Anesthesiology 2009; 111:632–9

Contact-free Infrared Thermography for Assessing Effects during Acupuncture: A Randomized, Single-blinded, Placebo-controlled Crossover Clinical Trial

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Background: **Although evidence of its effects is tentative, acupuncture has long been used in the treatment of multiple maladies. So far, it has not been possible to discriminate the effects of the venue from specific results of needling itself, thus physicians merely depend on patients' statements. The authors investigated the efficacy of infrared thermography in distinguishing response to true acupuncture as compared to nonacupoint cutaneous and muscular needling (sham or minimal acupuncture), as well as without manipulation.**

Methods: **Thermographic imaging was performed in 50 healthy volunteers randomly assigned to four groups: Acupuncture of Hegu (LI 4), needling of a cutaneous and a muscular point where no acupuncture point has been described yet, and without manipulation. In a crossover protocol, each proband completed all four arms of the protocol in a random order. Infrared thermograms were gathered at defined points in each group.**

Results: **A significant increase in surface temperature occurred within 2 min after needling the acupuncture point Hegu (from 30.1 ± 2.7°C [SD] to 31.2 ± 3.0°C and to 31.9 ± 2.5°C after 10 min, $P < 0.001$), whereas needling of the cutaneous and muscular point, as well as without any manipulation resulted in a decrease of temperature in the monitored area.**

Conclusion: **Contact-free infrared thermographic imaging is a reliable and easy-to-handle tool to distinguish between needling at Hegu and needling of a nonacupoint ("sham" acupuncture).**

ACUPUNCTURE has been applied at least for the past 2,000 yr originating in China being a part of traditional Chinese medicine. It is assumed that needling initiates and eases the flow of *qi*, with *qi* being vital energy that flows along meridians. Stagnation and/or lack of *qi* may lead to maladies. If its flow is obstructed, it may cause swelling and lack of energy in the distal part of the meridian, resulting in pain, for example. Although the effects of acupuncture have not scientifically been proven yet, its use is widespread. When transferred into Western medicine, doubts on effect and mechanism arise as evidence-based medicine is becoming inevitable, and many questions on efficacy and mode of action of this ancient method are still unanswered yet.

In randomized trials on the efficacy of acupuncture, usually some form of sham acupuncture or no treatment at all serves as a control. In sham acupuncture, needles are placed just under the skin and/or at locations where no acupuncture point has been described. Another possibility is the use of obviously different remedies in control groups, such as transcutaneous electrical nervous stimulation or laser treatment, as minimal acupuncture may not be a physiologically static placebo. Still, the impact of psychological effects remains unclear. Findings of clinical investigations are controversial, and relieving effects of sham acupuncture are discussed, as double-blinding, choice of acupuncture and sham points, as well as psychological effects of the patient-therapist-interaction cannot be ruled out.

With the aid of thermometry infrared electromagnetic waves of 0.7–1000 μM (which the human eye is unable to identify) can be visualized, healthy human bodies emit waves with a length of 3–10 μM. Temperature differences as low as 0.1°C can be pursued and may help track response to acupuncture as opposed to needling of nonacupoints to objectively estimate effects of needling. This procedure was pursued by a few research groups in the past. Unfortunately, because of lack of control groups and/or low number of probands, validity of these investigations may be low when trying to distinguish sham from true acupuncture.

The objective of this investigation was as follows:

1. to distinguish skin response during true acupuncture from sham acupuncture by contact-free thermographic imaging, which is important in studies on acupuncture where sham acupuncture often serves as a control
2. to find an objective method to judge the effect of inserting acupuncture needles in true and sham acupuncture

It could be shown that dermal reaction to true needling was different as opposed to sham acupuncture or no manipulation. Still, further investigation such as measurement of sympathetic activity (*e.g.*, hormone release, microneurography), endogenous opioid release, and functional magnetic resonance imaging is necessary to evaluate the exact physiologic basis.

