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Meridian study on the response current affected by electrical pulse and acupuncture

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Abstract

Acupuncture and its meridians are important components of traditional Chinese medicine, and numerous opinions have been previously expressed regarding these meridians. This study aims to explore the phenomenon of meridians from the perspective of electronic physics by studying these meridians for the response current affected by electrical pulse and acupuncture. In this study, acupuncture which applies an electrical pulse was used to research the physical properties of the meridians. Different kinds of pulses were applied to the human body to realize abnormal electrical signals. Comparing these electrical measurement results with the isothermal transient ionic current (ITIC) theory, we found that the transmission of meridian messages may be related to ion conduction. The movement of ions induced by acupuncture and electrical stimulation can lead to drift and diffusion currents through the meridians. The ionic conduction of meridian hypothesis is proved in that the substances delivered by meridians are in fact ions.

Keywords: Acupuncture, Chinese medicine, Electrical pulse, Meridian theory, Ion current

Introduction

Acupuncture has been used for more than three thousand years. Now it is not only known as an important treatment instrument for musculoskeletal illness, but is also widely used to treat internal-medical diseases [1–4]. Though acupuncture is widely used for healing the disease in human body, better clarity is needed of the composition of meridians and their fundamental theory [5–7].

Meridian theory is a core component and foundation of acupuncture and *tui-na* massage. There are many different kinds of hypothesis on the nature of meridians [8]. They can be divided into four theoretical parts: those of nerve conduction theory [9, 10], body fluid circulation theory [11, 12],

fascia and connective tissue structure doctrine [13, 14], and biological field (or energy) doctrine [15, 16]. Each hypothesis interprets the meridian essence of Chinese medicine from a different perspective, and these different hypotheses try to explore the essence of the meridian from individual reasonable points of view. However, each hypothesis can only explain part of the meridian essence and cannot provide a comprehensive interpretation of the meridian system. This study aims to explore the phenomenon of meridians from the perspective of electronic physics by comparing different kinds of pulses to explain an abnormal current, proving that the movement substance is ions.

Electroacupuncture involves the insertion of needles into acupoints and introducing an electrical current through that needle, thus combining electricity and the needle to enhance the stimulation and the effects of acupuncture. When choosing two or more meridians to use electroacupuncture, the acupoint and meridian act like electrodes and a current channel, such that the current

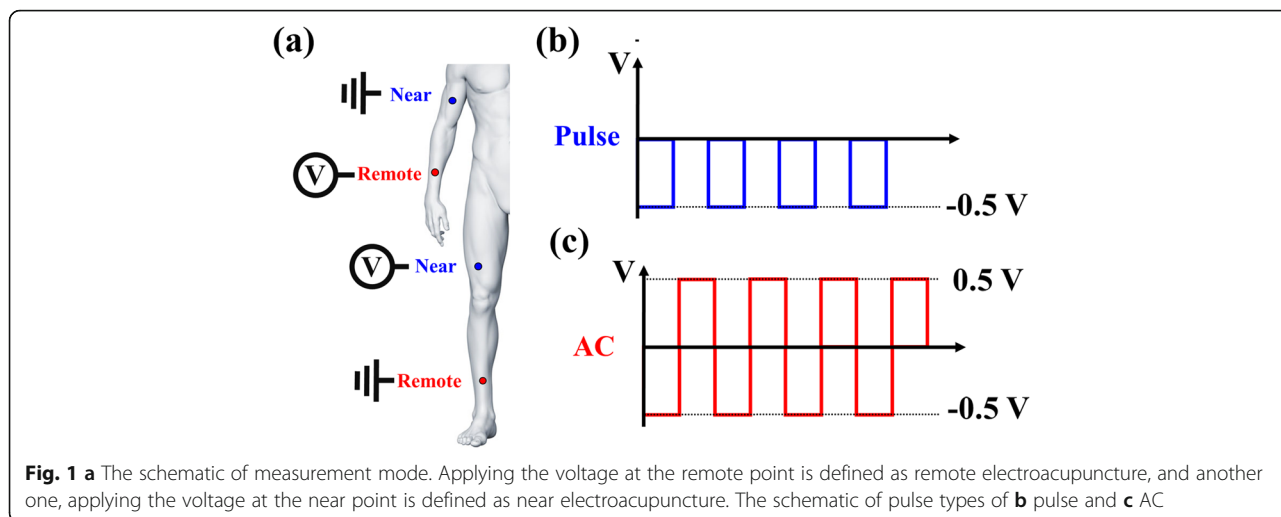
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passes through the meridians. By applying direct and alternating pulses into the *hegu* and *quchi* points in this work, the oscilloscope signal and responding current can be measured. This is very similar to the ITIC theory. For ions, it is very small substance moving to form the current [17–20]. In addition, many nanomaterials and devices used this theory to explain their model [21–24]. It is important to realize the transport mechanism in the ITIC theory. Moreover, by introducing the ion current model and comparing the difference in response current from direct and alternating pulses, the physical characteristics of meridians can be understood more clearly.

