Cardiovascular Effect of Electro-acupuncture

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Summary: We have studied changes in both cardiac performance and the peripheral circulation in order to investigate cardiovascular influences due to electro-acupuncture stimulation (EAP) at the two meridian acupoints (Pericardium and Large Intestine) related to cardiovascular activities. 1) No significant changes were seen in blood pressure and heart rate after EAP at P 4-6. However, the impedance SV and CO were increased markedly with the same condition of EAP. 2) As for stroke volume and cardiac output, EAP had greater effects than dopamine 4 µg/kg/min and dobutamine 8 µg/kg/min and had almost the same effect as Haemaccel 2 ml/kg (0.25 µg/kg/min). 3) No significant changes were seen in blood gas tensions or electrolytes but plasma colloidal osmotic pressure tended to decrease. 4) After EAP at LI 4-10, radial artery was dilated; and the constrictive response of radial artery under the influence of autonomic nerves remained as normal. 5) Changes in cardiac performance, peripheral blood circulation and somatosensory evoked potentials (SEP) were maximal about 10 minutes after EAP was applied. 6) Concerning EAP effects on cardiac performance and peripheral blood circulation and SEP, EAP at P4-6 and LI 4-10 induced significant changes but EAP at non-acupoint had no significant effects.

Key words: electro-acupuncture — impedance — cardiography — non-invasive measurement — dopamine — dobutamine

Introduction

Although the physiological basis of the circulatory effects of acupuncture has not been clearly elucidated, the clinical effectiveness of acupuncture has been widely recognized for many years. Lee et al. (1976, 1981) showed an antidepressant effect in dogs of electro-acupuncture EAP at Jen Chung (GV-26) on cardiovascular function, which had been depressed by morphine under halothane and nitrous oxide anesthesia.

In order to investigate cardiovascular effects of EAP at Pericardium Meridian (P 4-6) and Large Intestine (LI 4-10) (Fig. 1), which have not been investigated quantitatively and hemodynamically, impedance cardiography and ultrasonic blood flow measurements were employed. These are non-invasive methods (Kubicek et al. 1970, 1974; Granerus and Elg, 1982; Milson et al. 1982; Tanaka et al. 1977) for measurement of changes in stroke vol-
Fig. 1. Acupoints

Methods

With an attempt to perform quantitative investigations of cardiovascular changes due to certain conditions of EAP, which was determined by the traditional method of search for acupoint with injection of the needle deep enough to produce a subjective feeling of numbness, heaviness, and swelling in deep tissues beneath the skin acupuncture point (the so-called Teh Chi sensation). The degree of the electrical stimulation was adjusted so as not to be stressful but, rather, pleasant for subjects with visible muscle twitches. EAP at P4-6 was maintained for 15 minutes at a frequency of 1.4 Hz. Various types of wave form of EAP are shown on Fig. 2 and we used the uppermost one.

Twenty-one, healthy male subjects, aged 23 to 57 years (average age 37.0 ± 11.5 years) and without a history of cardiovascular disease were investigated for sequential changes in blood pressure, mean blood pressure, heart rate, impedance stroke volume, cardiac output and total peripheral resistance by means of impedance cardiography (Nihon-Koden, AI-600G and ED-600G with frequency of 50 kHz, 250 Arms): blood flow, velocity pattern and diameter of radial artery were estimated with an ultrasonic velocimeter (Nihon-Koden) and a pulsed doppler velocimeter (Echovar F8G). The impedance stroke volume was calculated using

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\text{Impedance Stroke Volume} = \frac{\text{Impedance Cardiography Measurement}}{\text{Heart Rate}}
\]
Fig. 2. Wave forms of EAP

Kubicek’s formula (1974). \( SV = \rho \left( \frac{L}{Z_0} \right)^3 \left( \frac{dz}{dt} \right)_{\text{min}} T \). \( \rho = 66 \times \frac{3+1.9\text{Hct}}{3-1.9\text{Hct}} \), \( L \) = the mean distance between the two inner electrodes in cm. \( Z_0 \) = the mean thoracic impedance between electrodes in ohms. \( \frac{dz}{dt} \) \( \text{min} \) = the minimum value of \( \frac{dz}{dt} \) occurring during the cardiac cycle in ohms per second. \( T \) = the ventricular ejection time in seconds, which was obtained from the \( \frac{dz}{dt} \) waveform or from the heart sound, and measured from the initial baseline crossing of the \( \frac{dz}{dt} \) \( \text{min} \) to the beginning of the second heart sound. ] Arterial blood gas analysis, serum electrolytes, hematocrit and plasma colloidal pressure were determined after EAP for 15 min, intravenous administration of dopamine (2-4 \( \mu \)g/kg/min), dobutamine (8 \( \mu \)g/kg/min), nitroglycerine (0.5 \( \mu \)g/kg/min) and nitroprusside (0.5 \( \mu \)g/kg/min) for 3.5 min and volume-loading due to a plasma expander, Haemaccel (2 ml/kg) infused intravenously over a period of 8-10 min (Table 1). Statistical significance of results was determined using one-way analysis of variance among groups and Student’s t-test for paired or unpaired data when appropriate. \( P<0.05 \) was considered significant.