Materials and Methods

Probands

The study protocol was approved by the ethics review board (Hamburg, Germany, record number 2974). Fifty healthy volunteers aged 31.5 ± 10.9 yr (range, 21–66 yr;

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Received from the Department of Anesthesiology, Division of Pain Management, University Medical Center Hamburg-Eppendorf, Hamburg, Germany. Submitted for publication December 19, 2008. Accepted for publication May 5, 2009. Support was provided solely from institutional and/or departmental sources.

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median 29 yr; men/women, 21/29) were included after written informed consent was obtained. To ensure blinding, they had never received acupuncture before participating in this study. Participants were recruited with written announcements on the medical campus. They were insured according to German medical law for testing of innovative procedures (proband cover).

Needling Points

With Hegu (LI 4) being an essential acupoint in the treatment of various disorders often initiating the "de-*qi*" phenomenon (emanating sensation of warmth/cold and/or well-being supposed to denote successful needling distinct from the sensation during perforation of the skin with a needle), this easily accessible site was chosen. The sham acupuncture locations were accordingly selected on the hand where no acupoint has been described in traditional Chinese medicine to compare cutaneous response monitored thermographically. To rule out cutanovasal reactions to needle insertion, subcutaneous puncture was performed at the metocarpophalangeal joint of the index finger (articulationes metacarpophalangeales II) distant from Hegu, as superficial manipulation at acupoints may facilitate reactions as in true acupuncture (acupressure). To exclude a musculovasal reaction, the second sham point was chosen in the abductor pollicis brevis muscle.

Procedure

The investigation was realized respecting common guidelines for clinical trials; *i.e.*, Declaration of Helsinki, International Conference on Harmonization—Good Clinical Practice after the study protocol, proband cover, proband information, and informed consent approval by the ethics review boards.

Preinclusion testing included history taking (interviews and questionnaires) and physical examination including pregnancy testing in fertile women, since hormonal changes may alter cutaneous response and acupuncture at Hegu may provoke uterine contractions. Test persons were excluded if they were on any medication or alterations in any body system were disclosed; *i.e.*, probands had to be classified as Category I according to the Catalogue of the American Society of Anesthesiologists (no preexisting comorbidities). To identify subjects with undiagnosed or subclinical Raynaud's syndrome where cutaneous perfusion might be impaired, cold provocation testing was carried out in each case. Here, both hands were placed in ice water for 3 min, as vasospasms will be induced in patients with primary Raynaud's syndrome with this procedure. Changes in skin color as well as occurrence of pain were monitored, but did not occur in any proband.

Probands were randomly assigned to the order of the four arms of this investigation: Set I, thermographic imaging without needling; Set II, thermographic imaging with true acupuncture at Hegu; Set III, thermographic imaging with cutaneous sham acupuncture; and Set IV, thermographic imaging with muscular sham acupuncture. Each healthy subject underwent each set of the investigation in a random order. They were asked to refrain from eating, drinking, and smoking 4 h before arriving for the investigation, and to adhere to the recommendations of the American Academy of Thermology.[1] As volunteers had no experience with or knowledge about acupuncture, they were oblivious about the treatment performed. During thermographic imaging without needling, probands were told that needling could not be performed since baseline measurements revealed inconstant temperature. Sterile single-use disposable needles were used, with a size of 0.20 × 15 mm (Seirin B-type needle No. 3; 3B Scientific, Hamburg, Germany). The needle was advanced about 0.5-0.8 Cun (Chinese measure; 1 Cun equals the width of the thumb at the interphalangeal joint) in all three arms with insertion of a needle. This depth is recommended for true needling at Hegu in textbooks on acupuncture. Needles were inserted perpendicular to the skin in true and muscular needling, and at an angle of approximately 5–10 degrees in subcutaneous needling. No further manipulation was carried out.

On arrival, subjects acclimatized for 30 min in a standardized room with laminar air flow at 23.5°C and a humidity of 45–50%. Meanwhile, the exact course of that day's treatment was explained again to the volunteer by the thermographist, who was unaware of the needling point before the intervention. A curtain was put up between the face of the volunteer and the therapist to shade the proband from the acupuncture site and to reduce the chance of nonverbal communication. Initial thermograms were taken before needling to compare skin temperature before manipulation. Next, a needle was inserted according to the protocol that had been put up for each proband, and thermographic imaging was repeated immediately upon as well as at 1, 2, 3, 4, 5, 10, 20, and 30 min after needling. The needle was removed 10 min after insertion. The therapist was not allowed to converse with the proband, and touching/manipulation at the area to be monitored was kept to a minimum. No adverse events occurred (collapse, hemorrhage, infection, excessive pain, or sweating).

