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CLINICAL STUDY

Frequency steps and compositions determine properties of needling sensation during electroacupuncture

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Abstract

OBJECTIVE: To investigate the relationship of electro-parameters and the electroacupuncture sensation (EAS), which is thought to be an important factor for optimal treatment.

METHODS: The frequency steps and compositions of three frequently used electrical stimulations were set when the switch of the electroacupuncture apparatus was turned to the second or third grade of the dense-disperse frequency wave (DD2 and DD3, respectively) or the second grade of the continuous wave (C2). Three groups of patients according to the three electroacupuncture stimulations were divided again into three sub-groups according to the stimulated acupoints: the face acupoint Quanliao (SI 18), the upper-limb acupoint Quchi (LI 11) and the back acupoint Dachangshu (BL 25). The EAS values were measured every 5 min during 30 min electroacupuncture treatments using a visual analogue scale.

RESULTS: The frequency compositions of the three electroacupuncture stimulations were 3.3 and 33 Hz, 12.5 and 66.7 Hz, and 3.3 and 3.3 Hz; each frequency step was 30, 54 and 0 Hz, respectively. In each sub-group of the C2 group, the EAS values from 10 to 30 min were significantly weaker than at 0 min. The sensation fluctuations in the DD2 and DD3 groups were different during the 30 min.

CONCLUSION: The greater the frequency step of the electroacupuncture stimulation, the longer the needling sensation lasted. The electroacupuncture stimulations of the DD3 group were unsuitable for the facial acupoint because of its painful and uncomfortable EAS, but more suitable for the back acupoint.

Key words: Electroacupuncture; Electroacupuncture apparatus; Electroacupuncture sensation; Radio waves

INTRODUCTION

Needling sensation is of great importance during acupuncture treatment in Traditional Chinese Medicine (TCM).[1] TCM doctors must pay close attention to their patients' reactions to lifting-thrusting and twirling the needle, and they believe that the needling sensation is closely related to the curative effect of acupunc-

ture. Several pilot studies show that the needling sensation is beneficial to treatment.[2,3]

Electroacupuncture apparatuses have been used for acupuncture treatment since 1960 and have lightened the workload of the acupuncturist. Electroacupuncture sensation (EAS) is a needling sensation aroused by an electroacupuncture apparatus, and has been discussed since the apparatus came into popular use. The earlier apparatuses only emitted a single-frequency signal, called a continuous wave. It is soon found that the EAS becomes weak and even disappears quickly (in approximately 5-10 min) while the patient is being treated by the continuous wave.[4] The rapid decline of the EAS was much faster than the sensation produced by twirling and lifting-thrusting the needle during manual acupuncture. This phenomenon is called the time-dependent electroacupuncture sensation decrease (TESD).

Sensory physiology has shown that constant stimulation causes sensory adaptation.[5,6] The TESD phenomenon is just one example of sensory adaptability. Subsequently, the dense-disperse frequency (D.D.) wave is introduced into the electroacupuncture apparatus to overcome TESD. The D.D. wave consists of two frequency-alternating electrical pulses. The relatively low-frequency pulses are called disperse-frequency pulses, and the high-frequency ones are called dense-frequency pulses. Usually, there are more than three separate grades of continuous waves and D.D. waves on the faceplate of the electroacupuncture apparatus. The frequency composition of each grade is different. [4] The second grade of the continuous wave (C2), the second grade of the D.D. wave (DD2) and the third grade of the D.D. wave (DD3) are used most widely by acupuncturists in China. However, many acupuncturists still complain that DD2 does not fully avoid the TESD, and they have to increase the magnitude of the stimulus to avoid the TESD. Additionally, DD2 and DD3 sometimes make patients too uncomfortable in the treatment.

Although the D.D. wave has been used for more than 50 years, how EAS is evoked by the D.D. wave evoked is still unclear. The present study aimed to elucidate its regularity.

MATERIALS AND METHODS

The frequency compositions of the D.D. wave and the continuous wave of the electroacupuncture apparatus (CMNS6-1, Jiajian Medical Instrument Company, Suzhou, China) were tested by a digital signal oscilloscope (Tektronix TDS2022B, Beaverton, OR, USA).