Experimental Methods

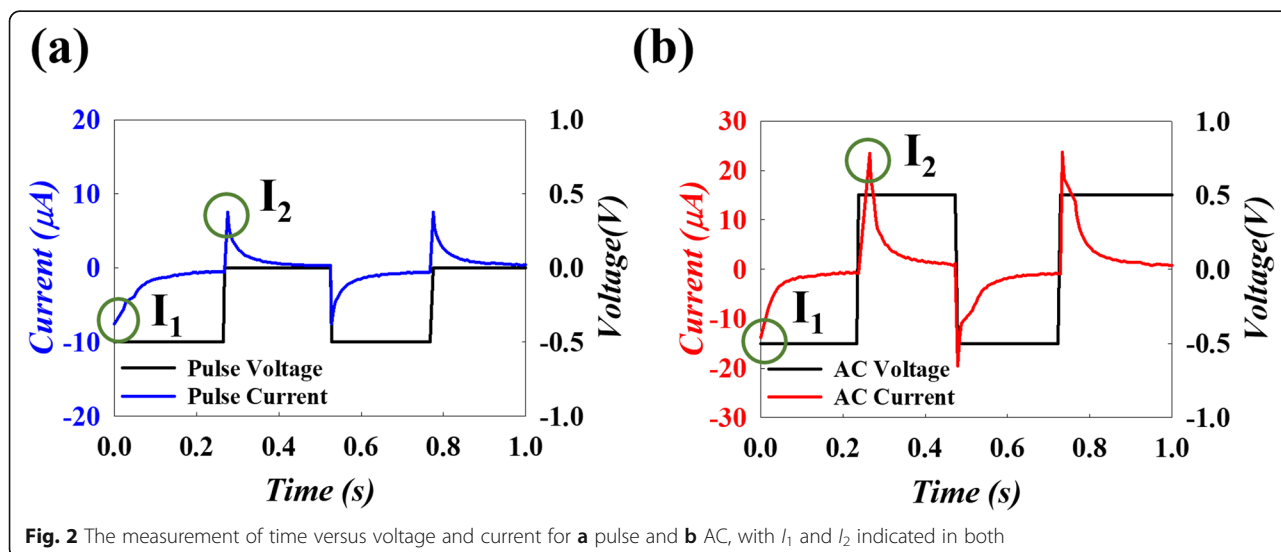
Participant Selection

This clinical trial was approved by the Institutional Review Board of Chang Gung Medical Foundation (IRB

permit no. 201800392A3). Written informed consent was obtained from all participants before enrollment. After certain initial assessments, 30 volunteers who met the inclusion criteria mentioned below were recruited; they included 15 men and 15 women, aged between 20 and 30 years. They were all well informed about this project and signed the consent before the experiment. We chose healthy volunteers as subjects in this study and therefore did not target any particular acupoint. The positions were instead chosen for their common use and convenient location in order to observe the phenomenon of ion transport in meridians.