Assessment of Temperature

Specific points on the hands in the thermographic images were analyzed before, during, and after needling. As temperature changes are most likely to be observed in the tips of the fingers, one point was chosen at the middle of the nail bed of each finger and another point at the middle of each metacarpal bone. This was performed in both hands, separately for each proband. The median of these 20 values was taken and compared intra- and interindividually.

Statistical Analysis

Number of Probands. Before the investigation, the number of probands (n) was calculated with the chi-square test to obtain statistically significant results with a power of 90% and a level of significance of 0.01. To assess n, the expected probability of a change in temperature during true acupuncture, sham acupuncture, and no acupuncture was estimated: The odds of a temperature increase of ≥ 0.5°C when needling Hegu were reckoned to be 75% of the cases, whereas the likelihood of an increase to this extend in the sham acupuncture group as well as no needling was approximated to be $\leq$ 20% of the cases. Intending to reveal, in addition, intraindividual as well as interindividual differences, a total of 50 persons were examined in a crossover design.

Statistical analysis was performed with the aid of Sigma Stat 3.1 (Systat Software, Erkrath, Germany). Median scores were analyzed with the Kruskal-Wallis one-way ANOVA by ranks to assess differences on the median in each group at each point. The null hypothesis was defined as no difference between the groups. With the Friedman repeated measures ANOVA by ranks, significant differences within the groups were calculated. A P value of 0.01 was defined to be statistically significant. This value was chosen to address a potential Type-I error, as two different tests were conducted. Significance testing was two-tailed: Increase as well as decrease of surface temperature was analyzed.

Results

Differences between median temperatures for different points of assessment between the arms were analyzed with the aid of the Kruskal-Wallis test.

In the initial thermogram (after 30 min of acclimatization), no statistically significant difference could be detected when comparing the different arms of the study ($P = 0.864$); hence, the initial condition was comparable in all four arms. Exact temperatures for all sets at all points are given in table 1.

When inserting the needle, a significant difference could be perceived. Cutaneous needling did not alter mean temperature; muscular needling resulted in a temperature decrease. Opposed to that, insertion of the needle at Hegu produced a temperature increase. Findings at 1 and 2 min into the examination were similar. After 3 min, a one-time significant difference between temperatures after cutaneous and muscular needling could be identified that persisted at 4 min into the examination. Nevertheless, the temperature increase after needling Hegu remained significantly higher at all points, and persisted for the remaining duration of the observation (fig. 1).

To detect differences within each arm of the study, the Friedman test was applied for median temperatures. Looking at the group without manipulation, a slight decrease in temperature could be observed as compared with the preinterventional temperature. Nevertheless, no significant difference could be detected ($P = 0.518$), even though temperature kept decreasing towards the end of the observation.

Surface temperature after needling Hegu increased significantly at every point ($P < 0.001$). Initial temperature rose after inserting the needle and peaked at 10 min as the needle was removed. Then a slight decrease could be detected for the remaining 20 min. However, temperature never reached as low values as initially measured.

During cutaneous needling, an insignificant change of temperature was identified after 2 min into the examination ($P = 0.021$). It persisted at 3 and 4 min and again insignificantly rose at 5 min. After 20 min into the examination a decrease occurred, again persisting for the rest of the observation.

As results were analyzed after muscular needling, a significant decline of temperature could already be observed at inserting the needle ($P < 0.001$). Temperature stabilized, but after removing the needle, an additional decrease was identified for the remaining time of the observation.

Quantification of Temperature Differences

Temperature differences were observed at all points during the examination. Depending on the type of needling (true/sham/no acupuncture), these differences varied. It is eminent that needling of Hegu resulted in an increase of surface temperature, whereas no needling or sham acupuncture produced a steady state or decrease (fig. 2). As temperature differences were most prominent at 10 min, this point was chosen to quantify differences between and within the groups. They were divided into five subgroups: Temperature loss or increase < 0°C, increase ranging from 0–0.4°C, increase ranging from 0.5–0.9°C, increase ranging from1.0–1.4°C, and increase > 1.5°C.

