Clinical and Research Observations on Acupuncture Analgesia and Thermography

Mathew H. M. Lee[1] and Monique Ernst[2]

[1] New York University, Goldwater Memorial Hospital, Franklin D. Roosevelt Island, New York, N.Y. 10044, USA
[2] Chronic Pain Unit, Goldwater Memorial Hospital, New York University Medical Center, and Department of Psychiatry, Beth Israel Medical Center, New York, N.Y. 10044, USA

Introduction

The concept of acupuncture become popular among the American medical community and lay public as a potential therapeutic tool following the American rapprochement with the People's Republic of China in 1972. They found this idea both exciting and vaguely unsettling to their accustomed ways of thinking.

I (Lee) was privileged to be selected to accompany a group of Chinese-American medical scholars to visit the People's Republic of China upon the invitation of Chairman Mao. During the 7-week visit in 1973, various surgical, dental, and medical acupuncture procedures were observed. I visited various researchers, especially Dr. Chang Hsiang-Tung at the Shanghai Scientific Institute of Physiology.

In 1973, New York State established a Commission on Acupuncture to promote scientific inquiry and appropriate training of practitioners, and to protect the public from harm and exploitation. Having been named to this Commission commenced my initial reluctant journey into an exciting area of pursuit.

It became obvious that the patient with chronic pain that could be safely helped with acupuncture was in no mood to wait for research results. The resolution of this paradox was self-evident: We needed to make clinical observations first and then return to the laboratories. The challenge presented by such a research effort was heightened by the possibilities for uncovering basic neurological, biophysical, and biochemical knowledge about the functioning of the human body that heretofore had remained unknown. In addition, the prospect of adding acupuncture to the armamentarium of pain therapy and dental analgesia appeared to be an exciting challenge.

Our initial work involved the observation of acupuncture analgesia in dentistry followed by the development of a precision tooth pulp stimulation technique for assessment of the pain threshold. Subsequently, an acupuncture dental pain research model was born. We then became involved in testing aspirin and other medication to see how they altered these thresholds, as compared with acupuncture. Naloxone was also given. Our focus, in terms of acupuncture stimulation points, was directed at the first dorsal interosseous muscle (LI.4 Hegu) and the tibialis anterior muscle (St.36 Zusanli). More recently, we have enlisted thermography to evaluate the sympathetic effects of acupuncture. This chapter will summarize our findings.

Clinical Dental Analgesia

Based on observations in the People's Republic of China, we decided to attempt first to investigate the use of acupuncture clinically for inducing analgesia in routine dental procedures. The major purposes of this investigation were to attempt to replicate findings reported in the Chinese literature and to assess the feasibility of acupuncture analgesia as an alternative method for achieving anesthesia in treating dental problems.

Methodology

Twenty subjects, ten males and ten females, volunteered for participation in this study [37 a]. All subjects were between 18 and 30 years of age, in good health, and were in need of routine dental treatment. All subjects had a history of previous dental care with local anesthetic.

Prior to undergoing any treatment, all subjects were interviewed to determine their attitudes toward dental treatment and to obtain some background on their knowledge and impressions of acupuncture. Immediately after this brief interview, the subjects were brought to a dental treatment area where they were seated in the dental chair and the acupuncture procedure initiated. Sterilized standard steel 27-gauge needles were used for the acupuncture procedure. Prior to insertion of the needles, the selected areas on the skin were swabbed with alcohol sponges. Analgesia was attempted by the induction of acupuncture needles at the two LI. 4 Hegu points and at the ipsilateral temporal mandibular joint area. In order to achieve and maintain any analgesic effect, the needles were continuously manipulated throughout the dental procedure. At brief intervals, testing was conducted to determine whether an acceptable analgesic effect had been achieved. Such testing involved applying pressure with a dental explorer to the gingival tissues of the area to be treated or piercing the mucous membranes in the problem area with the point of the explorer. Only when complete analgesia was obtained was any dental treatment initiated. Continuous monitoring of patient reactions was diligently observed throughout the course of the procedure. To provide additional subjective information during treatment, each subject was encouraged to give verbal reports of his or her reactions, including the occurrence of any sensations or other physiological changes. If analgesia was deemed ineffective at any point during the procedure, then the dental treatment was stopped. Before continuing any further dental work, anesthesia was induced by the conventional method of procaine nerve block.

In no instance was any premedication given to the subjects. At the completion of the dental procedure, each subject was kept under observation for a minimum of 1 h, and all subjects were given scheduled appointments for follow-up observation on the day after treatment. In addition, at the conclusion of the dental procedure, each subject was again interviewed briefly to determine individual reactions to the entire procedure.

Results

Of the 20 cases included in the study, 16 were deemed truly successful: the major criterion was the maintenance of a satisfactory analgesic effect throughout the entire course of the dental procedures performed.

Among the types of dental problems successfully treated with acupuncture, 7 cases were tooth extractions, of which one was an impacted tooth with surgical removal of bone with mallet and chisel as well as motor-driven instrumentation, 12 cases involved cavity preparation and complete removal of caries, and 1 case involved deep gingival scaling and curettage. (Note: these figures are based on the fact that, for several of the subjects, more than one dental procedure was performed.) Of the remaining 4 cases, one was not successful. For the other three, a degree of acupuncture analgesia was obtained, but it could not be adequately maintained to complete the required dental procedure.

Monitoring of each subject during the acupuncture procedure showed that, on average, an analgesic effect could be obtained in about 3 min from insertion of the first needle. Moreover, at the completion of the dental procedure, the subjects reported the return of sensation approximately 30 s after termination of the manipulation of the needles.

