Scand J Rehab Med 29: 243–250, 1997

EFFECTS OF REPEATED SENSORY STIMULATION SESSIONS (ELECTRO-ACUPUNCTURE) ON SKIN TEMPERATURE IN CHRONIC PAIN PATIENTS

Lars-Erik Dyrehag MD,[1] Eva G. Widerström-Noga DDS, PhD,[1,*] Sven G. Carlsson PhD [2] and Sven A. Andersson MD, PhD[1]

*From the [1]Department of Physiology and Pharmacology, and the [2]Department of Psychology, Göteborg University, Sweden. *Present affiliation: The Miami Project to Cure Paralysis, University of Miami School of Medicine, Miami, Florida*

ABSTRACT. Changes in skin temperature and haemodynamics were studied during experimentally administered electro-acupuncture before and after a 4-week period of electro-acupuncture (EA) treatments. Subjective pain intensity was evaluated using a pain questionnaire. Twelve patients with long-lasting nociceptive pain were included. Before clinical treatment, skin temperature tended to decrease after 30 minutes' stimulation. In contrast, a significant increase was seen after the clinical treatment. No significant changes were seen for blood pressure, heart rate or pain intensity before and after the clinical treatment. The data indicate that an increased skin vasoconstrictor sympathetic activity may be responsible for the decreased skin temperature during the electro-acupuncture in the initial test sessions, whereas an inhibition of skin sympathetic activity and/or a release of vasodilatatory substances may be responsible for the increase in temperature after completed clinical treatment. Despite a small number of subjects and correction for multiple inference, the difference in temperature effects before and up to 3 months after acupuncture treatment was significant.

Key words: electro-acupuncture, sensory stimulation, skin temperature, chronic pain, haemodynamics, human.

INTRODUCTION

Techniques that are stimulating sensory afferents such as acupuncture are nowadays frequently requested by patients. The method is primarily used for pain relief. The clinical effects are promising and the incidence of side effects is low. Even though the knowledge about the physiological mechanisms involved in acupuncture analgesia has increased during recent decades (5), there are still many questions to be answered. It is important to improve the understanding of the effects of sensory stimulation on the autonomic nervous system since there are clinical pain conditions that are affected by disturbed sympathetic activity (6). Studies have shown positive results in the treatment of causalgia and reflex sympathetic dystrophy using sensory stimulation techniques (22). For some time now, skin temperature change has been used as an indirect indicator of autonomic activity after different types of sensory stimulation (acupuncture, transcutaneous nerve stimulation (TENS)) (1, 10, 24). However, research has shown contradictory results. Wong & Jette (28) evaluated different modes of TENS in 12 healthy subjects and reported a skin temperature decrease in the fingertips both ipsi- and contra laterally to the stimulated upper extremity. The mean skin temperature changes ranged from 1.4 to 3.5°C below baseline at the termination of the stimulation, regardless of the TENS mode used. The changes in temperature increased toward baseline within 25 minutes after cessation of stimulation. Ernst & Lee (10) investigated sympathetic effects in 19 healthy subjects by measuring skin temperature in different sessions where manual needle stimulation or electro-acupuncture was administered for 15 minutes. Both modes of stimulation produced a generalized warming effect lasting for at least 15 minutes after cessation of stimulation. In addition, electro-acupuncture initially induced a local short-term cooling effect during the stimulation period.

Kaada (17) reported large increases in skin temperature in patients with Raynaud's disease and diabetic polyneuropathy. After 30–45 minutes of low-frequency TENS at remote sites, the skin temperature increased 7–10°C for 4–8 hours or more in their cold limbs. In body parts with normal temperature only a slight increase (0.5–2°C) was observed. It was suggested that homeostatic regulatory mechanisms counteracted any further temperature rise. The rise in skin temperature was also associated with relief of ischaemic pain. Following repeated stimulation in an ischaemic region, healing of long-standing ulcers (9, 18, 21) as well as improved healing after surgery (20) has been reported.

The referred studies show at least partly divergent results. To our knowledge skin temperature changes during and after repeated sessions of sensory stimulation have not been investigated previously. The aim of this study was to determine whether a series of acupuncture treatments influences autonomic activity measured as skin temperature, blood pressure and heart rate and to investigate how these changes relate to clinical pain relief.