Inclusion and Exclusion Criteria

According to a prospective survey, despite its benefits, acupuncture can also lead to some side effects [25]. As an invasive treatment, it may sometimes induce either



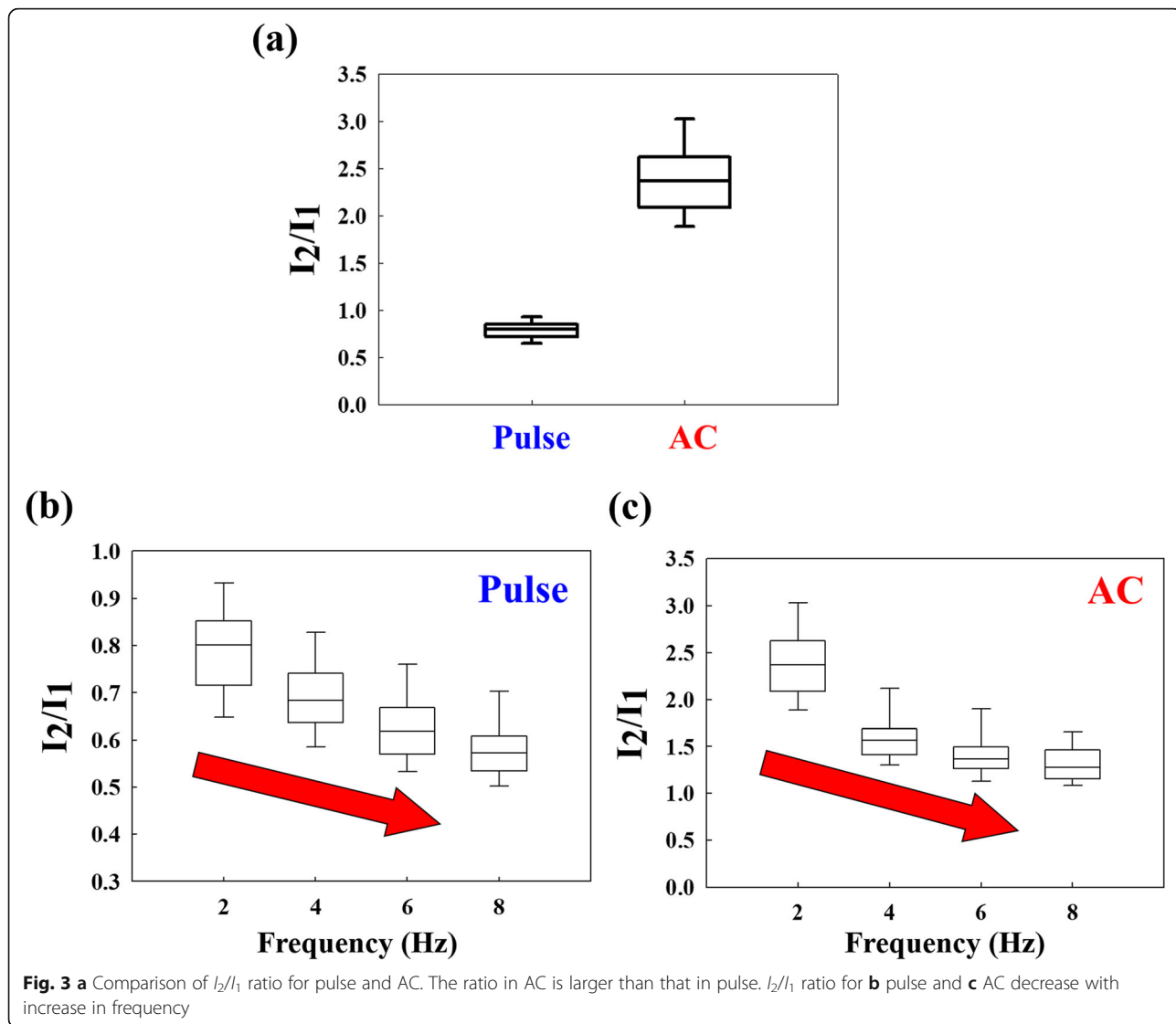
local or systemic adverse reactions [25–27]. Moreover, a systemic review shows that life-threatening events may also develop, albeit rarely. As a result, the exclusion criteria were very stringent. Bleeding and hematoma are the most common adverse reactions. Volunteers with bleeding tendencies (platelet counts less than 20,000 and/or thrombocytopenic purpura) were excluded. Volunteers with chronic medical conditions who were prescribed anti-coagulants were also excluded. In addition, pregnant women and volunteers with pacemakers were excluded.