Figure 3 depicts the differences in temperature at inserting the needle 2, 10, and 30 min into the examination, as these were the points when major differences could be detected. As can be seen from the figure, an increase could be observed when needling Hegu, whereas no manipulation and cutaneous as well as muscular needling resulted in a decrease.

Grouping probands without manipulation according to the abovementioned differences, in 70% a decrease in surface temperature was detected, in 12% temperature increased ≤ 0.4°C, in 8% it rose 0.5–0.9°C, in 10% an increase of 1.0–1.4°C could be observed, whereas no one had an increase of ≥ 1.5°C.

As compared with this, in the acupuncture group only 6% of the probands showed a decrease of surface temperature, in 8% temperature increased ≤ 0.4°C, in 20% a rise of 0.5–0.9°C could be detected, another 20% presented an increase of 1.0–1.4°C, whereas 46% of the test persons had an increase of ≥ 1.5°C.

Table 1. Temperatures for Each Arm of the Investigation at Each Set Point

Time	No Manipulation	Hegu True Needling	Cutaneous Needling	Muscular Needling
Before				
Mean ± SD	30.1 ± 2.5°C	30.1 ± 2.7°C	30.1 ± 2.4°C	29.8 ± 3.3°C
Median	30.9°C	30.8°C	30.5°C	31.2°C
Range	22.6–34.2°C	20.8–34.1°C	22.9–34.2°C	19.5–33.9°C
Needling				
Mean ± SD	n.a.	30.7 ± 2.9°C	30.0 ± 2.8°C	29.5 ± 3.5°C
Median	n.a.	31.6°C	30.6°C	30.5°C
Range	n.a.	20.5–34.0°C	22.5–34.0°C	18.5–33.7°C
1 min				
Mean ± SD	30.2 ± 2.9°C	30.8 ± 2.9°C	29.9 ± 2.8°C	29.5 ± 3.5°C
Median	30.9°C	31.7°C	30.5°C	30.6°C
Range	22.4–34.4°C	20.7–34.2°C	22.5–34.2°C	18.7–33.8°C
2 min				
Mean ± SD	30.1 ± 3.0°C	31.2 ± 3.0°C	29.9 ± 2.9°C	29.5 ± 3.5°C
Median	31.1°C	31.9°C	30.7°C	30.6°C
Range	21.9–34.4°C	20.7–34.7°C	22.3–34.0°C	19.0–33.9°C
3 min				
Mean ± SD	30.1 ± 3.0°C	31.4 ± 3.0°C	30.0 ± 2.9°C	29.5 ± 3.5°C
Median	31.1°C	32.3°C	30.8°C	30.5°C
Range	20.2–35.0°C	20.7–34.9°C	22.6–34.2°C	18.6–33.9°C
4 min				
Mean ± SD	30.2 ± 2.8°C	31.5 ± 2.9°C	30.0 ± 2.9°C	29.5 ± 3.5°C
Median	30.1°C	32.3°C	30.8°C	30.5°C
Range	22.6–35.0°C	20.5–35.2°C	22.7–34.3°C	18.6–34.1°C
5 min				
Mean ± SD	30.2 ± 2.9°C	31.7 ± 2.7°C	30.1 ± 2.9°C	29.3 ± 3.5°C
Median	31.0°C	32.3°C	30.9°C	30.4°C
Range	18.0–35.0°C	20.6–34.9°C	22.5–34.5°C	18.2–34.1°C
10 min				
Mean ± SD	30.1 ± 2.8°C	31.9 ± 2.5°C	29.9 ± 3.0°C	29.3 ± 3.6°C
Median	31.0°C	32.5°C	30.9°C	30.7°C
Range	22.6–34.0°C	20.8–34.7°C	22.7–34.8°C	18.6–34.3°C
20 min				
Mean ± SD	30.2 ± 2.6°C	31.8 ± 2.4°C	29.6 ± 3.0°C	29.3 ± 3.4°C
Median	31.0°C	32.5°C	30.4°C	30.5°C
Range	22.7–34.6°C	21.0–34.6°C	21.6–34.4°C	19.3–33.7°C
30 min				
Mean ± SD	29.8 ± 2.8°C	21.0–34.6°C	29.4 ± 3.0°C	29.0 ± 3.3°C
Median	30.6°C	32.2°C	30.5°C	30.1°C
Range	22.5–34.2°C	21.3–34.7°C	21.6–34.5°C	19.3–33.4°C