MATERIAL AND METHODS

Subjects

The study was performed on 12 randomly selected patients with an average age of 43 ± 3 years (range: 28–59 years). The average duration of pain was 62 ± 13 months (range: 10–132 months).

The patients were recruited from the Multidisciplinary Pain Centre, Östra Hospital in Göteborg. All subjects gave informed consent to procedures approved by the Ethical Committee of the Faculty of Medicine at Göteborg University.

Inclusion criteria. Men or women aged up to 65 years with nociceptive musculoskeletal pain predominantly localized in the brachio-cervical region and with a minimum duration of 6 months.

Exclusion criteria. (1) Pain of neurogenic origin; (2) widespread, diffuse pain; (3) abuse of alcohol or other drugs.

Experimental design

Each patient was randomized to either early treatment with electro-acupuncture (EA) (group A, 3 males and 3 females) or to a waiting list for receiving EA 4 months later (group B, 6 females). In group A, one test session was performed before treatment and in group B three test sessions were conducted before treatment to control for reproducibility. The second test session was performed 4 weeks after the treatment/waiting-list period, and the third at follow-up 3 months after the treatment/waiting-list period, week 16. After these assessments group B received treatment with EA, followed by the last test session in week 20 (group B only).

Test sessions

The patients were instructed to avoid physical exercise one hour prior to the test sessions. Each test session lasted for 80 minutes during which the patient was seated comfortably in a chair with head, arm and leg support. Room temperature was 24 ± 1°C. Skin temperature, blood pressure and heart rate were measured before, during and after EA stimulation, as shown in Fig. 1. The subjects were given a 20-minute rest period at the start of the test session in order to acclimatize themselves to the experimental situation and stabilize blood pressure, heart rate and skin temperature. Thirty minutes of sensory stimulation (EA) followed and the session ended after another rest period.

EA in test sessions

Eight sterile stainless steel acupuncture needles (Acupur, 0.25 mm diam, 25 mm long) were used in each session. After insertion to a depth of 10–20 mm, depending on the location, the needles were twirled to evoke "the needle sensation", often described as tension, numbness, tingling, tenderness and sometimes radiating paraesthesia from the point of insertion. The needle sensation was strived for since it is reported to relate positively to pain relief following acupuncture (11). Acupuncture points in muscles of the face and arms were selected. The acupuncture points used (abbreviations below refer to the nomenclature recommended by WHO) are indicated in Fig. 2: 1. Over the prominence of the contracted m. masseter anterior and superior to the angle of the lower jaw, (ST 6); 2. in the m. masseter, below the zygomatic arch, in the depression anterior to the condyloid process of the mandible (ST 7); 3. in the m. extensor carpi radialis longus and m. brachialis between the end of the cubital transverse crease and the lateral epicondyle of the humerus, when the elbow is half-flexed (LI 11); 4. in the m. extensor carpi radialis longus, 40–50 mm distal to the previously described location of stimulation (LI 10).

The needles were placed bilaterally and the same locations were used in all subjects. When "the needle sensation" was achieved, the needles were attached to an electrical stimulator (WQ-6F: Wilkris & Co. AB, Stockholm, Sweden) producing trains (3.5 seconds' duration) of single pulses (0.5 ms) at an alternating frequency of 2 Hz and 15 Hz for 30 minutes (8, 12). ST 6 and ST 7 were connected to one output of the stimulator

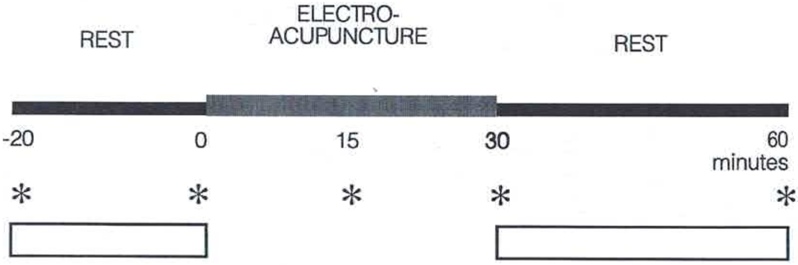

Fig. 1. Time schedule for the test sessions: after 20 minutes' rest the patients received sensory stimulation (electro-acupuncture) for 30 minutes. Skin temperature (*) was measured 5 times during the session. Blood pressure and heart rate were measured continuously (open bars) during the session except for during the stimulation period.