Acupuncture Needles

The acupuncture needles used in this experiment were produced under the same conditions, in the same factory (Dong Bang Acupuncture Inc.), and on the same day, to minimize experimental error.

Experiment Process

In this experiment, the semiconductor measurement analyzer Agilent B1500A is used to input the human body meridian waveforms, and the flow directions of electrical signals are defined as remote electroacupuncture and near electroacupuncture, respectively, as shown in Fig. 1a. Remote electroacupuncture means that the electrical signals go through from limbs to body, and near electroacupuncture means that the electrical signals go through from body to limbs. The Chinese medicine treatment of electroacupuncture usually uses a square waveform. This is the reason we decided to use square waveforms, instead of triangle waveforms. In addition, when applying voltage, two different waveforms are given by alternating current (AC) and pulse, as shown in Fig. 1b. AC is a continuous square wave going back and forth between 0.5 and -0.5 V, and pulse is a continuous square wave starting from 0 to 0.5 V. Further, the



experiment uses AC and pulses of four frequencies (2, 4, 6, and 8 Hz). All data evaluations in this study were repeated thrice, which are presented as mean \pm standard deviation.

Result and Discussion

First, we chose the LI meridian with remote and near electroacupuncture between *hegu* and *quchi* points to start the experiment and measured the responding current. For AC, as the voltage was 0.5 V, the response

current was 13 μ A, and the current was 26 μ A at 0.5 V, as shown in Fig. 2a. In contrast, the current of the pulse waveform also read 10 μ A when the voltage was at 0.5 V. However, there was an abnormal reverse current of about 8 μ A at voltage of 0 V, as can be seen in Fig. 2b.

In order to analyze this abnormal current, the initial current value was defined as I_1 , and the abnormal reverse current was defined as I_2 . We divide I_2 by I_1 to find the difference between pulse and AC. The pulse ratio was close to 1, which indicates that the current is