Temperature is in degrees Celsius at all points of investigation of all four arms. In the first column, time at each point is given. In columns 3–6 the corresponding temperatures of the four arms of the investigation are given (mean ± SD, median as well as range). Note that temperature increase in true needling can be depicted on insertion of the needle (Hegu) and remains significantly elevated throughout the investigation.

n.a. = not applicable.

When needling the cutaneous point as well as the muscular point, results resembled those observed in the group without any needling: Decrease of surface temperature was observed in 60% of the probands with cutaneous needling and in 84% of the probands receiving sham acupuncture into the muscle. Twenty eight percent of the probands in the group with cutaneous needling and 6% with muscular needling showed an increase in temperature of 0.4°C or less, whereas a rise of 0.5–0.9°C could be found in 8% of the probands receiving cutaneous stimulation as opposed to 6% in the group with muscular needling. No proband in the cutaneous needling group and 6% in the muscular needling group presented an increase of 1.0–1.4°C, only 4% of the test persons in the cutaneous needling group, and no one in the muscular needling group showed an increase of ≥ 1.5°C.

Discussion

Evidence of acupuncture effects is indeterminate. A physiologic and neurobiological basis has been demonstrated in previous investigations that will be discussed in the following. Still, some reasonable doubts remain.

As the gold standard for demonstrating a specific effect over placebo, double-blind placebo-controlled clinical trials have been accepted.[2] The major problem research and evidence based medicine in acupuncture have to face is the concept of blinding and the control group. Double-blind designs have not been possible: The acupuncturist has to be aware of the method applied.[3] If needles are used, patients expect the sensation of a skin prick, which is difficult to simulate,[4,5] hence, a special needle was introduced for placebo needling.[6,7] In study