In those cases in which acupuncture was successful, the patients reported no side effects during or after treatment, a general positive reaction and willingness to repeat the procedure, and a greater decrease in posttreatment discomfort as compared with standard anesthetic techniques. Postoperative bleeding was minimal and in no case were postoperative analgesics required. Additionally, in each of the cases, there was no evidence of edema or postoperative complications. As a result, most of these subjects preferred acupuncture analgesia to the standard methods of anesthesia usually employed in their previous dental treatments.

Acupuncture Dental Pain Research Model

With an 80% success rate in our dental clinical experience, it was mandatory to reassess our position - thus, the evolution of our acupuncture dental pain research model. What was needed was an accurate, replicable pain stimulus model (Fig. 1). Obviously the tooth, innervated by sensory fibers only, appeared ideal. A new technique for administering electrical stimulation to the dental pulp provided a precise, well-quantified measurement for assessing the efficacy of a variety of analgesic agents [14]. The test was developed in collaboration with Dr. Barry Dworkin, Rockefeller University. Its reliability and validity for measuring pain intensity were established in double-blind pharmacological studies, using aspirin, codeine, and placebo [39]. The dental stimulation technique optimized accuracy, reliability, and comfort for the subject [14] and permitted repeated pain measurements during prolonged sessions as well as at intervals of months without any change in the baseline condition. Special consideration was given to insure constancy of the current density delivered to the pulp nerve as well as to free the subject from holding the stimulation device in place. The use of a therapeutic filling as the cathode provided a constant geometrical relationship between the pulp

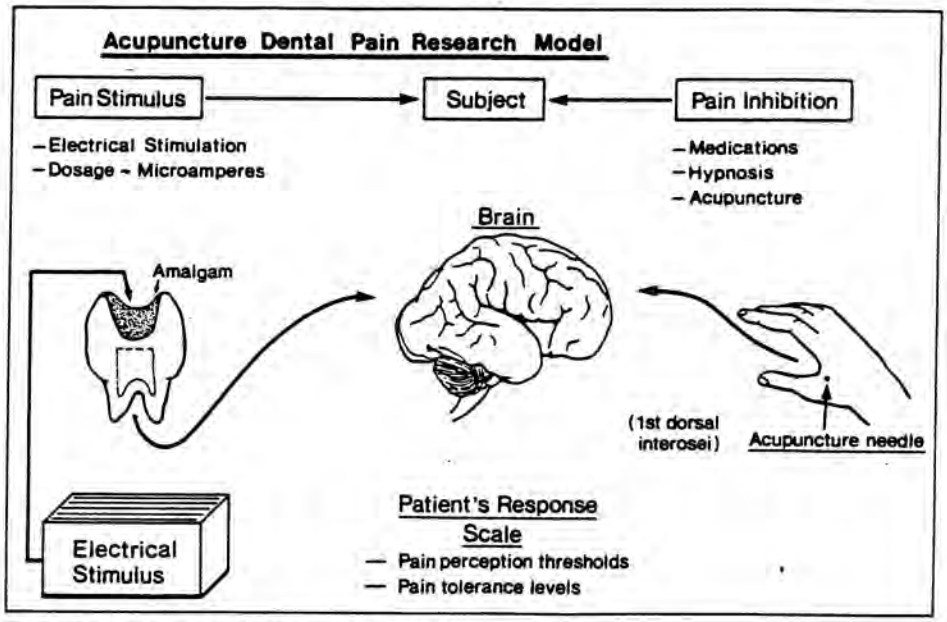

Fig. 1. Acupuncture dental pain research model

nerve and the electrode of stimulation (Fig. 2). The fabrication of an individual rubber mold containing the electrode of stimulation (platinum EEG Grass electrode), by preventing saliva leak, and by its watertight adhesion to the stimulated region, maintained the resistance of the preparation constant (Fig. 3). This technique was designed for cross-over experiments. The use of well-trained subjects minimized stress factors.

We examined, in humans, the analgesic effects of nonsegmental electroacupuncture (EA) limited to a single point LI.4 Hegu and the influence of naloxone on experimental pain [16].

Electroacupuncture analgesia is well documented in the clinical pain [11, 20, 41, 55] as well as in experimental pain literature [9, 27, 44, 51]. Numerous studies have implicated the endogenous opioid system in its mechanism of action [24, 56, 58]. However this subject is still controversial, especially with regard to the effect of naloxone, a specific narcotic antagonist agent [54], on the analgesic effect [8, 44, 49]. Many factors account for the discrepancy in the results of the naloxone studies, including the type of experimental pain model.

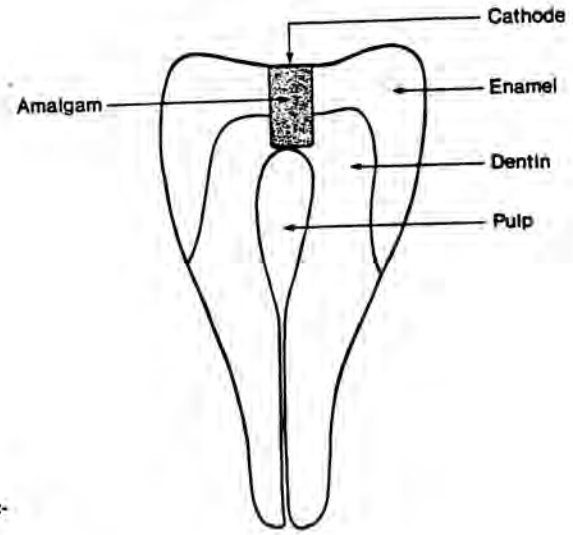

Fig. 2. Sagittal view of the tooth. The dental filling is used as the electrode of stimulation

Methods

Five normal female paid subjects (25-35 years old) participated in 65 sessions under four conditions (control, EA, EA + naloxone, EA + placebo). Each subject was fully accustomed to the experimental procedure at the beginning of the experiment, after having participated in preliminary training sessions. The sessions were 60 min long and consisted of seven pain measurements at 10-minute intervals. They were performed at the same time of day, at 1-week intervals. Session order was randomized.

