Electroacupuncture: Current Strength-Duration Relationship For Initiation of Hypesthesia In Man

Nobusada Ishiko, Toshikatsu Yamamoto, Nobuki Murayama
And Takamitsu Hanamori
Department of Physiology, Miyazaki Medical College,
Kiyotake-machi, Miyazaki (Japan)

Summary

Electrical stimulation through an acupuncture needle in a Chinese point of the human hand decreased the subjectively estimated sensation elicited by noxious and by tactile stimulation of the ipsilateral finger. A hyperbolic relationship was found between the stimulus duration (T, ses) required for the initiation of hypesthesia and the intensity of current (I, mA) passed through the acupuncture needle: 

\[ I = 0.11 + 18/T \]

Electroacupuncture, a pain relieving technique, utilizes electrical pulses for stimulating various loci through needle electrodes. It produces hypalgesia or a rise in pain threshold within a circumscribed area, this effect outlasting for some minutes the stimulation \( (1, 9, 12, 14) \). To provide a modern basis for acupuncture analgesia, evidences based mainly on neurophysiological \( (2, 5, 10, 15) \), humoral \( (11, 14, 16) \) and psychophysical \( (3, 4, 6, 8) \) investigations have been presented. However, little information is available concerning the stimulus factors, such as strength and duration, to effect the sensory depression. We have investigated the relationship in man between these parameters, in regard to depression of the sensation of touch-hypesthesia and experimental pain-hypalgesia.

The experiments were performed on 13 male subjects 18-49 years old. A sterilized acupuncture needle was inserted into ‘Ho-Ku’ point located between metacarpal bones I and II of the right hand. The stimulator employed for electroacupuncture had constant voltage output with the current variable from 0 to 2 mA by means of a variable series resistor between output and needle. It could generate, at a rate of 2/3 sec, a negative going square wave of 1 sec in duration on which brief positive going pulses of 667 Hz were superimposed, the polarity referring to the needle electrode. The indifferent electrode was a metal plate placed on the ipsilateral hand plam. To elicit tactile sensation the right index finger was tapped with a small hair bundle \( (1. 5 \text{ mm}^2, \text{ in tip dimension}) \) driven by an electromagnet. For experimental pain, the nail bed of the same finger was stimulated by a steel needle which was driven by another electromagnet. These mechanical stimulations were applied every 2-3 sec before, during and after acupunctural stimulation. All the subjects were instructed to compare the subjectively estimated magnitude of each experimental sensation with that of the immediately preceding one. They had to indicate their estimates by a set of 3 buttons connected to different potential outputs; the output level 3 (vertical scale in Fig. 1) was used for the
magnitude of sensation perceived before onset of acupunctural stimulation, whereas levels 2 and 1 were to signal a just noticeable difference from levels 3 and 2, respectively. Spontaneous changes in the level 3 were scarcely observed since every experiment was preceded by the training period of several min during which the subjects were asked to establish a criterion for perceived sensations. To evaluate the hypesthetic effect of acupunctural current, intensities ranging from 0 to 0.8 mA were employed. Because most of the subjects complained a pricky sensation at the needle tip as soon as the intensity had reached around 0.1 mA, a steplike increase in the current intensity (Fig. 1B) was necessary to reach a final level higher than 0.1 mA. The intensity of current applied, the magnitude of sensation and the onset of mechanical stimuli were displayed on a polygraph.

Of 13 subjects tested, two abandoned the experiment because of discomfort to acupunctural stimulation whereas another one indicated instability in the perceived magnitude of level 3, probably because of difficulty in establishing criteria for experimental sensations. In the remaining 10 subjects, the effect of acupuncture on touch was studied by performing 15 examinations of touch on 9 subjects and 3 examinations of pain on 3 subjects, respectively. Fig. 1A

Fig. 1. Depressant effects of electroacupuncture to 'Ho-Ku' point on pain and touch in a subject A: upper trace represents change in the subjectively estimated magnitude of sensation to noxious and tactile stimulation (lower bars) of the finger. Period between a pair of vertical dotted lines in left and right indicates duration of electroacupuncture. B: intensity of current passed through acupuncture needle.
Fig. 2. Relationship between intensity of acupuncture current (left hand ordinate) and time (abscissa) required for initiation of sensory depression in 10 subjects. The sensory stimulus was touch (▲) or pain (△). The quantity of electricity (right hand ordinate) was calculated as I•T (○).

Fig. 1 thus illustrates that the magnitude of perceived pain decreased from level 3 to 2, 60 sec after onset of the acupuncture stimulus whereas depression from level 3 to 2 in the magnitude of sensation to touch occurred 40 sec after a rise from 0.3 to 0.5 mA. In two of 15 examinations, acupunctural stimulation of more than 30 min failed to produce hypesthesia, probably because of insufficient intensity of current applied. Results obtained from the remaining 13 examinations showed that hypesthetic effect of acupuncture appeared between 20 and 1270 sec after onset of the stimulus. Hypalgesia was obtained from 20 to 1620 sec after the start of acupuncture in three examinations.

To determine factors influencing the time of initiation of sensory depression, in Fig. 2 the intensity of final current (I, mA) employed for producing hypesthesia (▲) was plotted against the duration (T, sec) of acupunctural stimulation, together with the result in hypalgesia (△). The stimulus duration referred to here was the period between the time of application of final current and the beginning of a decrease in the estimated level. The relationship between the quantity of electricity (i.e., the product I•T) and the stimulus duration (○) could be fitted by a linear regression line (solid line) which had a significant correlation coefficient (r=0.87, P<0.001). Correlation coefficients were lower when fitting data by sigmoid and power functions. A hyperbolic relationship therefore exists between I (mA) and T (sec):

\[ I = 0.11 + 18/T \]

It yielded a curve (dotted line) from which the utility time and rheobase were found to be 164 sec and 0.11 mA, respectively. Different durations of acupunctural stimulation have been reported to be necessary for producing hypalgesia, i.e., 1-30 min [8]. The present study suggests that this span might be due to differences in the intensity of current employed.

By adopting the methodology of signal detection theory, hypalgesia produced by acupuncture as well as by other procedures has been a target of analysis for an independent evaluation of the physiological and attitudinal components of pain [7, 13]. From the reports concerned [3, 4, 6, 8], it seems reasonable to consider that acupuncture can significantly reduce the subject's sensory sensitivity to pain while increasing the response bias against reporting the dental stimulation as painful [3, 4]. With the method used in the present experiment, however, it was not possible to distinguish between a suppression of sensation and an increased bias in subjective rating.

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