Results

Fig. 3 shows that EAP (P4-6) did not change blood pressure and heart rate significantly but induced a remarkable increase in impedance stroke volume and Heather Index. Administration of dopamine and Haemaccel induced the same trend in changed impedance cardiographic variables. Total peripheral resistance was significantly decreased.

In order to evaluate the cardiovascular change quantitatively and to confirm the increase of stroke volume and the decrease of peripheral resistance due to EAP at P4-6, a comparison was made with sequential changes of blood flow, velocity pattern and diameter of radial arterial blood vessel due to EAP at Large Intestine meridian 4-10 for 10 min or stellate ganglion block (SGB); this was achieved with the use of the ALVAR pulsed doppler velocimeter (Echovar F8G), which is not only a non-invasive approach but is a more direct and quantitative method than the bioimpedance technique. Fig. 4 shows that EAP at LI4-10 induced a remarkable increase in radial arterial blood flow, velocity and diameter of the vessel, in fact as great as that elicited by SGB.

Statistical studies indicated that P4-6 EAP produced a significant increase of
**TABLE 1**  
*Experimental Arrangements*

<table>
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<tr>
<th>$P \ 4\sim6 \ groups$</th>
<th>$LI \ 4\sim10 \ groups$</th>
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**Measurements:**  
1 Blood Pressure (BP)  
2 Heart Rate (HR)  
3 $Z_0$  
4 $\Delta Z_{max}$  
5 $(dz/dt)_{min}$  
6 R-Z interval  
7 Total Peripheral Resistance (TPR)  
8 Blood Gas, Acid-Base Balance, Electrolytes, Hematocrit, Colloidal Osmotic Pressure  
9 Stroke Volume (SV)  
10 Heather Index (HI)

**Procedures:**  
EAP and pharmacological approach, Haemaccel, Dopamine, Nitroglycerine, Dobutamine, Nitroprusside

**Instruments:**  
Impedance cardiography  
(Nihon Koden Al 600 G, ED 600G)

**Measurements:**  
1 Blood Flow (BF)  
2 Blood Flow Velocity (BFV)  
3 Vessel Diameter (VD)  
4 Plethysmograph

**Procedures:**  
1 Electric Acupuncture (EAP)  
2 Stellate Ganglion Block (SGB)

**Instruments:**  
1. Ultrasonic pulsed doppler velocimeter (ALVAR Echovar F8C)  
2. Ultrasonic velocimeter (Nihon Koden QFM 1100)  
3. Bio-physiograph (San Ei).

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**Fig. 3.** The Changes of impedance S.V. and C.O. due to EAP, Dopamine (i.d.) and Haemaccel. Each shaded area denotes blood pressure amplitude of radial artery.
impedance stroke volume without a significant change of blood pressure or heart rate, while peripheral resistance was moderately decreased (Fig. 5).

Changes in impedance stroke volume Heather Index and impedance cardiac output induced by EAP at P4-6, were compared with those resulting from the intravenous infusion of dopamine and Haemaccel. It was found that the increase in impedance stroke volume due to EAP for 15 min was greater than that due to the administration of dopamine (4 μg/kg/min for 5 min; Fig. 6). The degree of increase in impedance stroke volume due to EAP at P4-6 was not attained by a 3-min infusion of dopamine (2-4 μg/kg/min) but was similar to that attained by volume loading with Haemaccel (2 ml/kg for 10 min).

Fig. 7 shows that the equi-effective doses of dopamine, and dobutamine which did not induce a significant rise in blood pressure did not elicit a significant increase of impedance stroke volume and
Fig. 6. The changes of impedance Stroke Volume, Heather Index and cardiac output due to EAP, Dopamine (i.v.) and Haemaccel

Fig. 7. The Changes of S.V., H.I., C.O., and T.P.R. due to Dopamine (i.v.), Dobutamine (i.v.) and Haemaccel

Heather's Index.