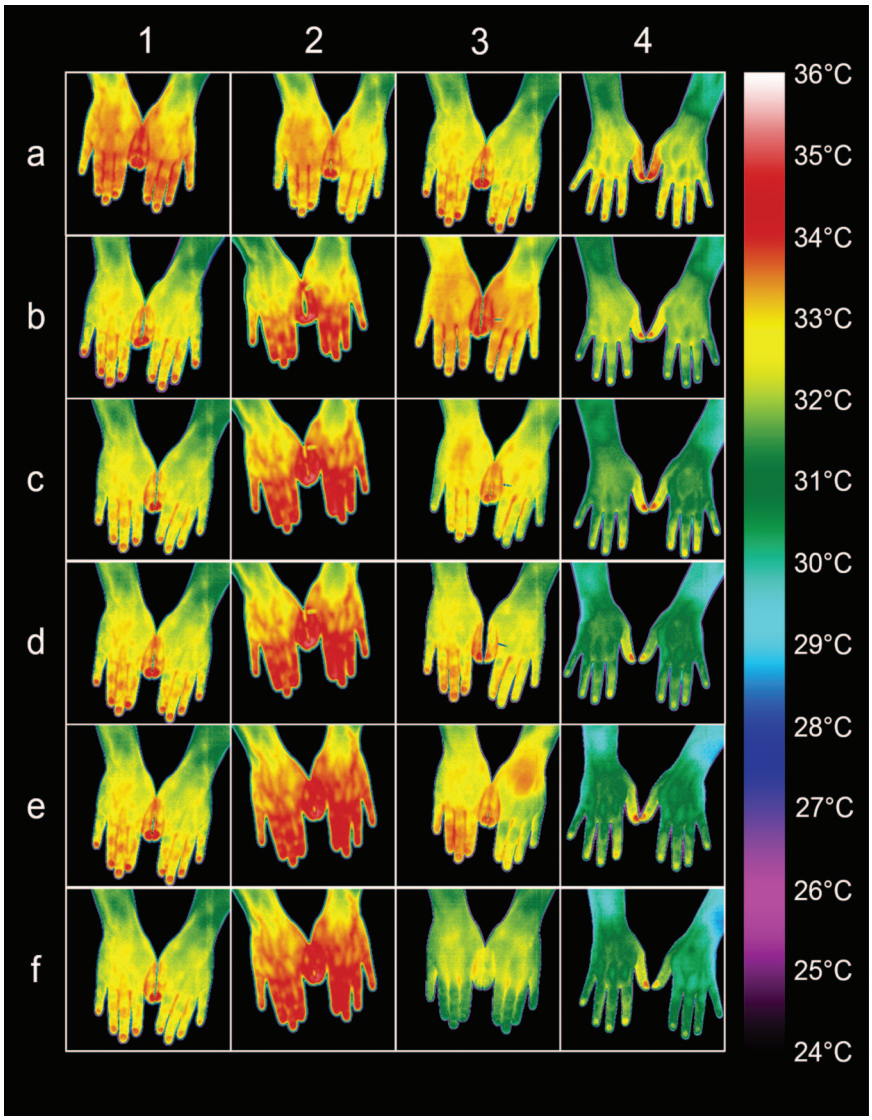

Fig. 1. Thermograms of one proband throughout the investigation on 4 different days after acclimatization for 30 min: Column 1, thermograms without manipulation; column 2, thermograms on needling Hegu; column 3, thermograms after cutaneous needling; column 4, thermograms after muscular needling. Row a, thermograms before intervention; row b, thermograms at inserting the needle (1 min into investigation); row c, thermograms at 5 min into investigation; row d, thermograms at 10 min into investigation (just before removing the needle); row e, thermograms at 20 min into investigation; row f, thermograms at 30 min into investigation. Note that after needling Hegu (column 2) an increase in temperature can be detected (acra light up in red), whereas a decrease in temperature can be found in columns 1, 3 and 4 (acra turn from a reddish color to green/blue). At the very right, a reference bar for color-coding of different temperatures is given.

designs involving laser treatment, the patient may be blinded by switching the laser off.[8] Randomized trials in acupuncture involve sham acupuncture as a control that engages needles placed subcutaneously remote from acupoints,[9] presupposing that needling is the characteristic treatment element but physiologic effects could still be involved. Physical functioning may measure some difference.[10] As neither acupuncture nor sham acupuncture can easily be explained biologically, the effects are difficult to discuss. Therefore, it is inevitable to state the difference objectively, because in previous acupuncture trials the success of the sham acupuncture over no-treatment controls caused uneasiness about blinding and general credibility.[11–13] Because of the lack of a satisfactory placebo treatment to acupuncture,[8,14] it has not been possible to differentiate effects of the therapeutic setting from specific effects. Patients' symptoms can be relieved by a pain-suppressing system in the spinal cord activated by stimuli (ice massage, heat, vibration) as diffuse as noxious inhibitory controls[15] and the release of endogenous opioids.[13] The impact of psychological factors cannot be ruled out completely.[6]

Looking at these obstacles and therapists depending on patients' statements, it is inevitable to implement an instrument to objectively determine results. Usually temperature is stable for each region of the body, with minor or no disparity bilaterally reproducible in measurements over years.[16,17] Changes in surface temperature can be detected with infrared thermography,[18] comprising many advantages (*i.e.*, easy to handle, real-time visualization, and superior sensitivity, contrast, and resolution). Thermoregulation is sustained sympathetically.[19] Under physiologic conditions, surface temperature is least stable at the tips of the fingers;[20] they are efficient in adapting the temperature of the whole organism by varying emission of heat.[19, 21]

Thermography has been applied in negotiation acupuncture effects: No specific effects of needling could be evaluated in a study without a control group.[22] This is of major importance, as minor manipulation (*e.g.*,