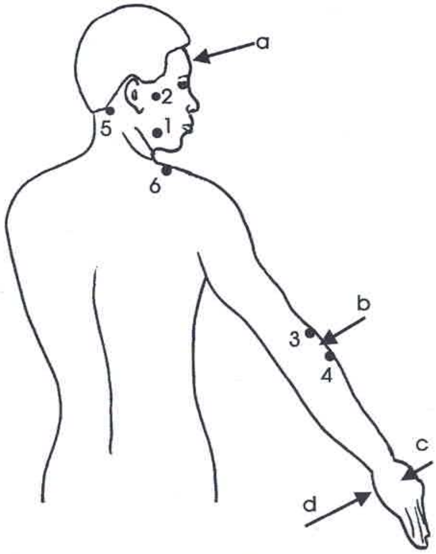

Fig. 2. The stimulation sites (filled dots) for the electro-acupuncture (EA) were stimulated bilaterally. In the test sessions 1, 2, 3 and 4 were stimulated, whereas 3, 4, 5 and 6 were used in the clinical EA treatment. The locations where skin temperature was measured during the test sessions are indicated with arrows (a–d).

and LI 10 and LI 11 to another. The electrical stimulation gave strong, but not painful contractions of the muscles in regions of insertion. The current was usually increased during the stimulation period in order to prevent adaptation and maintain the strength of muscle contractions.

EA treatment

The clinical treatment consisted of 8 electro-acupuncture treatments (EA), given twice a week at regular intervals during 4 consecutive weeks. After the first test session, group A received EA, whereas group B was placed on a waiting list and received EA after the third test session. The same stimulation technique was used in the clinical treatment and the experimental situation. However, the choice of stimulation sites differed somewhat between the clinical and the experimental situation. Instead of stimulating the m. masseter (ST 6, ST 7) two points in the neck–shoulder region were used bilaterally (Fig. 2): 5. in the m. splenius capitis and m. semispinalis capitis in the depression between the m. trapezius and m. sterno-cleido-mastoideus just below os occipitale, (GB 20); 6. in the m. trapezius at the midpoint between vertebrae C7 and acromion at the highest point of the shoulder (GB 21). GB 20 and GB 21 were connected to one output of the stimulator and LI 10 and LI 11 to another. In addition to the electrical stimulation sites, 2–4 other points were manually stimulated. Their locations were determined by each patient's clinical pain distribution. These needles were twirled every tenth minute to evoke "the needle sensation". The treatment was carried out by two skilled physiotherapists with long experience in acupuncture. All patients received 4 treatments by each physiotherapist.

Skin temperature measurement

During each test session skin temperature was measured with a digital infrared thermometer, Microscanner™ D-series (Exergen Corporation, USA) five times, at –20, 0, 15, 30 and 60 minutes in relation to the start of EA. The accuracy for this self-calibrated equipment is ± 0.3°C and the reliability is ± 0.1°C. The recording sites are shown in Fig. 2: (a) on the forehead, (b) distal to the lateral epicondyle of the upper arm, (c) on the dorsal surface of the hand, centred over the midpoint of the third metacarpal bone, and (d) on the volar surface of the hand, centred over the midpoint of the third metacarpal bone. The forehead measure was taken in the midline, all the others on the right side. The distance from the tip of the thermometer to the skin surface was always 40 mm. The field-of-view was approximately 60°.

Haemodynamics

Systolic and diastolic blood pressure and heart rate were measured using an automatic non-invasive oscillometric blood pressure monitor (Dinamap® Model 845, Critkon Instruments, USA). A blood pressure cuff was attached to the patient's left arm and recordings of blood pressure and heart rate were made intermittently, every third minute, before and after the sensory stimulation. The average duration of each sampling period was approximately 15 seconds. The Dinamap blood pressure measurements have been shown to correlate closely with intra-arterial recordings; the correlation coefficients for systolic and diastolic blood pressure have been estimated to be $r = 0.92$ and $r = 0.90$, respectively (23).

