Power Spectrum Features of Acupoint Bioelectricity Signal

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Abstract: Background: Since the 1950s, many studies have been conducted on the electrical properties of acupuncture points (acupoints), especially their bio-resistance characteristics. Results of such studies have been inconclusive due to factors such as sweat gland density and compounding factors of applying electrical stimulation. In this study, a power spectrum instrument was used to assess the power spectrum and power of acupoints and non-acupoints without electrical stimulation. Using such instrumentation, specificity of electrical signals of acupoints was also explored. Methods: Thirty-six subjects (29 females, 7 males) participated in the study. Stainless steel acupuncture needles (diameter 0.35 mm, length 50 mm) were used. Five acupoints were tested: ST36, SP6, GB39, GB37, and KI9. Four control sites 0.5-1.0 cm adjacent to each acupoint were chosen. After needle insertion into the acupoint and control sites, the needles were attached to the power spectrum instrument to acquire any electrical signals. Acquire signals were analyzed using self-written software. Results: Power spectrum difference between acupoint and non-acupoint signals was 0-2 Hz. Results of t-test or signed rank sum test (α = 0.05) found that electrical signals between acupoints and non-acupoints were markedly different (P < 0.05). Conclusion: Acupoint bioelectricity signals are higher than adjacent non-acupoints. The most significant difference is distributed between 0 Hz to 2 Hz.

1. Introduction

A large volume of research has been conducted on acupuncture points (acupoints) and meridians (channels), focusing on the physiologic effects of acupoints and their electrophysiologic characteristics. The therapeutic effect of acupuncture has been confirmed by numerous clinical trials, showing that specificity of a given acupoint is associated with its efficacy. For example, acupuncture applied at ST2, ST25, and ST36 increases gastric antral volume [1]. Copious randomized controlled trials have found treating acupoints is efficacious over treating non-acupoints (sham) [2]. However, studies have also shown no therapeutic differences between
acupoints and non-acupoints [3,4].

Since the 1950s, many studies have been conducted on the electrical properties of acupoints, especially their bio-resistance characteristics [5,6,7]. Such studies have suggested that acupoints maybe the particular channel transmitting electrical signals, compared with non-acupoints, acupoints can enhance conductivity, reduce electrical resistance or impedance, and increase electrical potential [8-10].

Many factors affect acupoint resistance properties, such as sweat gland density, acupoint location, electrode polarization and frequency, among others [11]. To overcome these factors, Gow et al., for example used a Kelvin probe that circumvented skin contact to detect acupoint resistance. However, applicability of this method may be limited as the probe is sensitive to ambient field and movement artifacts [12].

Instead, we propose that applying technology similar to electrocardiography or electroencephalography may detect the true nature of the electrical signal of acupoints. In this study, power spectrum instrumentation was used to collect electric signals at acupoints and non-acupoint control locations. External electrical stimulation was not applied, allowing better understanding of the difference, if any, between signals found at acupoints and non-acupoints, and specificity of the electrical signals.

2. Materials and Methods

2.1 Subjects

Thirty-six subjects (29 female, 7 male) between 23 and 30 years old were recruited to participate in the study during February–July 2018. Participants were recruited in Xiyuan Hospital of China Academy of Chinese Medical Sciences.

Subjects were excluded if they were under 18 years old, pregnant, had clear signs and symptoms of disease, suspected of having significant organic disease, lactating, or menstruating. On the day of the study, volunteers were queried about their previous day’s emotional and dietary circumstances and those who experienced excess emotions (such as a bout of anger), ate cold or spicy food, or over-ate were excluded. Testing took place in the Nephrology Department of Xiyuan Hospital.

2.2 Acupoints Tested

Acupoints tested were located on the right side: ST 36, SP 6, GB 37, GB 39, and KI 9. Non-acupoint control points were situated 0.5-1.0 cm around the tested acupoints. The signal acquisition instrument required a reference electrode. A non-acupoint site on the right ulnar styloid process was chosen because of its limited number of sweat glands, allowing for voltage stability. A grounding electrode was also required, and the apex of the right lateral malleolus was selected for attachment (Figure 1).
2.3 Experimental Device

The study was conducted with a USB-ME16-FAI System (Multi Channel Systems, Reutlingen, Germany), a highly sensitive electrical signal acquisition instrument (Figure 2). We wrote a MATLAB (MathWorks, Natick, MA) program to analyze the power spectrum of acquired signals.

2.4 Experimental Procedure

The experiment was performed in a quiet environment with minimal air flow and an ambient temperature of 18°C-24°C. Participants were shielded from any electromagnetic radiation.