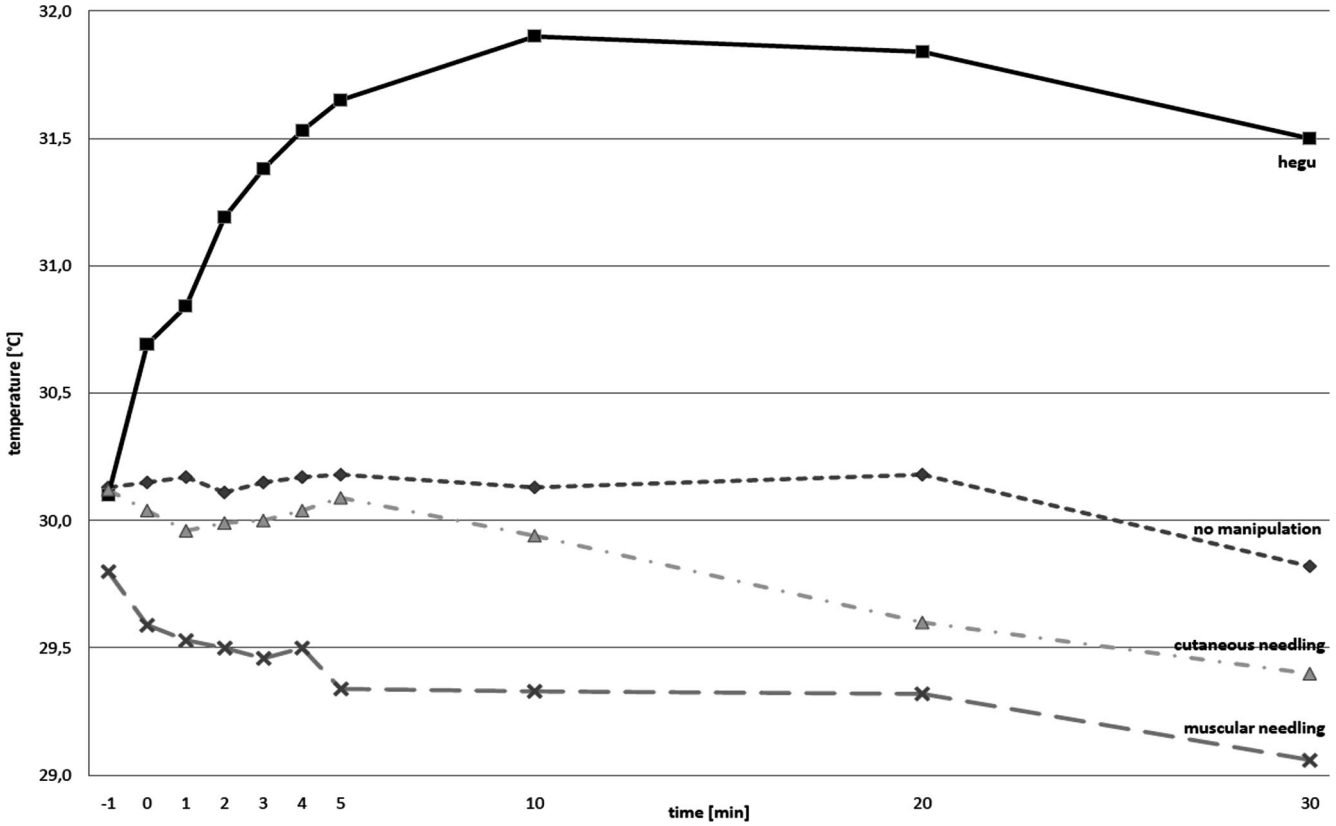

Fig. 2. Graphic portrayal of temperature over time. The line with *square dots* depicts the temperature on needling Hegu. Here, a significant increase in surface temperature can be depicted, whereas no (*diamonds with interrupted line*), cutaneous (*triangles, line with dots and strokes*) as well as muscular (crucifix with strokes) needling results in significantly lower surface temperature. The drop of temperature at the end of the investigation after 30 min is insignificant.