Fig. 8 shows the result of a comparative study of changes in impedance stroke volume and Heather Index due to EAP (P4-6), dopamine, dobutamine, Haemaccel, and those resulting from vasodilators, such as nitroglycerine and nitroprusside in a 63 year-old male subject. We found that $\frac{\Delta Z_{\text{max}}}{\Delta}$ (the maximum amplitude of impedance change during systole ($\Omega$)) and $(\frac{dz}{dt})_{\text{min}}$ were significantly increased with an insignificant change of blood pressure after EAP for 10 min. Thirty minutes later, these increases were restored to the control level. The degree of the increase of impedance stroke volume due to EAP was of the same order as that due to a transfusion of Haemaccel 2 ml/kg for 8 min. Nitroglycerin (0.5 μg/kg/min) and nitroprusside (0.5 μg/kg/min) did not induce a significant increase of $\Delta Z_{\text{max}}$ and $(\frac{dz}{dt})_{\text{min}}$. Fig. 9 shows that EAP at P4-6 caused the appearance of double peaks on the $\frac{dz}{dt}$ tracing, and at the
Fig. 8. Changes of impedance cardiographic variables due to EAP, Dopamine, Dobutamine, Haemaccel and Nitroglycerine, Nitroprusside

As shown in Fig. 10, during the procedure of EAP, plasma concentration of noradrenaline (NA) and adrenaline (A) were not significantly changed and colloidal osmotic pressure of plasma showed a tendency to decrease. With the experi-
mental data that EAP produced a cardiovascular effect equivalent to the volume loading due to an infusion of 2 ml/kg plasma expander for 10 min, it could be speculated that peripheral vessels with capillary beds dilate and extracellular fluid translocated into the capillary beds and a slight degree of hypervolemia is induced by EAP.

Moreover, it is interesting that "placebo EAP" adjacent to LI4–10 and P4–6 did not elicit significant changes in impedance cardiographic variables.

**Discussion**

Impedance cardiograph has already progressed to being a powerful clinical and research tool (Kubicek et al. 1970; 1974; Granerus and Elg, 1982). It is a safe, non-invasive, convenient method which provides new and valuable information relating to the more intimate mechanisms of cardiac pumping (Milson et al. 1982; Tanaka et al. 1977).

Acupuncture analgesia (Mao et al. 1980) has been widely used in pain clinics, and has been proved effective for certain types of chronic pain. Neurophysiological and neurohumoral mechanisms which may be involved in acupuncture analgesia have been extensively investigated (Pomeranz and Chiu, 1976; Han and Terenius, 1982; Carstens et al. 1979; Shen et al. 1975).

An afferent pathway to the post lateral part or periaqueductal central gray area (PGA) from dorsal root and an efferent pathway from PGA to pain-inhibitory pathway distal to the dorsolateral funiculus of the spinal cord (DLF) have been investigated as related to acupuncture analgesia (Takeshige, 1982). The neurohumoral interactions (Obayashi et al. 1980; Fujita et al. 1978) between various neurotransmitters such as neuropeptides, endorphins, catecholamines such as noradrenaline and dopamine, and the hypothalamic hormones, such as ADH, have been considered in relation to central effects (Kumazawa, 1978; Hosoya, 1982; Jisheng et al. 1979) of acupuncture analgesia, which have been separated from those due to non-acupuncture point stimulation, namely placebo acupuncture or stress analgesia (Millan et al. 1980; Takeshige, 1982; Anderson et al. 1974; Stewart et al. 1976).

With these observation, the neurohumoral mechanism related to EAP may be considered to involve a circulatory effect in some way (Omura, 1976). Cardiovascular interactions related to EAP have not, however, been clearly investigated.

Acupuncture at P4–6 has been long and effectively used, primarily in treating (Shanghai Chinese Medical College, 1977) various conditions of cardiovascular illness. However, measurement of minute-to-minute and beat-to-beat changes in cardiovascular parameters due to EAP would be fraught with difficulties particularly a quantitative evaluation in a clinical study.

Modalities of central analgesic effect due to EAP have been long recognized and been recently much investigated from a neurophysiological stand point. Much of the work on EAP was concerned with analgesic mechanisms associated with presynaptic inhibition of transmission in as-
cending pain pathways. EAP, which would activate acupuncture afferent pathways, may involve interactions of neurophysiological and/or neurohumoral mechanisms, which induce cardiovascular effects. Under those conditions of EAP in which blood pressure and heart rate were not changed, impedance stroke volume was increased significantly to the same extent as that following administration of Haemaccel (2 ml/kg). It may be considered that a hypervolemic-like status resulted, and furthermore, this hypervolemic-like effect attained the maximum level about 5-15 min after EAP was applied, and the maximum effect fell at the same time as peak latency of SEP (Tayama et al. 1981) was maximally delayed after the application of EAP. It should be further investigated that these cardiovascular changes due to EAP at P4-6, L14-10 would be induced by the neurohumoral mechanism which involves the delay in peak latency of SEP.

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