The pain measurement consisted of the evaluation of two pain levels: pain detection determined by the lowest intensity of stimulation consistently perceived by the subject, and pain discomfort determined by the intensity of stimulation which, if persisting, would prompt the subject to take a pain relief agent.

Experimental dental pain was produced by electrical stimulation (600-ms train of 100×1 ms rectangular pulses, intensity range between 0 and 500 μA) delivered by a constant current stimulator to a therapeutic filling of a molar or premolar of the superior jaw. This technique has been described in detail previously [14]. The electrode of stimulation (EEG Grass Instrument) was inserted into a silicone rubber mold which isolated the filling from the saliva and the buccal mucosa. The indifferent electrode, composed of three gold disk electrodes, was placed in the buccal pouch. Pain thresholds were determined through the method of ascending limits [65] for which stimuli were delivered every 8 s.

The electroacupuncture (EA) was delivered to the right Hegu hand point with a sterile Chinese acupuncture needle. The LI.4 Hegu point, located in the first dorsal interosseus muscle, has been used extensively in acupuncture studies due to its well-known orofacial analgesic effects [2, 61]. The electrical stimulation consisted of a 0.8-ms rectangular pulse delivered at 2-Hz frequency by a constant current stimulator. The intensity was adjusted to a level slightly above pain threshold,

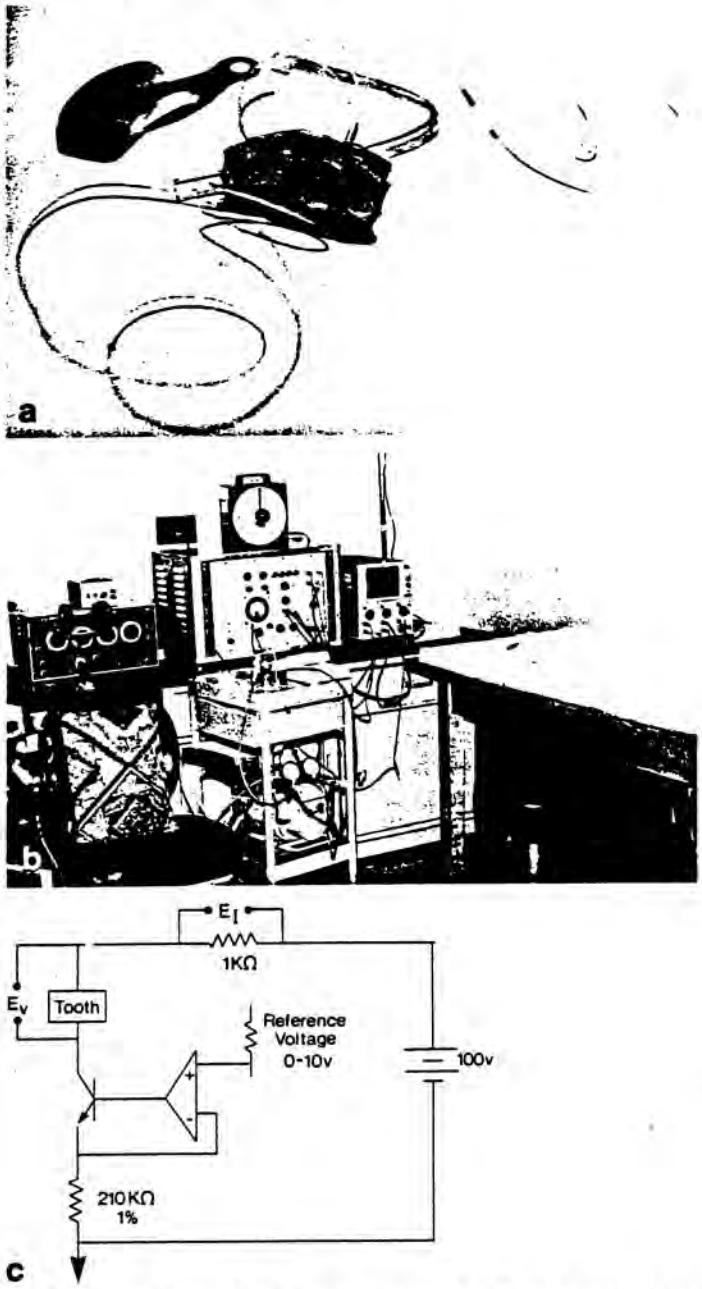

Fig. 3. **a** Silicone rubber mold showing electrode and Teflon-insulated connecting wire. **b** Experimental setting. The subject signals perception of the stimulus by pressing a button on either side which lights the experimenter's panel. **c** A partial schematic diagram of the current control section of the stimulator. Note that the reference ground is isolated. E_I and E_V are used to calculate the preparation impedance

which provoked muscular twitches (8–15 mA). EA was initiated after the first pain measurement and was maintained until the end of the session. Although unpleasant, the EA stimulation was reported to be quite bearable and not disturbing to concentration.