Subjects and groupings

Totally 270 subjects, ranging in age from 18 to 68 years, were selected from the outpatient department of the People's Hospital of Fujian Province, Fuzhou, China. All subjects were conscious and could walk into the consulting room. Subjects were assigned to groups blindly. This study was approved by the Clinical Research Ethics Committee of the Fujian Academy of Traditional Chinese Medicine. Documented consents from all patients were obtained. 217 subjects, 111 women and 106 men, completed the measurement and the data was analyzed in the end.

Subjects with primary symptoms of facioplegia, neck pain or backache were selected and divided into three groups (DD2, DD3 and C2) randomly according to a random number table. The three frequently used electroacupuncture stimulations, the second and third grade of the dense-disperse frequency wave (DD2 and DD3), and the second grade of the continuous wave (C2) were adopted respectively in the groups.

The acupoints Quanliao (SI 18), Quchi (LI 11) and Dachangshu (BL 25) were selected. Each group was then divided again into three sub-groups. Subjects with a chief complaint and symptoms of facioplegia were divided into sub-groups DD2-ql, DD3-qc and C2-ql, subjects with neck pain into sub-groups DD2-qc, DD3-qc and C2-qc and subjects with backache into sub-groups DD2-dcs, DD3-dcs and C2-dcs in the order of their visits (Figure 1).

Subjects were divided into three groups and each group was then divided again into three sub-groups. C2, subjects were treated with the second grade of the continuous wave; DD2, subjects were treated with the second grade of the dense-disperse frequency wave; DD3, subjects were treated with the third grade of the dense-disperse frequency wave. ql: The subjects with the primary symptoms of facioplegia were treated with acupuncture at Quanliao (SI 18). qc: The subjects with the primary symptoms of neck pain were treated with acupuncture at Quchi (LI 11). dcs: The subjects with the primary symptoms of backache were treated with acupuncture at Dachangshu (BL 25). Ages were compared by one-way analysis of variance (ANOVA) in each sub-group among all three groups, with no significant differences ($P > 0.05$, data not shown).

Visual analogue scale (VAS)

A cardboard ruler was made according to the method of international VAS[7,8] for detecting EAS. The ruler consisted of side A and side B. There was one mark in the middle of side B labelled as the standard feeling point. There were 20 marks with 1-cm intervals from the right to the left on side A. The standard feeling point on side B was at the same place as mark 10 on side A (Figure 2).

Electroacupuncture method

The subjects took a recumbent position in a quiet room at 20-27 ℃. Stainless-steel acupuncture needles with 0.3 mm × 25 mm and 0.3 mm × 40 mm were used (Jiajian Medical Instrument Company, Suzhou, China).

For the sub-groups DD2-ql, DD3-ql and C2-ql, a 25-mm needle was inserted vertically into left Quanliao (SI 18), and a 40-mm needle was inserted agley (at

