncture stimulation subject decreased continuously, but the value with acupuncture stimulation 3 subjects increased more in section 2

than in section 1 and recovered in section 3 and section 4. However, there was no statistically significant difference.

Second, this study showed a significant elevated HF total power between 1 section and 2 section and between 1 section and 4 section in the non-acupuncture group, between 3 section and 4 section in the 100Hz electroacupuncture group, and between 1 section and 2 section in the manual acupuncture group, but no change in the 2Hz electroacupuncture group. This study showed a significant VLF total power between 2 section and 3 section in the 2Hz electroacupuncture group and between 1 section and 4 section and between 2 section and 4 section in the 100Hz electroacupuncture group.

Third, we measured LF/HF ratio in all 4 groups. The result was no statistically significant difference. The present study results showed that parameters measured with heart rate variability had differences. This study may be the basis of research about effects of acupuncture and electroacupuncture.

### Acknowledgement

This paper was supported by Wonkwang University in 2011.

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