In the pharmacological sessions, a brachial biceps intramuscular injection of either 0.8 mg naloxone (4 cc) or isotonic saline (4 cc) was given after the second pain measurement in a double-blind procedure.

The results were analyzed by means of a three-way analysis of variance [31].

Results

Dental pain detection and pain discomfort thresholds remained stable during the control condition with a fluctuation range of 2% ± 1%. In contrast, they increased progressively and significantly ($P < 0.0001$) during EA treatment (27% increase with 60-min EA). The magnitude of the threshold increase at 60 min was similar for the detection level and the discomfort level (detection 27.5% ± 3.1%, discomfort 27.1% ± 2.8). This increase was partially blocked by the double blind intramuscular injection of 0.8 mg naloxone ($P < 0.005$) (Figs. 4, 5). The experimental

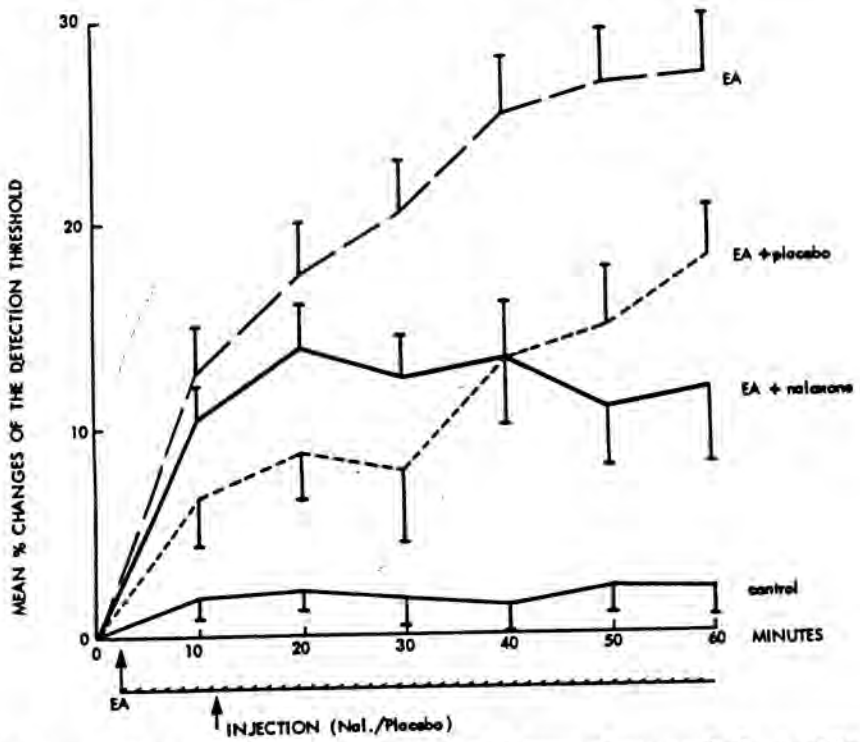

Fig. 4. Detection threshold changes (mean percentage of reference values ± standard error of the mean) during 60-min period under four conditions: *control* ($n = 18$), *EA* ($n = 22$), *EA + naloxone* ($n = 14$), and *EA + placebo* ($n = 11$) in five subjects

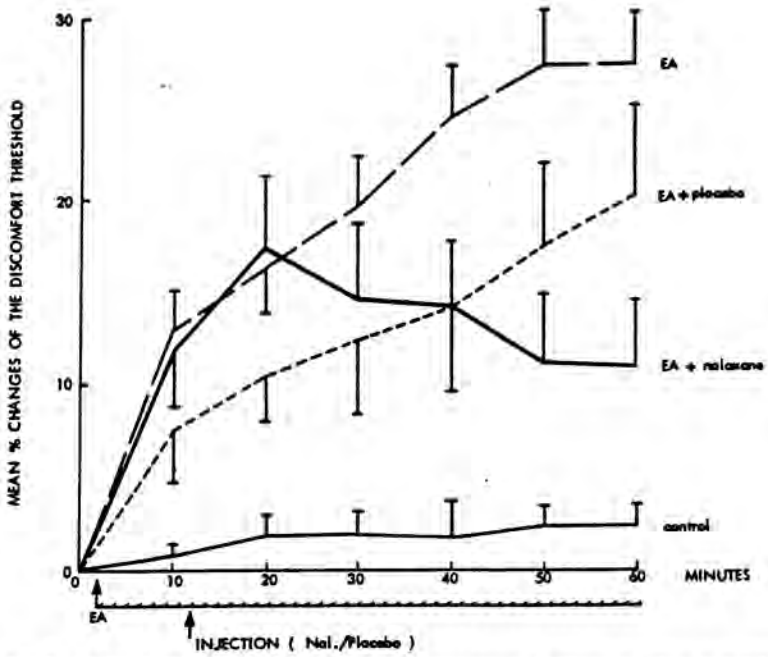

Fig. 5. Discomfort threshold changes (mean percentage of reference values ± standard error of the mean) during 60-min period under four conditions: *control* ($n = 18$), *EA* ($n = 22$), *EA + naloxone* ($n = 14$), and *EA + placebo* ($n = 11$) in five subjects

conditions were carefully controlled in order to prevent the occurrence of a stress analgesic effect.