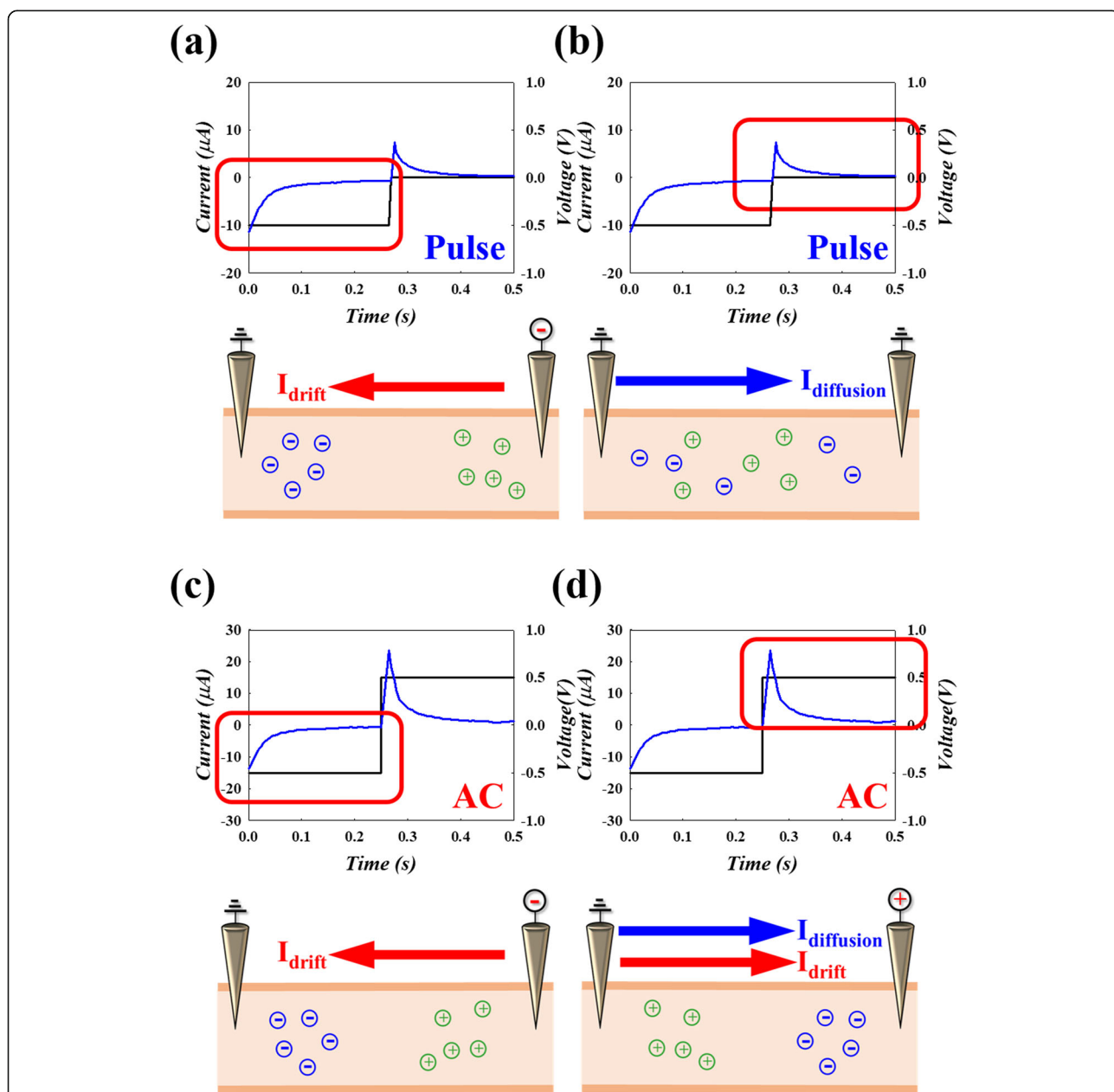


Fig. 4 The model for explaining the phenomenon of the pulse electric feature **a** drift current caused by voltage and **b** diffusion current caused by concentration gradient. For AC electric feature **c** drift current caused by voltage; **d** reverse voltage generate the larger current than diffusion current of pulse

negative at negative voltage, but will reverse back at the same amount without any voltage applied. However, in the AC ratio, the value was close to 2. This indicates a forward current at a negative voltage, but when reverse voltage is applied, the current will not only flow back but also increase with the response current. Therefore, the AC ratio becomes larger than the pulse ratio, as shown in Fig. 3a. Similarly, we change different frequencies and plot the ratio of I_2/I_1 against the frequency. In the pulse experiments, we found that the higher frequency showed a smaller ratio because there was not enough time for the compensation current in the higher frequency (shorter period) pulse, as shown in Fig. 3b. In addition, AC experiments with different frequencies demonstrate the same trend, as shown in Fig. 3c. The ratio decreased as the frequency increased in both pulse and AC experiments.

The I - V curve was used to analyze the mechanism inside the meridians of the human body. In the beginning, the current increases sharply and gradually decreases and saturates after exceeding the peak maximum value. We found that this was similar to the isothermal transient ionic current (ITIC) mechanism [28–33]. In the ITIC theory, the anions and cations will move by electrical field to the two sides of the channel, resulting in the increase in current [34]. When the ions accumulate at the two sides, the current will gradually decrease because of the barrier from the space charge. Therefore, the way of conducting electricity in the human body is mainly through ions.

From the ITIC theory, the electrical signal transference in meridians is very similar to the ion current. As a result, following measurement results and the ITIC theory, for applied voltage of 0.5 V at initial, the ions will move by the electric field, leading to drift current, and will accumulate at the two sites, as shown in Fig. 4a. However, when the voltage was not applied, the abnormal current was read by the diffusion current of the different concentration of ions. Therefore, the current direction was opposite to that of the drift current, as shown in Fig. 4b. Similarly, in AC pulse conditions, 0.5 V was applied, leading to the drift current in Fig. 4c. However, when the voltage changed from 0.5 to -0.5 V, both diffusion current and drift current with the opposite electric field were formed, leading to a current twice than measured at initial, as shown in Fig. 4d.