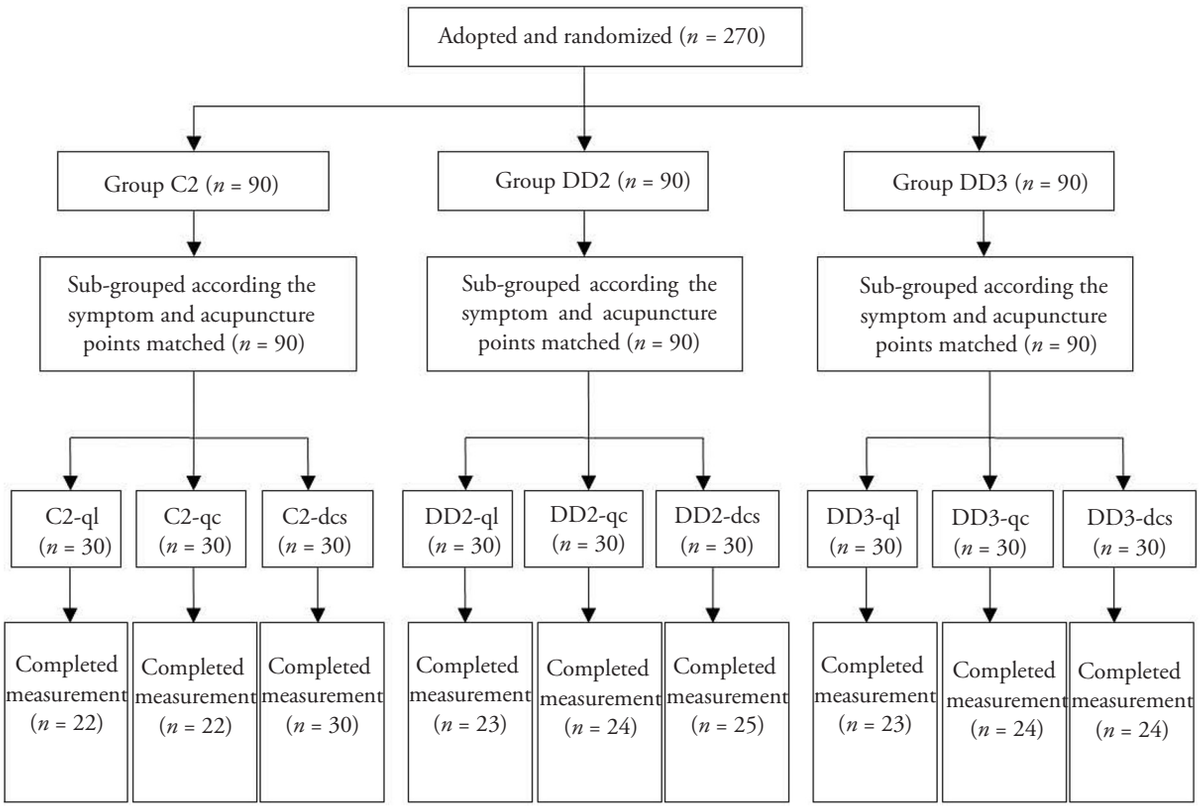

Figure 1 Groupings and case numbers

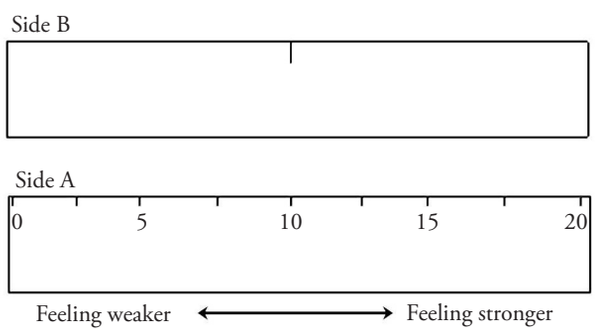

Figure 2 The ruler of the visual analogue scale

approximately 15 degree from the horizontal plane) into left Dicang (ST 4) to a depth of 10 mm. For the sub-groups DD2-qc, DD3-qc, and C2-qc, the two acupoints [left Quchi (LI 11) and left Binao (LI 14)] were needled separately with 40-mm needles vertically to a depth of 15 mm. For the sub-groups DD2-dcs, DD3-dcs and C2-dcs, the two acupoints [left Dachangshu (BL 25) and Shenshu (BL 23)] were needled separately with 40-mm needles vertically to a depth of 20 mm.

The two output ends of the electroacupuncture apparatus (CMNS6-1, Jiajian Medical Instrument Company, Suzhou, Jiangsu, China) were connected to the two acupoints of every subject to form an electric circuit. The two acupoints of the electro-circuit for the sub-groups were, respectively: Quanliao (SI 18) and Dicang (ST 4) for the sub-groups DD2-ql, DD3-ql and C2-ql; Quchi (LI 11) and Binao (LI 14) for the sub-groups DD2-qc, DD3-qc and C2-qc; and Dachangshu (BL 25) and Shenshu (BL 23) for the sub-groups DD2-dcs, DD3-dcs and C2-dcs.

Measure of EAS

The EAS data were recorded with the VAS by asking the patient to rate their sensation every 5 min during the 30-min acupuncture treatment.[3,4] After needling the acupoints, the strength knob of the apparatus was slowly turned from the smallest strength to adaptive strength while making sure that EAS felt by the subject was not painful and not very uncomfortable. While viewing side B of the VAS cardboard ruler, the patient was asked to remember the sensation of the moment (0 min) and was told that EAS was located on the midpoint of side B of the ruler. The EAS at 0 min was regarded as the standard EAS.