Discussion

The absence of a differential analgesic effect of acupuncture on low and high pain sensory levels is in contrast with the findings of Chapman et al. (1976) who reported a stronger acupuncture effect on low pain intensity than on high pain intensity [10]. The use of pain discomfort threshold rather than pain tolerance threshold may account for this discrepancy. However, the degree of pain threshold increase (27%) found in our study is in accordance with the reports in the literature. Mayer et al. (1977) observed a 27% increase of dental pain thresholds after 30 min of LI.4 Hegu manual acupuncture [44]. Lynn et al. (1977) reported a 20% pain relief in patients after nonsegmental EA [42]. A review of the literature indicates that segmental EA yields a stronger pain threshold increase: 40% reported by Sjolund et al. (1979) [57], 57% reported by Fox et al. (1976) [20], and 87% reported by Chapman et al. (1977) [9]. This discrepancy suggests that segmental acupuncture activates more efficiently than nonsegmental acupuncture a central analgesic system, or that it triggers an additional specific segmental analgesic system.

Apart from psychological hypotheses such as placebo [46], hypnosis [29, 33], and stress [8], three neurophysiological theories have been proposed for the EA analgesic mechanism of action.

1. A segmental spinal inhibition of nociceptive inputs based on the gate control theory [45] results in an immediate, short-lasting, segmental, and nonopioid analgesia.

2. The central, endogenous, opioid, analgesic system accounts for a general, long-lasting, analgesic effect [43].

3. The third hypothesis involves the activation of the diffuse noxious inhibitory controls (DNIC), recently introduced by LeBars et al. (1981) [34]. These authors reported the spinal inhibition of convergent cells of the dorsal horn by nonsegmental peripheral noxious stimulations in rats. Nonconvergent cells were not affected, and nonnoxious stimulations were ineffective.

The partial blockade of the acupuncture analgesic effect by naloxone suggests the implication of endogenous opioid substances in EA analgesia. It does not support the hypothesis of psychological factors as the unique basis for acupuncture analgesia. Indeed, most studies agree on the absence of naloxone influence at low dosage (<2 mg) on the analgesia produced by either placebo [40] or by hypnosis [23, 47, 60]. The naloxone-insensitive component of EA analgesia may be accounted for by psychological factors as well as by non-opioid neurophysiological analgesic systems. In addition, there has recently been a growing interest in the study of the relationship between the sympathetic nervous system and pain modulation [17, 18]. Edwall et al. (1971) [15] suggested that the pulp nerve activity is modulated by the local vasomotor tone, which in turn may be modified by EA treatment.

In conclusion, this study is evidence of the analgesic effect of nonsegmental EA of a single point on experimental dental pain and its partial reversal by naloxone 0.8 mg IM. This finding suggests that the endogenous opioid system is activated either by a specific acupuncture mechanism, or by a nonspecific one such as the DNIC system or the sympathetic nervous system.

The Sympathetic Effect of Acupuncture

The studies which have attempted to appraise the role of the sympathetic nervous system in acupuncture show contradictory findings. Some authors report an increase in the sympathetic activity following acupuncture upon the cardiovascular function in dogs [35]. Others report a decrease in the sympathetic tone resulting in peripheral vasodilation [36, 38]. Omura [50] reports a transient increase followed by a long-lasting decrease in the sympathetic activity. The discrepancy in the findings stems from the difficulty in monitoring sympathetic activity, as well as from the different types of acupuncture techniques. The recent use of thermography [5] in the medical field represents a major advance for clinical research by providing a simple, reliable, and sensitive tool for assessing peripheral sympathetic activity through measurements of surface skin temperature.

We conducted experiments to assess the peripheral sympathetic effect of manual and electrical acupuncture, as well as the central autonomic effect of manual

acupuncture, by means of, respectively, thermography and cardiorespiratory function measurements (blood pressure, heart rate, and respiratory quotient).

Thermography Studies: Measurement of Peripheral Sympathetic Activity

Skin temperature is a function of blood perfusion, which represents an index of sympathetic activity. The increase in sympathetic vasomotor tone induces vasoconstriction and hence decreases skin temperature. Conversely, the decrease in sympathetic vasomotor tone induces vasodilation and thus increases skin temperature. Thermographic scans visualize surface temperature and, by recording all body temperature, permit the differentiation of regional, segmental, and central sympathetic changes. In a preliminary report [37] we demonstrated via thermography a skin temperature (Tsk) rise in both hands of three subjects after unilateral LI.4 Hegu manual acupuncture, which suggested a sympatholytic effect. This finding gave rise to two experiments measuring skin temperature changes in the face, hands, and feet after manual acupuncture and electrical acupuncture of the LI.4 Hegu hand point in the first experiment [17], and of the St.36 Zusanli knee point in the second experiment [18]. Both acupuncture modalities (electrical and manual) were used since there is evidence of a specific analgesic response pattern according to the type of acupuncture technique. Generalized analgesia is described with manual acupuncture [3, 12, 48] and segmental analgesia with electrical stimulation [45, 63].

Methods

Nineteen normal subjects (32 ± 8 years old; 17 females and 2 males) were used in both experiments which were performed at 3-week intervals. The sessions, control, manual acupuncture (MA), and EA, were randomly distributed. The subjects were instructed not to eat, drink, or smoke at least 2 h prior to the session. The experimental room was at a constant temperature of 23 °C and draft free. A 20-min rest period at the start of each session acclimatised the subject to the experimental setting and stabilized Tsk.

Temperature of the hands, feet, and face were recorded by means of an infrared color thermograph (Inframetrics, Model 525). Each session lasted about 1 h. Basal Tsk was recorded at t_0, immediately after the rest period. Color slides of the thermograms of the hand dorsum, foot dorsum, and face were taken every 5 min during the following 30 min.