Pain assessment

The Multidimensional Pain Inventory (MPI) (19) was administered before each test session. The Pain Severity subscale was used to evaluate changes in perceived pain. The subscale is an average of the patient's ratings of present level of pain, severity of pain during the last week and suffering due to the pain. The three items have a 0 to 6 format, with 6 representing the highest level of pain or suffering. The test–retest reliability for Pain Severity has been estimated to 0.82 (19).

Statistics

Values are expressed as means (SEM) unless otherwise stated. The statistical analyses were conducted using the Wilcoxon signed-ranks test for paired samples and the Mann-Whitney U-test for independent group comparisons (4). All tests were two-tailed. Statistical significance was considered when $p < 0.05$. The Holm modification of the Bonferroni correction was used to control for multiple inferences (14).

RESULTS

Skin temperature

No significant changes in skin temperature were observed for any of the two groups during the prestimulation periods ((–20)–0 min). The value at zero time (0 min) was referred to as baseline temperature. The absolute values of baseline skin temperature were in the range of 27–36°C if all measured sites are considered. The highest mean skin temperature was measured on the forehead, the lowest on the dorsal surface of the hand. In Fig. 3, the deviations from baseline of the skin

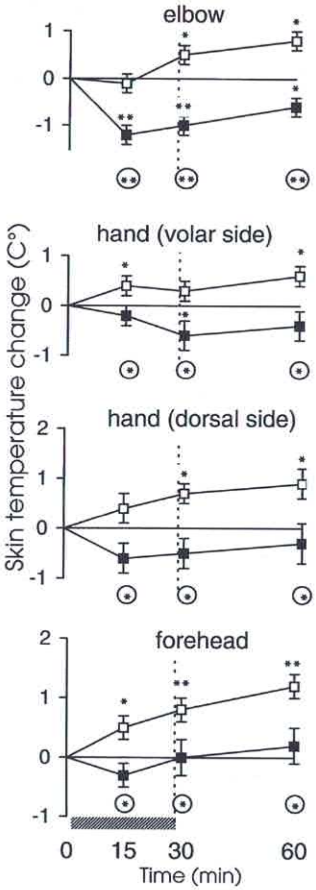

Fig. 3. Skin temperature changes measured in four different locations during the test session when 30 minutes of EA was administered (filled bar). The filled squares represent measurements performed before EA treatment, whereas the open squares represent measurements after EA treatment. The mean value and SEM are indicated in each point. Asterisks indicate significance levels for comparisons with baseline, *$p<0.05$, **$p<0.01$, *** $p<0.001$. Circled asterisks show significance levels between sessions, post-hoc corrected for multiple inferences.

temperature are shown during 30 minutes of electro-acupuncture (EA) and 30 minutes post-stimulation.

Group A participated in one test session and group B in three test sessions before the EA treatment started. In all test sessions prior to the EA treatment the skin temperature changes at each location were similar in both groups.

Figure 3 shows the results of the first test session and the first post treatment session for both groups A and B. The mean deviation from baseline of the skin temperature was less than ± 2°C and the range for all individuals was −2.5 to +2.4°C.

The response patterns were fairly uniform when individual subjects were compared. Figure 4 shows individual records for the elbow measurement; similar pictures were seen for the other recording sites. During the three test sessions before the EA treatment the skin temperature showed various degrees of decrease in both group A and group B, contrasted by increased temperature following the EA treatment.

Skin temperature changes during EA test sessions

Before treatment. Before the patients had received the series of acupuncture treatments the skin temperature tended to decrease at all recorded sites except on the forehead. At the elbow, it had decreased significantly after 15 minutes of acupuncture ($p<0.01$) and remained significantly ($p<0.05$) below baseline at the end of the test session. In absolute values the temperature change was −1.0°C at completion of stimulation (10 out of 12 patients showed decrease, 1 patient increased skin temperature, 1 patient showed no change). On the volar side of the hand the temperature was also significantly decreased ($p<0.05$) at the termination of stimulation.