According to this result, the same experiments were carried out in 12 meridians. In Table 1, the ratio of I_2/I_1 all show the same result. Pulse had an abnormal response current, and the ratio was close to 1, while the ratio in AC was about 2.

Our findings are similar to the body fluid circulation theory. Acupuncture on the meridian acupoint can induce ion passive diffusion. In body fluid circulation

Table 1 Average and standard deviation of I_2/I_1 ratio to AC and pulse for 12 meridians

Meridians	AC	Pulse
<i>Yangming</i> large intestine meridian in hand (LI)	1.57 ± 0.53	0.51 ± 0.18
<i>Taiyang</i> small intestine meridian in hand (SI)	1.66 ± 0.42	0.54 ± 0.14
<i>Shaoyang Sanjiao</i> meridian in hand (SJ)	1.57 ± 0.33	0.64 ± 0.11
<i>Shaoyin</i> heart meridian in hand (HT)	1.25 ± 0.38	0.73 ± 0.63
<i>Taiyin</i> lung meridian in hand (LU)	1.59 ± 0.30	0.64 ± 0.12
<i>Jueyin</i> pericardium meridian in hand (PC)	1.60 ± 0.32	0.64 ± 0.15
<i>Taiyang</i> bladder meridian in foot (BL)	1.76 ± 0.46	0.77 ± 0.32
<i>Shaoyang</i> gallbladder meridian in foot (GB)	1.55 ± 0.42	0.64 ± 0.10
<i>Yangming</i> stomach meridian in foot (ST)	1.52 ± 0.46	0.53 ± 0.14
<i>Shaoyin</i> kidney meridian in foot (KI)	1.69 ± 0.46	0.63 ± 0.13
<i>Jueyin</i> liver meridian in foot (LR)	1.59 ± 0.38	0.50 ± 0.16
<i>Taiyin</i> spleen meridian in foot (SP)	1.38 ± 0.50	0.58 ± 0.15

theory, the meridians consist of ions and neurotransmitters, because human tissue is a complex electrolyte electrical conductor composed of moisture, inorganic salts, and charged biocolloids. When a pulse is applied to the human body, the ions will move directionally, eliminating the polarization of the cell membrane. Consequently, the ion concentration and distribution shows significant variety, affecting human tissue function. It is also the basic electrophysiological element.

One limitation of this study is that diseases may negatively affect the signal transmission of the meridian. We enrolled 30 volunteers, but not patients, to participate in this research. Electronic signal response in acupuncture meridians of patients suffering a specific disease require future study.

Conclusion

This study used different kinds of pulse (pulse and AC) to realize abnormal response current by the reverse voltage. This abnormal current can be explained via the ITIC theory, demonstrating that the movement of ions leads to the drift and diffusion currents. Therefore, the ions can be confirmed to be the substance transferred by the meridians.

Abbreviations

ITIC: Isothermal transient ionic current; AC: Alternating current; LI: *Yangming* large intestine meridian in hand; SI: *Taiyang* small intestine meridian in hand; SJ: *Shaoyang Sanjiao* meridian in hand; HT: *Shaoyin* heart meridian in hand; LU: *Taiyin* lung meridian in hand; PC: *Jueyin* pericardium meridian in hand; BL: *Taiyang* bladder meridian in foot; GB: *Shaoyang* gallbladder meridian in foot; ST: *Yangming* stomach meridian in foot; KI: *Shaoyin* kidney meridian in foot; LR: *Jueyin* liver meridian in foot; SP: *Taiyin* spleen meridian in foot

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Authors' Contributions

Yu-Chiang Hung, Wen-Chung Chen, Hao-Xuan Zheng, and Tsung-Ming Tsai performed the electrical measurements. Ting-Chang Chang and Yu-Chiang Hung were involved in the planning and supervised the work. Wen-Chung Chen, Yung-Fang Tan, Shih-Kai Lin, and Ying-Hsin Lu processed the experimental data, performed the analysis, drafted the manuscript, and designed the figures. Wen-Long Hu and Yan-Wen Liu performed the acupuncture. All authors discussed the results and commented on the manuscript. The author(s) read and approved the final manuscript.

Availability of Data and Materials

All data are fully available without restriction.

Competing Interests

The authors declare that they have no competing interests.

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