In the acupuncture sessions, a sterile Chinese acupuncture needle was inserted in the left LI.4 Hegu point (first dorsal interosseus muscle) or in the left St.36 Zusanli point (motor point of the tibialis anterior muscle) [2] immediately after the first temperature recording and was removed 15 min later (t_{15}). Temperature recording was continued for another 15-min period (t_{30}). MA consisted of twirling the needle in between temperature recordings, until the subject experienced a painful sensation. EA was delivered to the acupuncture needle by a constant current stimulator. Rectangular 0.8-ms pulses at 1 Hz frequency were adjusted at an

intensity strong enough to evoke muscle twitching and sensation of tapping or pounding just below the pain sensation threshold (7-15 mA).

In the control sessions, the subjects were sitting quietly during the whole period of temperature recordings (30 min).

Data was collected by averaging the temperature of standardized areas of each body segment under study.

Left and right hands as well as left and right feet did not show any statistical difference in the Tsk changes. Therefore, they were analyzed as a unit.

A three factor analysis of variance compared the mean Tsk changes at 5 min (t_5), 15 min (t_{15}), and 30 min (t_{30}) after the beginning of the Tsk recording and within the conditions (control, Hegu MA, Hegu EA, Zusanli MA, Zusanli EA). Planned pair-wise comparisons (LSD Fischer test) were made among the means [32]. The criterion for significance was set at $P<0.05$.

Results

The initial mean Tsk (t_0) of hands, feet, and face was similar in the five conditions. This indicated that the 20-min rest period was adequate to establish homogenous basal Tsk for all five conditions. The analysis of variance showed that all effects and interactions were significant.

MA of both points induced a Tsk increase that was maximal at the end of the session (t_{30}), most significant for the face ($F[4,72]=24.26$; LSD=0.70; $P<0.001$), less significant for the hands ($F[4,72]=3.07$; LSD=2.01; $P<0.01$), and did not reach the criterion of significance for the feet ($F[4,72]=2.77$; LSD=1.3; NS). The only statistical difference between the MA effects of both points appeared in the magnitude of the Tsk increase in the face, with the Hegu hand point yielding the strongest effect.

EA of both points induced a Tsk increase in the face, with the LI.4 Hegu hand point yielding the strongest effect. It was maximal at the end of the session and most significant for the face; again the face Tsk increase was significantly greater with LI.4 Hegu point EA than with St.36 Zusanli point EA; in the feet, Hegu point EA increased Tsk, while Zusanli point decreased Tsk (Figs. 6, 7).

Compared to the control condition, MA and EA of LI.4 Hegu and St.36 Zusanli points induced a nonsegmental, long-lasting, warming (sympatholytic) effect, which was distributed according to a craniocaudal gradient, i.e., maximum effect in the face, and which was stronger with MA. In addition, EA induced an initial segmental cooling (sympathomimetic) effect (in the hands with LI.4 Hegu point and in the feet with St.36 Zusanli point) that decreased during the remainder of the session.

Discussion

The similar temporal course and spatial distribution of the Tsk changes after stimulation of either a knee point or hand point is consistent with the hypothesis of the activation of a central sympathetic inhibitory system. The somatotopicity of this system is unrelated to the site of peripheral stimulation.

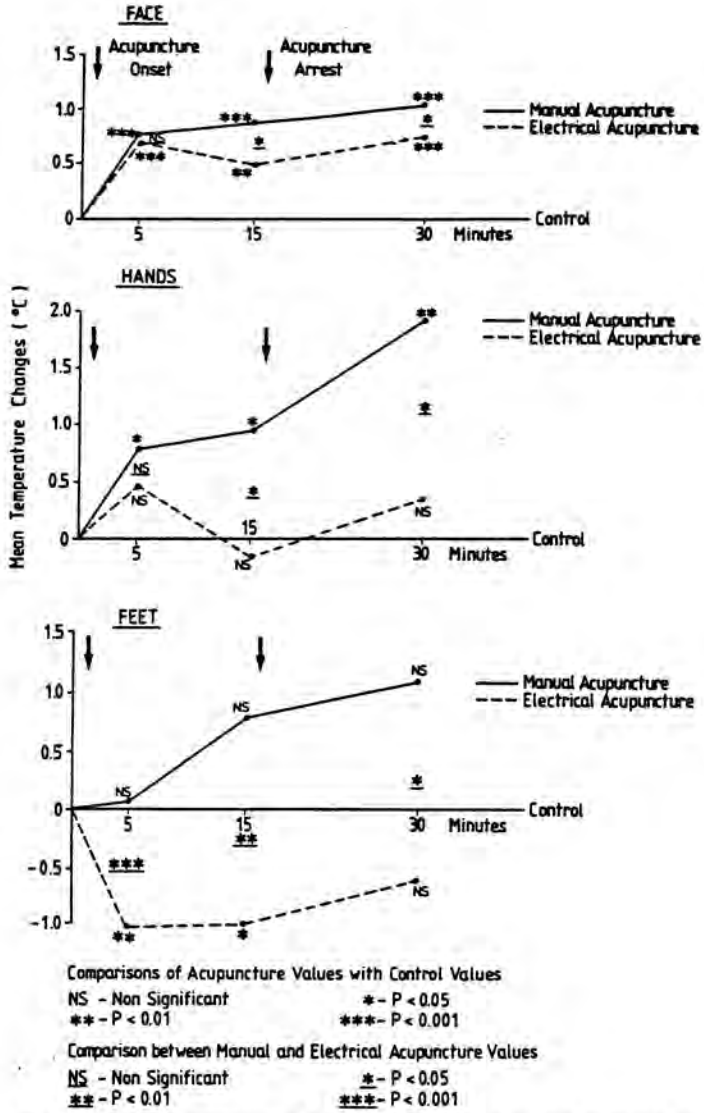

Fig. 6. Mean skin temperature changes during manual and electrical acupuncture of the LI.4 Hegu hand point, with the control values as reference ($n = 19$)