Participants were asked to arrive 10 minutes prior to start of the experiment so that they could sit quietly and relax. They were then asked to lie supine on a treatment table with the right upper arm and right lower leg exposed. Participants were also asked to stay awake during the experiment. In order to ensure the accuracy of the test, a single practitioner was responsible for a single acupoint.

To ensure good skin contact, the reference and ground electrodes were cleaned with 75% isopropyl alcohol before attachment to the skin. Disposable electrode pads were supplied by Beijing Tianhe Weiye Medical Equipment Factory (Beijing, China). The electrodes were then connected to the signal acquisition instrument with lead wires. The five acupoints were tested individually: ST36, SP6, GB39, GB37, and KI9. Four non-acupoint sites were selected to serve as controls. They were located 0.5-1.0 cm lateral, medial, superior, and inferior to each acupoint. These areas were cleaned with 75% isopropyl alcohol.

Off-the-shelf disposable steel acupuncture needles (Suzhou Huanqiu Acupuncture Medical
Appliance Co. Ltd., Suzhou, China) were used (diameter 0.35 mm; length 50 mm). The needle at the acupoint was inserted to a depth of 15 mm and deqi was obtained. To ensure reliability of the results, insertion depth of acupoint and control point needles were the same, though deqi was not apparent at the control points (Figure 3). One end of a lead wire was attached to the needle handle, with the other end attached to the signal acquisition instrument. Bioelectric signals of acupoints and control points were recorded synchronously by the USB-ME16-FAI instrument. Duration of each test was approximately 1 min. After all needles were removed, subjects were advised to rest quietly for 5 min.

We denoised the signals with db5 wavelet. Using Welch’s method, power spectral density (PSD) was evaluated. Analyzing the power spectrum of the signal after filtering, the sampling frequency of instrument was 1000 Hz, thus the power spectrum analysis range was to maximum of 500 Hz. To easily observe the specificity, 0-2 Hz, 0-10 Hz, 0-50 Hz, 0-500 Hz were analyzed.

2.5 Statistics

The Shapiro-Wilk normality test was applied if the data were consistent with a normal distribution based on the t-test. If the data did not meet normal distribution, signed rank sum test was used. Differences between acupoints and non-acupoints were considered significant if $P < 0.05$ or less.

3. Results

Five acupoints and their associated non-acupoint control points were scanned on 36 participants. Typical signals recorded by the instrument on the right leg are shown in Figure 4.

Fig.3 Placement of Needles At Acupoint and 4 Surrounding Control Points.

Fig.4 Typical Signals from Right Leg. a. Before Denoising. B. after Denoising.
Analyzing the power spectrum of the signal after filtering, results showed that the difference in power spectrum between acupoint and non-acupoint bioelectrical signals was 0-2 Hz (Figure 5).

![Graphs showing power spectrum comparison between acupoints and control points.](image)

Fig.5 Average Power Spectrum of Acupoints and Control Points.

The first statistical analysis showed that the difference between bioelectrical output of acupoints and non-acupoints was significant (P < 0.05). ST 36, SP6, GB 37, and GB 39 were considered different from their control points. With KI9, the data did not meet normal distribution, thus using signed rank sum test the difference between this acupoint and its control points was significant (P < 0.05) (Table 1).

A second statistical analysis assessed all 48 pieces of data using Shapiro-Wilk method, finding that the results did not meet normal distribution. Next, using the t-test (alpha 0.05) it was revealed that the difference between acupoint and non-acupoint bioelectrical output was significant (P < 0.05) (Table 2).

Table 1 (Unit Uw)

| Name | Num | Acupoint power value | Non-acupoint power value | Acupoint power value | Non-acupoint power value |
|------|-----|---------------------|-------------------------|---------------------|-------------------------|
| ST 36 | 1 | 1135.70 | 1106.30 | 3403.90 | 3265.60 |
|      | 2 | 882.03 | 848.60 | 378.62 | 344.47 |
|      | 3 | 1925.30 | 1853.80 | 893.47 | 849.89 |
|      | 4 | 1474.80 | 1422.70 | 1892.60 | 1633.20 |
|      | 5 | 1194.00 | 1127.50 | 125910.00 | 121480.00 |
|      | 6 | 1949.50 | 1850.30 | 43357.00 | 39865.00 |
|      | 7 | 2195.40 | 2103.70 | 372670.00 | 348470.00 |
|      | 8 | 685.83 | 663.23 | 153120.00 | 155470.00 |
|      | 9 | 2745.40 | 2588.20 | 88900.00 | 85157.00 |