After treatment. Following the series of EA treatments the skin temperature increased significantly at all recording sites in both group A and group B. The group mean temperature increased gradually during the EA and continued to increase during the following 30 minutes. At the elbow, the temperature increase was slightly delayed but was significant ($p<0.05$) at the end of the stimulation period. On the forehead the skin temperature increase was most marked. During and after the stimulation, t15 and t30, skin temperature increased significantly, ($p<0.01$) and at the termination of the session t60 the average increase was +1.1°C ($p<0.01$). All 12 patients increased their forehead skin temperature compared to baseline. For all recording sites, differences between temperature changes before and after treatment were significant ($p<0.05$) even when corrected for multiple inferences (Fig. 3).

Follow-up session. Group A was examined 3 months after completion of the acupuncture treatment series. The temperature change was similar to that observed in the previous session after the treatment (Fig. 4). During the session the temperature increased gradually and at the last assessment the group mean temperature was more than 1°C above baseline at all locations. On the forehead the increase was most marked, +1.8°C at the end of the session. All 6 patients showed augmented

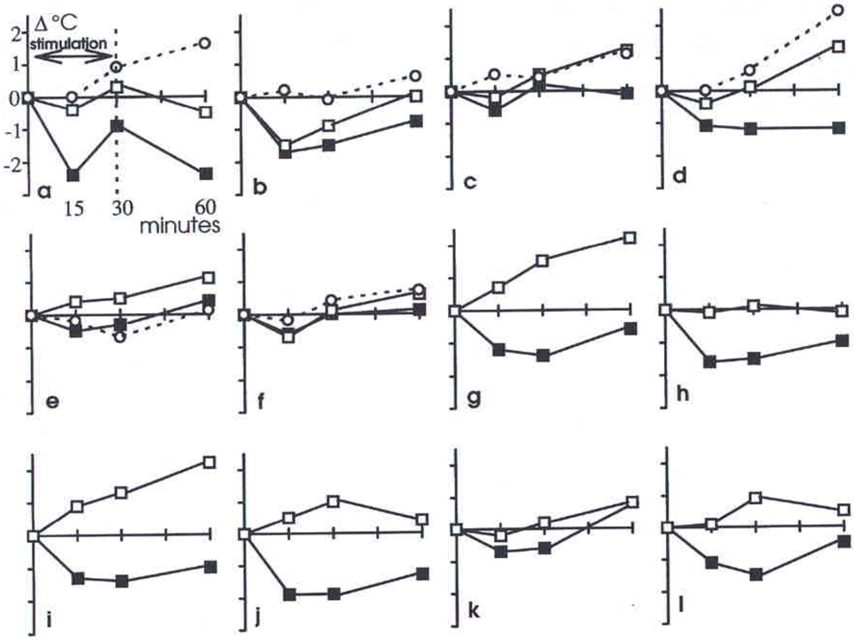

Fig. 4. All 12 patients' individual skin temperature responses (recorded at the elbow) to EA before (filled squares) and after (open squares) clinical EA treatment. Group A: (a–f), group B (g–l). The dashed line (open circles) shows skin temperature change 3 months after EA treatment in group A.

values. The temperature increase was significant at the $p<0.05$ level at all locations at the end of the session.

Haemodynamics

The baseline values for the haemodynamic variables were established as the median of the repeated assessments during 10 minutes immediately prior to stimulation. The registrations from the first and last 10 minutes after the end of sensory stimulation formed the post-stimulation values (t30–40) and (t50–60). The results of the haemodynamic measurements are shown in Table I, where the mean values for the whole group are presented. The blood pressure did not change significantly during the test sessions before or after the EA treatment. The heart rate decreased significantly in all test sessions following the acupuncture stimulation. In both groups the decrease was similar before and after the EA treatments and also in the follow-up session in group A.