The initial sympathomimetic activation observed after electrical acupuncture reflects the activation of segmental vasomotor reflexes rather than a generalized emotional arousal [6]. This is consistent with Procacci's findings [52] demonstrating a segmental sympathetic reflex by inhibiting skin potential response in both ipsilateral and contralateral limbs, after unilateral sympathetic block. Bilateral connections on a segmental level of the sympathetic innervation are also evi-

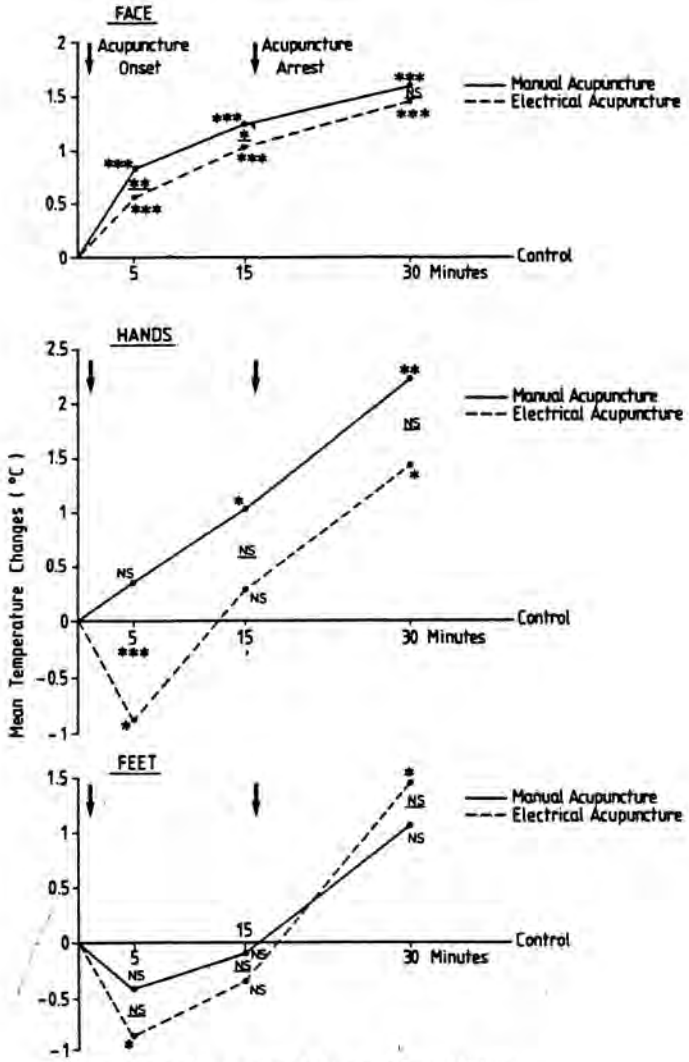

Fig. 7. Mean skin temperature changes during manual and electrical acupuncture of the St. 36 Zusanli knee point, with the control values as reference ($n = 19$)

denced by the well-known "mirror image" of reflex sympathetic dystrophy, which shows a contralateral extension of the dystrophic process. The segmental activation of the sympathetic nervous system is in agreement with the observation of an exacerbation of the sympathetic dystrophy symptoms after transcutaneous electrical stimulation treatment [1]. The short duration of the sympathomimetic effect may result from a depressive effect exerted by the "specific" sympatholytic effect of acupuncture. The development of an adaptation to the repetitive stimulation is unlikely since adaptation of a preganglionic reflex to repetitive stimulation of afferent fibers in the spinal nerves begins at a stimulation frequency of 1/s and is complete at rates above 5/s [6].

In a larger perspective, although the literature relative to interactions between pain control and the sympathetic nervous system is limited, there is evidence of relationships between both functions. The sympathetic nervous system has been shown to play a significant role in the stabilization of the cutaneous pain threshold in humans [22]. Several analogies between peripheral sympathetic vasomotor tone and pain sensation have been reported: thermography studies identified chronic pain areas as cold spots and acute pain areas as warm spots [19, 62, 64]. Dorsal column stimulation has been associated with a Tsk increase in the region of analgesia [21]. The somatotopically organized analgesic system found in the midbrain area of the rat mirrors the cephalocaudal gradient distribution of the sympatholytic effect observed in our study [53].

Acupuncture analgesia may be mediated at least partly by the central endogenous opioid system [3, 12, 43, 51]. Anatomical, physiological, and pharmacological observations indicate common features of the central endogenous analgesic system and the thermoregulatory function: opiate receptors are found in high concentration in the brain stem and in the hypothalamic thermoregulatory centers [4, 26, 59]. Electrical stimulation of the nucleus raphe magnus has been shown to produce analgesia [48] as well as to inhibit thermogenesis [13]. Serotoninergic systems implicated in acupuncture analgesia [25] are believed to be part of the central thermoregulatory pathway [7]. Administration of morphine and endorphin intravenously and intraventricularly produced hypothermia secondary to peripheral vasodilation and depression of the thermoregulatory center [30, 66]. This strongly suggests that endogenous opioid systems may be involved in the acupuncture sympatholytic effect.