The measure of EAS was repeated at 5, 10, 15, 20, 25, and 30 min. To record each EAS, side B of the ruler faced the patient, and side A faced the doctor. At every measurement, the subject was asked to compare the EAS at that time with the standard EAS, and to locate each position on side B of the ruler on the left or the right from the midpoint, according to whether the subject's EAS was weaker or stronger. The left of the standard feeling indicated a weaker sensation and the right indicated stronger. The corresponding value on side A was the value of the EAS at that time point. A total of seven values of EAS were obtained in each case.

Statistical analysis

All data were analyzed using SPSS software (version 13.0, SPSS Inc., Chicago, IL, USA). The numerical value of the EAS for each group at each time point was expressed as mean ± standard deviation ($\bar{x} \pm s$). ANOVA was used for comparisons of groups and sub-groups and least significant difference *t*-test was

used for comparison between any two means. $P < 0.05$ was considered statistically significant.

RESULTS

Frequency compositions and steps

The frequency compositions and parameters on the electroacupuncture apparatus are listed in Table 1.

EAS at the face acupoint Quanliao (SI 18)

The EAS values at 10, 15, 20, 25 and 30 min in the sub-group C2-ql were significantly smaller than the value at 0 min ($P < 0.01$). The EAS values at 20, 25 and 30 min in the sub-group DD2-ql were smaller than the value at 0 min ($P < 0.01$, Table 2). The rate of decrease of EAS in the sub-group DD2-ql was significantly slower than that of the sub-group C2-ql ($P = 0.012$, Table 2). The EAS was too strong to be bearable for the sub-group DD3-ql (Table 2).

EAS at the upper-limb acupoint Quchi (LI 11)

EAS values at 5, 10, 15, 20, 25, and 30 min in the sub-group C2-qc were significantly smaller than the value at 0 min ($P < 0.01$). EAS values at 15, 20, 25 and 30 min in the sub-group DD2-qc were significantly smaller than the value at 0 min ($P < 0.01$, Table 3). For the sub-group DD3-qc, EAS values at 20, 25 and 30 min were significantly smaller than the value at 0 min ($P < 0.01$, Table 3). The rates of decrease of EAS in the sub-groups DD2-qc and DD3-qc were significantly slower than that of the sub-group C2-qc ($P < 0.05$, Table 3).

EAS on the backside acupoint Dachangshu (BL 25)

For the sub-groups DD2-dcs and C2-dcs, EAS values at 10, 15, 20, 25 and 30 min were significantly smaller than the respective values at 0 min. For the sub-group DD3-dcs, the EAS values at 15, 20, 25 and 30 min were significantly smaller than the value at 0 min ($P < 0.01$, Table 4). The rate of decrease of EAS of the sub-group DD2-dcs was not significantly different from that of the sub-group C2-dcs ($P = 0.570$, Table 4).

Sensation disappearance time point

The time point at which EAS was no longer significantly different from that at 0 min was named the sensa-

Table 1 Frequency compositions and steps of the electroacupuncture apparatus

Program of the D.D. wave	Disperse frequency		Dense frequency		Frequency step (Hz)
	Composition (Hz)	Duration (S)	Composition (Hz)	Duration (S)	
1st	2.5	6.0	25.0	5.0	22.5
2nd	3.0	5.5	33.0	9.0	30.0
3rd	12.0	5.2	66.0	9.0	54.0
2nd program of the continuous wave	3.3	-	-	-	0

Notes: the electroacupuncture apparatus, CMNS6-1, was made by Jiajian Medical Instrument Company, China. The frequency compositions and steps were tested by a digital signal oscilloscope.

Table 2 The electroacupuncture needling sensation at the face acupoint Quanliao (SI 18) ($\bar{x} \pm s$)

Group	*n*	0 min	5 min	10 min	15 min	20 min	25 min	30 min
C2-ql	22	10	9.54±1.61	8.06±1.95[a]	6.34±2.00[a]	4.67±2.42[a]	3.27±1.96[a]	1.92±1.85[a]
DD2-ql	22	10	9.98±0.11	9.30±0.94	8.84±1.61	7.40±1.26[a]	4.46±1.52[a]	2.44±1.50[a]
DD3-ql	30	-[b]	-	-	-	-	-	-