Pain assessment

Pain ratings with the Pain Severity subscale of the MPI were assessed the week before and the week after the series of acupuncture treatments. The subscale decreased from 3.6 ± 0.4 (mean ±SEM) the week before treatment to 3.1 ± 0.3 the week after the EA treatment. Six patients reported a decrease in pain, 5 patients an increase and 1

Table I. *Mean values (± SD) on cardiovascular variables in an experimental session where 30 minutes' electro-acupuncture was administered (n = 12)*

	Session	Baseline	t30-40	t50-60
SBP	Before treatment	129 ± 18	129 ± 20	130 ± 22
(mm Hg)	After treatment	123 ± 16	125 ± 17	123 ± 17
DBP	Before treatment	78 ± 12	77 ± 11	77 ± 14
(mm Hg)	After treatment	78 ± 10	76 ± 10	77 ± 10
HR	Before treatment	77 ± 14	72 ± 10*	71 ± 11*
(beats/min)	After treatment	73 ± 11	69 ± 9*	69 ± 8*

Significance levels are given for pair-wise test compared to baseline. * $p < 0.05$.

patient reported no change in pain after the treatment. The reported decrease in pain did not reach statistical significance, however. No correlation was found between the degree of pain relief and skin temperature change in any of the test sessions.

DISCUSSION

The main finding of the present study was that the skin temperature response induced by electro-acupuncture was significantly different before compared with after a series of clinical acupuncture treatments. In pretreatment sessions acupuncture induced a significant decrease in skin temperature segmental to the stimulation site (elbow and volar hand), whereas after treatment a generalized and significant increase in the skin temperature occurred. This response was similar at the follow-up session 3 months later in group A.

The absolute changes in skin temperature were less than ± 2°C compared with baseline. Kaada (17) reported changes of the same magnitude in body parts with normal skin temperature.

An increase in skin temperature after sensory stimulation has been reported previously (10, 25). In a prospective study of 20 patients with neck and arm pain, Thomas et al. (25) reported a positive correlation between the mean finger skin temperature increase and pain relief as judged by the visual analogue scale (VAS). A significant difference between pre- and post-stimulation skin temperature (+0.55°C ± 0.86 (SD)) was seen in the 10 patients who showed a significant reduction in pain severity. In the 10 patients without pain relief on VAS, the pre- to post stimulation temperature change was non-significant.

The present study shows that the temperature may decrease, be unchanged or increase in response to acupuncture depending on the site and time of temperature recording in relation to a series of acupuncture treatments (Fig. 3). These differences make it difficult to correlate temperature with pain relief and limit the predictive therapeutic value of a temperature increase, suggested by Thomas et al. (25). The situation may be different in ischaemic pain with decreased microcirculation (17).

Cao et al. (7) measured changes in skin temperature and assessed changes in blood flow by the finger plethysmographic technique to investigate correlations between the analgesic effect of acupuncture and changes in skin temperature and blood flow. A high correlation between increased temperature in the palm, blood flow and analgesia was found. In spontaneously hypertensive rats (SHR), low frequency (2 Hz) electrical stimulation of hindlimb nerves elicited an increased sympathetic activity during the stimulation. This was succeeded by a long-lasting (more than 12 hours) significant reduction in blood pressure accompanied by a reduced nervous activity in branches of the splanchnic nerve. In comparison, similar stimulation of normotensive rats only gave a small short-lasting reduction in blood pressure (13, 29). The depressive effect was reduced by a large intravenous injection of naloxone, suggesting involvement of opioids (29). Thorén et al. (26) suggested that the depressed sympathetic activity induced by low frequency electrical stimulation or physical exercise may be related to release of beta-endorphin eliciting a postexcitatory depression on the vasomotor system. No changes in blood pressure were observed in the present study, which was consistent with what has been seen in another study examining healthy subjects' haemodynamic reactions to electro-acupuncture (27). Patients with essential hypertension have shown reductions in blood pressure when treated with acupuncture but in normotensive patients the decrease is small (5–10 mm Hg) (5).

The wide range of the temperature changes observed in the present study suggests that several mechanisms have to be considered. Following the clinical acupuncture treatment the group average temperature increased gradually at all recording sites during and after an acupuncture session. This indicates a central effect, which may be related to an increase in opioid activity (26). Changed sympathetic tone to superficial blood vessels plays an important role in thermoregulation and an inhibition of vasoconstrictor impulses or an active vasodilator mechanism also could explain the widely distributed increase in temperature observed. Local electrical stimulation has been shown to increase the blood flow in ischaemic skin flaps in rats (15) and to facilitate wound healing in reconstructive surgery (20). The suggested mechanism is antidromic activation of sensory fibres with local release of vasodilator neurotransmitter, such as vasoactive intestinal polypeptide (VIP), substance P (SP) and calcitonin gene-related peptide (CGRP) (16). Local release of vasodilator substances may explain the increase in skin temperature in the vicinity of the stimulating electrodes but can hardly contribute significantly to a generalized vasodilatation and increased temperature.