In conclusion, the sympathetic effects of acupuncture found in this study were temporally and spatially similar to two separate acupuncture analgesic mechanisms: (a) the finding of a long-lasting, generalized, sympathetic inhibitory effect with MA correlates with the generalized, endogenous, opioid analgesia produced by MA [3, 12, 43], and (b) the short-term, segmental, sympathetic excitatory effect associated with EA correlates with the segmental spinal analgesia produced by transcutaneous electrical stimulation (TENS) [45, 63].

These sympathetic effects were not observed after TENS (M. Ernst et al., unpublished results). In similar experimental conditions, TENS did not significantly alter skin temperature when compared with sham-TENS. TENS applied to the upper extremity tended to activate peripheral and central sympathetic tone, producing a relative, generalized, cooling effect associated with an increase in heart rate and blood pressure. When applied to the lower extremity, TENS tended

to inhibit peripheral and central sympathetic activity, as evidenced by a relative, generalized, warming effect with a decrease in heart rate and diastolic pressure. Kaada reported the occurrence of a widespread and prolonged vasodilation after TENS, which was not influenced by the injection of naloxone but was blocked by the central serotonin blocker cyproheptadine and was accompanied by the peripheral release of an "active" vasodilator [28]. The discrepancy in the results may be accounted for by the differences in the type of TENS techniques and experimental conditions used in both studies. Kaada utilized low-frequency stimulation (2 Hz), similar to the electroacupuncture technique, in patients with vascular disease, with no control group. He recorded skin temperature via a thermistor and an electronic digital thermometer. We used the traditional high-frequency TENS (80 Hz), in normal subjects with a control group, and recorded temperature changes via infrared thermography.

The findings of the above studies suggest differential sympathetic effects of MA, EA, and TENS. Further work is warranted to explore the neurophysiological relationships between the sympathetic and the analgesic effects of acupuncture and TENS.

Central Sympathetic Effects: Effects of Acupuncture on Cardiovascular and Respiratory Function Before, During, and After Exercise

We demonstrated in the above studies the production of peripheral sympathetic effects by acupuncture. We were interested in completing our findings by studying the influence and the modulatory role of acupuncture on central sympathetic activity. We evaluated the effects of MA on cardiorespiratory function under basal (rest) and activation (stress exercise) conditions (M. Ernst et al., unpublished results). We will present only the outlines of this work, which is still in progress.

Methods

Fifteen healthy subjects were randomly assigned to two groups, MA and sham-acupuncture. Each session consisted of 20 min equilibration, 15 min acupuncture/sham, 10 min arm crank exercise, 15 min recovery. Respiratory gas exchange, ECG, and blood pressure were monitored throughout the session under strictly standardized conditions. Manual acupuncture consisted of the bilateral needling of the LI.4 Hegu hand and the St. 36 Zusanli knee points and twirling of the acupuncture needle. Sham-acupuncture consisted of the superficial needling of non-acupuncture points close to the Hegu and Zusanli points and the fake manipulation of the acupuncture needle. Neither the subject nor the experimenter knew the acupuncturist's technique.

Results

In comparison with placebo, acupuncture decreased heart rate ($P<0.04$) and diastolic pressure ($P<0.04$) before exercise, and decreased diastolic pressure ($P<0.05$) and increased respiratory quotient ($P<0.03$) during and after exercise.

Discussion

Acupuncture produces a sympathetic inhibition, mimicking a beta-blocking effect, dampening the autonomic activation of stress exercise and reducing the cardiac output, which results in a respiratory quotient increase. This is in accordance with previous results showing a generalized decrease of peripheral sympathetic tone after acupuncture [17, 18]. In contrast to the hypothesis of a stress analgesic effect as proposed in the literature for the mechanism of action of acupuncture analgesia [8], this finding does not support the existence of a common sympathetic pathway to acupuncture analgesia and stress analgesia, since acupuncture antagonized stress sympathetic effects.

Future Research Directions

Our laboratory will continue to study the autonomic changes occurring during acupuncture and TENS, using pharmacological challenges, in order to clarify the chemical mediators of these acupuncture effects. The utilization of computerized thermography on a continuous dynamic basis offers a powerful diagnostic tool for the study of pain, acupuncture, and particularly soft tissue damage. We have witnessed that the progression of thermographic changes from a steady resting state to a definitive pain pattern during movement of an extremity correlated with a subject's verbal description.

Our studies clearly indicate that skin surface temperature alteration and patterns following acupuncture therapy can be visualized and measured via thermography. Of course, much delineation and refinement have yet to be resolved.

Therefore, our Chronic Pain Unit plans to direct a major thrust of its research effort into this area and thus hopes to contribute toward elucidating the interactions between sympathetic and analgesic acupuncture effects in clinical and experimental pain.

Summary

After demonstrating an 80% success rate in our dental analgesia studies using acupuncture, we developed an acupuncture dental pain research model utilizing a tooth pulp stimulation technique to measure pain. This technique allowed to measure alterations in pain under various medications, acupuncture and acupuncture challenged by naloxone. The sympathetic effect of acupuncture was observed using thermography as a measurement of peripheral sympathetic activity. A decreased gradient effect was witnessed when the LI.4 Hegu point (as opposed to the St.36 Zusanli point) was stimulated. The central sympathetic effects in terms of acupuncture affecting the cardiovascular and respiratory functions were demonstrated following exercise. Acupuncture produced a sympathetic inhibition mimicking a Beta blocking effect.

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