Notes: C2-ql: acupuncture was given at Quanliao (SI 18) with the second grade of the continuous wave; DD2-ql: acupuncture was given at Quanliao (SI 18) with the second grade of the dense-disperse frequency wave; DD3-ql: acupuncture was given at Quanliao (SI 18) with the third grade of the dense-disperse frequency wave. Analysis of variance was used for comparison between the groups C2-ql and DD2-ql ($P = 0.012$). Least significant difference *t*-test was used for comparison of EAS values of 5, 10, 15, 20, 25 and 30 min with 0 min in each sub-group. EAS: electroacupuncture sensation. Compared with 0 min in the same group, [a]$P < 0.01$. [b]Because the acupuncture sensation was too strong to be stimulated and measured, no data in this group could be obtained. EAS: electroacupuncture sensation.

Table 3 The electroacupuncture needling sensation at the upper-Limb acupoint Quchi (LI 11) ($\bar{x} \pm s$)

Group	*n*	0 min	5 min	10 min	15 min	20 min	25 min	30 min
C2-qc	23	10	9.78±0.34	8.21±1.06[a]	6.65±1.97[a]	4.90±2.30[a]	2.84±2.50[a]	1.62±1.91[a]
DD2-qc	24	10	9.98±0.12	9.05±1.02	7.68±0.96[a]	5.96±0.86[a]	4.00±1.04[a]	2.13±1.03[a]
DD3-qc	25	10	9.99±1.34	9.36±1.12	9.03±1.37	7.63±0.68[a]	6.47±1.20[a]	6.06±1.12[a]

Notes: C2-qc: Acupuncture was given at Quchi (LI 11) with the second grade of the continuous wave; DD2-qc: acupuncture was given at Quchi (LI 11) with the second grade of the dense-disperse frequency wave; DD3-qc: acupuncture was given at Quchi (LI 11) with the third grade of the dense-disperse frequency wave. Analysis of variance was used for comparison between the sub-groups FF-qc and DD2-qc, $P = 0.019$, and between the sub-groups C2-qc and DD3-qc, $P = 0.006$. Least significant difference *t*-test was used for comparison of the EAS values of 5, 10, 15, 20, 25 and 30 min with 0 min in each sub-group. Compared with 0 min in the same group, [a]$P < 0.01$.

Table 4 The electroacupuncture needling sensation on the back-side acupoint Dachangshu (BL 25) ($\bar{x} \pm s$)

Group	*n*	0 min	5 min	10 min	15 min	20 min	25 min	30 min
C2-dcs	23	10	9.94±0.35	8.35±1.03[a]	7.62±2.17[a]	5.72±2.72[a]	3.67±2.38[a]	2.02±1.90[a]
DD2-dcs	24	10	9.58±0.12	8.63±1.11[a]	7.48±1.36[a]	6.01±1.18[a]	4.43±1.43[a]	2.34±1.08[a]
DD3-dcs	24	10	9.87±0.16	9.76±1.10	8.54±1.36[a]	7.78±1.26[a]	7.14±1.04[ab]	6.32±1.30[ab]

Notes: C2-dcs: acupuncture was given at Dachangshu (BL 25) with the second grade of the continuous wave; DD2-dcs: acupuncture was given at Dachangshu (BL 25) with the second grade of the dense-disperse frequency wave; DD3-dcs: acupuncture was given at Dachangshu (BL 25) with the third grade of the dense-disperse frequency wave. Analysis of variance was used for comparison between the sub-groups C2-dcs and DD2-dcs, $P = 0.570$, and between the sub-groups C2-dcs and DD3-dcs, $P = 0.017$. Least significant difference *t*-test was used for comparison of the EAS values of 5, 10, 15, 20, 25 and 30 min with 0 min in each sub-group. Compared with 0 min in the same group, [a]$P < 0.01$. Compared with DD2-dcs at the same time point, [b]$P < 0.01$.

tion disappearance time point. The regularity of the characteristics of EAS at the different body regions with the different electrical stimulation types are summarized in Table 5.

Table 5 The time points of the electroacupuncture needling sensation significantly decreasing (min)

Group	Quanliao (SI 18)	Quchi (LI 11)	Dachangshu (BL 25)
C2	10	10	10
DD2	20	15	10
DD3	-[a]	20	15

Notes: C2: stimulation by the second grade of the continuous wave. DD2: stimulation by the second grade of the dense-disperse frequency wave. DD3: stimulation by the third grade of the dense-disperse frequency wave. [a]The electroacupuncture needling sensation was too uncomfortable to be bearable.