Continued Table 1:

| Name | GB 39 | GB 37 | KI 9 |
|------|-------|-------|------|
| Num | Acupoint power value | Non-acupoint power value | Acupoint power value | Non-acupoint power value | Acupoint power value | Non-acupoint power value |
| 1   | 1468.40 | 1397.90 | 327.34 | 304.29 | 105550.00 | 97348.00 |
| 2   | 2212.90 | 2126.00 | 923.11 | 921.77 | 137760.00 | 93227.00 |
| 3   | 1353.40 | 1269.20 | 489.34 | 480.80 | 276340.00 | 271600.00 |
| 4   | 3030.80 | 2960.90 | 474.53 | 478.75 | 124010.00 | 118280.00 |
|   | Name                          | Num | ST 36 | SP 6   | GB 39 | GB 37 | KI 9 |
|---|-------------------------------|-----|-------|--------|-------|-------|------|
| 1 | Each volunteer points power value percentage higher than the non-acupoints |     |       |        |       |       |      |
|   |                               | 1   | 2.66% | 4.24%  | 5.04% | 7.58% | 7.77%|
|   |                               | 2   | 3.94% | 9.91%  | 4.09% | 0.15% | 32.33%|
|   |                               | 3   | 3.86% | 5.13%  | 6.63% | 1.78% | 1.72%|
|   |                               | 4   | 3.66% | 15.88% | 2.36% | -0.88% | 4.62%|
|   |                               | 5   | 5.90% | 3.65%  | 5.56% | 5.48% | 3.81%|
|   |                               | 6   | 5.36% | 8.76%  | 5.41% | -1.29% | 6.17%|
|   |                               | 7   | 4.36% | 6.94%  | 4.99% | 2.66% | 7.50%|
|   |                               | 8   | 3.41% | -1.51% | 4.23% | 4.32% | 3.90%|
|   |                               | 9   | 6.07% | 4.40%  | 2.39% | 1.63% | 4.35%|
|   |                               | 10  |       |        |       | 3.80% | 13.59%|
|   |                               | 11  |       |        |       | 5.49% |      |
|   | Average                       |     | 4.36% | 6.38%  | 4.52% | 2.79% | 8.58%|

4. Discussion

Numerous studies on the characteristics of acupoints have shown that they do in fact possess bioelectric properties, including increased conductance, reduced impedance and resistance, and increased capacitance. Recent studies have focused on the volt-ampere characteristics of acupoints [13], using electrical impedance methodology [14, 15]. Yet the majority of instruments employed measure electrical skin resistance, which differs from detecting and monitoring acupoints. Controversial findings may be due to different measuring methods. Most studies have focused primarily on the efficacy and electrical characteristics of acupoints and their active response to external electric stimulation. This cannot be equated with acupoints’ own bioelectrical properties. We believe that applying signal acquisition methods similar to ECG and EEG testing to detect bioelectrical signals at acupoints may lead to understanding the true nature of the bioelectrical characteristics of acupoints.

Thus, in this study, we used a power spectrum instrument, which itself does not emit external electrical stimulation, to collect and screen acupoint bioelectrical signals allowing us to assess the power spectrum and power of acupoints and how they differ from non-acupoints. Furthermore, we were able to explore the specificity of the electrical signals of acupoints.

Our results show the bioelectricity of acupoints we measured have a higher PSD and power than control points in the low spectral region of 0-2 Hz. Moreover, specificity existed at all acupoints we tested with good consistency. Taken together, these indicate existence of low-frequency signals in acupoints, which suggest that acupoints possess bioelectrical properties.

To ensure consistency of signal acquisition at acupoints and non-acupoint control sites, we placed the reference electrode on the right ulnar styloid process, which has few sweat glands, and the group electrode on the apex of the right lateral malleolus. In addition, non-acupoint control points were chosen 0.5-1.0 cm proximal to tested acupoints. Finally, a single
investigator-practitioner did the needle insertion on all participants.

Limitations of our study include acupoints investigated were based on ease of testing, not on particular channels and that we tested only five acupoints. For these reasons, our results can only suggest that acupoints have bioelectrical properties and that these properties differ among the acupoints we tested. The results cannot extend to the properties of channels. Further studies are needed to investigate this and to clarify the mechanism of acupoint bioelectrical signals.

5. Conclusions

Findings suggest that acupoints ST 36, SP 6, GB 37, GB 39, and KI 9 have bioelectrical signals. The signals differ in power from among acupoints, and each acupoint’s signal differs from its adjacent non-acupoint control sites. Furthermore, bioelectrical signals are higher at acupoints than at adjacent non-acupoints. The most significant difference mainly distributes from 0 Hz to 2 Hz.

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