Changes in skin temperature are also closely linked to a person's emotional state. Emotional stress usually leads to cutaneous vasoconstriction (2) but vasodilatation has also been reported (3). It is likely that a patient exposed to a novel treatment method to some extent will be subject to anxiety, stress or fear. Furthermore, it seems possible that changes in parameters, such as different surroundings or a new therapist, may negatively influence the pain-relieving effect (27) and most likely also the sympathetic activity.

The results of the present study suggest that afferent input in somatic nerve fibres has a significant effect on skin temperature. The decrease in temperature as a result of the stimulation was most pronounced close to the stimulation sites, indicating a segmental increase in skin sympathetic vasoconstrictor activity, but after a series of EA treatments a significant increase in temperature was observed both near the stimulation sites and at more distant locals which favour a central effect. Taken together, these observations suggest that both local and more general effects on the autonomic function are involved. In order to achieve a temperature increase by the release of opioids and vasodilatory neuropeptides, it may be necessary to administer a number of stimulation sessions before a significant increase in skin temperature occurs.

ACKNOWLEDGMENTS

This study was funded by the Swedish Medical Research Council (Project 55), the Göteborg Medical Society and the Foundation for Acupuncture and Alternative Treatment Methods. The authors also express their thanks to Stina Morelius for excellent technical assistance, to Elisabeth Svensson, PhD, for statistical assistance, and to Bodil Mannheimer and Ulrika Kruse-Molander (both physiotherapists) for skilful administration of the clinical treatment.