DISCUSSION

Acupuncture needling sensations are complex and quantifying the sensation is difficult.[9] VAS is a response scale that can be used to quantify subjective feelings or sensations that cannot be measured directly by an instrument. EAS, a subjective feeling, conforms to the scope of the application of VAS.[7] For probing the possibility of using the self-report of the overall intensity of the needling sensation as a predictor of analgesic outcome of acupuncture, Benham *et al* [9,10] measured the intensity of overall needling sensation using a VAS and proved it was useful as a gross marker of the adequacy of acupuncture. The detection of EAS in the present study by VAS also proved to be efficient.

Table 1 shows that the frequency step of DD2 was smaller than DD3, and the frequency step of C2 was 0. The larger the step, the greater the change in stimulus. The magnitude of a stimulus change is an important factor for maintaining a feeling, which is the basis for the design of the D.D. wave. However, it is not clear which frequency step is suitable for the acupoints of different parts of the body. A suitable step makes EAS last a long time and the patient feel less uncomfortable.

Tables 2-4 show that in each sub-group, EAS declined during the 30-min acupuncture session. Table 5 shows that the sensation disappearance time point was 10 min in the face, upper limb and backside acupoint sub-groups in the C2 group. The sensation disappearance time point varied in the DD2 and DD3 sub-groups. In the DD2-ql sub-group, the sensation disappearance time point was 20 min, which was longer than those in the DD2-qc and DD2-dcs sub-groups. These data indicate that the acupoints on the face are more sensitive than those at the upper limb and backside. In the DD3-ql sub-group, EAS was too uncomfortable to stimulate the face acupoint, making it impossible to test EAS. However, in the DD3-dcs sub-group, the sensation disappearance time point was 15 min, which was longer than that in the DD2-dcs sub-group, indicating the acupoints on the backside can bear a larger FS.

Verum acupuncture at true acupuncture points is more likely to elicit needling sensation. Needling sensations mainly resulted in brain area activations, but not deactivations. These brain areas are related to the curative effect.[1,11-13] Takamoto *et al* [14] investigated induction of cerebral hemodynamic responses related to needling sensations and found that needling sensations could predict acupuncture effects on cerebral hemodynamics, regardless of the stimulated site. The effect of acupuncture stimulation in producing needling sensation was partly mediated by the central nervous system, including the supplementary motor area.[14]

The posterior central gyrus of the cerebral cortex (cortex 3-12 area) is the sensory projection area of the whole body surface.[15] The sensory projection area can be divided into many small different sensory projection areas. The size of each area is not proportional to the size of the corresponding body surface area. [16] The larger the corresponding cerebral cortical area, the finer the sensory discrimination of the surface area. For example, the size of the brain regions of the finger is much larger than that of the backside of the body, and the feeling in the fingers is much finer than that of the backside. The size of the brain region of the feeling-sensitive face is much larger than that of the upper limb, and the size of the brain region of the upper limb is larger than that of the entire backside. Therefore, sensory discrimination from strong to weak in descending order shows as follows: the face, upper limb and back.

The feeling discrimination of the face is finer, so the

acupoints on the face are more sensitive to a given frequency step than those on the limbs and backside. It was observed that the acupoint on the face could bear a 30-Hz step of DD2 but could not bear a 54-Hz step of DD3 (Tables 2, 4). Because the feeling discrimination of the back is less fine, the acupoints on the back could bear larger a 54-Hz step of DD3, leading to a larger EAS at 25 and 30 min in the sub-group DD3-dcs compared with DD2-dcs (Table 4).

In brief, DD3 is better for back acupoints than DD2 and C2 for forestalling a time-dependent decrease in electroacupuncture needling sensation. DD3 is not suitable for face acupoints because it produces an uncomfortable EAS. These results indicate that acupuncturists should choose the D.D. wave according to the body region so as to avoid both a fast weakening of EAS and patient discomfort. This study explores the relationship between frequency step and EAS, which is in favour of both selecting the intensity and frequency and selecting the adaptive frequency step.

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