REFERENCES

1. Abram, S. E., Asiddao, C. B. & Reynolds, A. C.: Increased skin temperature during transcutaneous electrical stimulation. Anesth Analg *59:* 22–25, 1980.
2. Abramson, D. I. & Ferris, E. B.: Responses of blood vessels in the resting hand and forearm to various stimuli. Am Heart J *19:* 541–553, 1940.
3. Allwood, M. J., Barcroft, H., Hayes, J. P. L. A. & Hirsjärvi, E. A.: The effect of mental arithmetic on the blood flow through normal, sympathectomized and hyperhidrotic hands. J Physiol (Lond) *148:* 108–116, 1959.
4. Altman, D. J.: Practical statistics for medical research. 1st ed. Chapman & Hall, London, 1991.
5. Andersson, S.: The functional background in acupuncture effects. Scand J Rehabil Med Suppl *29:* 31–60, 1993.
6. Blumberg, H. & Jänig, W.: Clinical manifestations of reflex sympathetic dystrophy and sympathetically maintained pain. *In* Textbook of Pain (eds. P. D. Wall & R. Melzack), pp. 685–698. Churchill Livingstone, Edinburgh, 1994.
7. Cao, X.-D., Xu, S.-F. & Lu, W.-X.: Inhibition of sympathetic nervous system by acupuncture. Acupuncture Electro-Ther Res Int J *8:* 25–35, 1983.
8. Chen, X-H., Guo, S-F., Chang, C-G. & Han, J-S.: Optimal conditions for eliciting maximal electroacupuncture analgesia with dense- and -disperse mode stimulation. American Journal of Acupuncture *22:* 47–53, 1994.
9. Eriksson, A. & Skoglund, C.R.: Smärtlindring och förbättrad sårläkning genom TNS vid perifiera cirkulationsrubbningar. (Effects of TNS on pain, skin circulation and wound healing in cases of peripheral vascular diseases.) Läkartidningen *85:* 1237–1241, 1988. (In Swedish)
10. Ernst, M. & Lee, M. H. M.: Sympathetic vasomotor changes induced by manual and electrical acupuncture of the Hoku point visualized by thermography. Pain *21:* 25–33, 1985.
11. Haker, E. & Lundeberg, T.: Acupuncture treatment in epicondylalgia: A comparative study of two acupuncture techniques. Clin J Pain *6:* 221–226, 1990.
12. Han, J. S. & Terenius, L.: Neurochemical basis of acupuncture analgesia. Annu Rev Pharmacol Toxicol *22:* 193–220, 1982.
13. Hoffmann, P. & Thorén, P.: Long-lasting cardiovascular depression induced by acupuncture-like stimulation of the sciatic nerve in unanaesthetized rats. Effects of arousal and type of hypertension. Acta Physiol Scand *127:* 119–126, 1986.
14. Holm, S.: A simple sequentially rejective multiple test procedure. Scand J Statist *6:* 65–70, 1979.
15. Jansen, G., Lundeberg, T., Samuelson, U. E. & Thomas, M.: Increased survival of ischaemic musculocutaneous flaps in rats after acupuncture. Acta Physiol Scand *135:* 555–558, 1989.
16. Jansen, G., Lundeberg, T., Kjartansson, J. & Samuelson, U. E.: Acupuncture and sensory neuropeptides increase cutaneous blood flow in rats. Neurosci Lett *97:* 305–309, 1989.
17. Kaada B.: Vasodilation induced by transcutaneous nerve stimulation in peripheral ischemia (Raynaud's phenomenon and diabetic polyneuropathy). Eur Heart J *3:* 303–314, 1982.
18. Kaada B.: Behandlung chronischer ulzera und peripherer ischämie mit transkutaner nervenstimulation (TNS). *In* Handbuch der akupunktur und aurikulotherapie. (ed. J. Bischko), pp. 16–35. Haug Verlag, Heidelberg, 1985.
19. Kerns, R. D., Turk, D. C. & Rudy, T. E.: The West Haven–Yale Multidimensional Pain Inventory (WHYMPI). Pain *23:* 345–356, 1985.
20. Kjartansson, J. & Lundeberg, T.: Effects of electrical nerve stimulation (ENS) in ischemic tissue. Scand J Plast Reconstr Surg *24:* 129–134, 1990.
21. Lundeberg, T. C. M, Eriksson, S. V. & Malm, M.: Electrical nerve stimulation improves healing of diabetic ulcers. Ann Plast Surg *29:* 328–331, 1992.
22. Meyer, G. A. & Fields, H. L.: Causalgia treated by selective large fibre stimulation of peripheral nerve. Brain *95:* 163–168, 1972.
23. Milsom, I., Svahn, S.-Ö., Forssman, L. & Sivertsson, R.: An evaluation of automated indirect blood pressure measurement during pregnancy. Acta Obstet Gynecol Scand *65:* 721–725, 1986.
24. Suter, B. & Kistler, A.: Beeinflusst akupunktur die hautdurchblutung uber das autonome nervensystem? Schweiz Med Wochenschr Suppl. *62:* 36–38, 1994.
25. Thomas, D., Collins, S. & Strauss, S.: Somatic sympathetic vasomotor changes documented by medical thermographic imaging during acupuncture analgesia. Clin Rheumatol *11:* 55–59, 1992.
26. Thorén, P., Floras, J. S., Hoffmann, P. & Seals, D. R.: Endorphins and exercise: physiological mechanisms and

clinical implications. Med Sci Sports Exerc *22:* 417–428, 1990.
27. Widerström-Noga, E.: Analgesic effects of somatic afferent stimulation – a psychobiological perspective. PhD thesis, University of Göteborg, Sweden, 1993.
28. Wong, R. A. & Jette, D. U.: Changes in sympathetic tone associated with different forms of transcutaneous electrical nerve stimulation in healthy subjects. Phys Ther *64:* 478–482, 1984.
29. Yao, T., Andersson, S. & Thorén, P.: Long-lasting cardiovascular depressor response following sciatic stimulation in spontaneously hypertensive rats. Evidence for the involvement of central endorphin and serotonin systems. Brain Res *244:* 295–303, 1982.

Accepted February 14, 1997

Address for offprints:
Lars-Erik Dyrehag
Göteborg University
Department of Physiology and Pharmacology
Medicinaregatan 11
SE-413 90 Göteborg
Sweden