scratches, cuts) cause typical cardinal symptoms of infection (*rubor, dolor, calor, tumor, functio laesa*). With calor (warming), an increase in surface temperature is expected. In the present study, penetrating the skin at Hegu clearly led to an increase of surface temperature. A cutanovasal or musculovasal reaction could be ruled out. The second major problem in the abovementioned study[22] was that less than 10 probands were examined. This decreases the validity of the acquired data, as can be seen from the negotiation of statistical

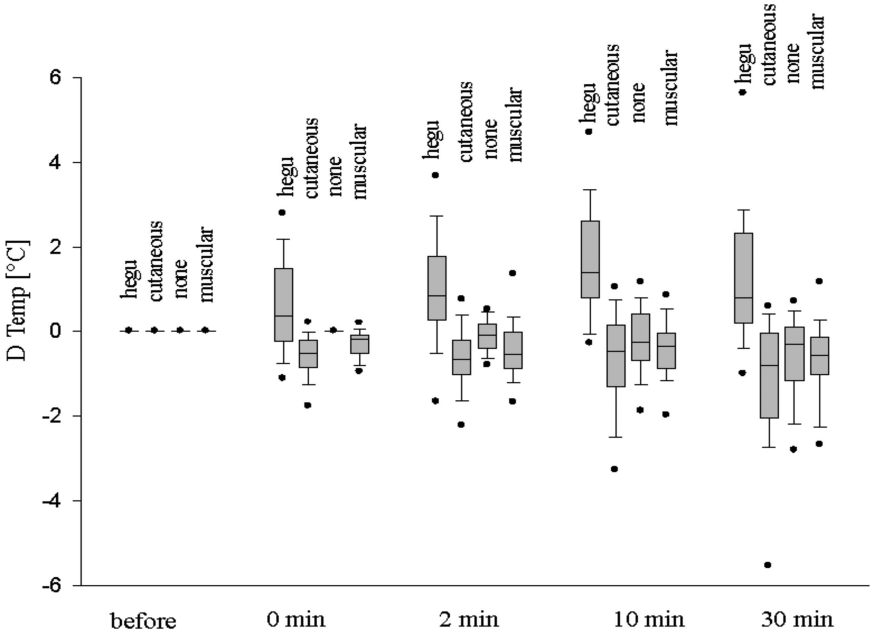

Fig. 3. Mean temperature differences of all four groups before, at insertion, 2 min after insertion, 10 min after insertion, and 30 min after insertion of the acupuncture needle at different locations. Note that mean temperature is significantly elevated when needling Hegu as compared to no, cutaneous, or no needling from insertion of the needle. The bar in the middle depicts median temperature. The upper end of the box is the value of the higher quartile (75%); the lower end shows the lower quartile (25%) of temperatures measured. The lines attached to the boxes represent the 90% interval, as dots above and below the boxes illustrate highest and lowest temperature observed, respectively.

analysis on the number of probands mentioned in the Methods section.

Increased skin temperature after sham acupuncture and after needling Neiguan (PE 6) has been described. A nervocutaneous reaction may be expected here, since two points close to the median nerve were chosen.[23] In the present study, a statistically significant decrease in surface temperature was detected in cutaneous stimulation, which may be attributed to the fact that sites for the insertion of needles was chosen far from major nerves supplying the hand.

According to the findings in the present study, a musculocutaneous reaction (*i.e.*, a change in surface temperature as a result of manipulation of the muscle that might induce an increase of blood flow or metabolic changes) on needling Hegu can be excluded. An intensified blood flow in the tibialis anterior muscle after penetration with a needle was detected that might not necessarily result in an augmented cutaneous blood flow.[24] As probes had to be inserted into the muscle for evaluating modified blood flow, it is unclear if increased flow may be attributed to the insertion of the acupuncture needle only. Further investigation is crucial to correlate surface temperature and muscular blood flow.

In the present investigation, a significant decrease in surface temperature after muscular needling was observed that might be explained by activation of the sympathetic nervous system with consecutive vasoconstriction caused by local pain. After cutaneous penetration, an insignificant decrease was detected, probably resulting from a minor sympathetic response as a result of a less painful stimulus. The fact that both hands reacted the same way is captivating and might hint towards more centrally controlled processes such as sympathetic response. Regulation of peripheral blood flow and vessel diameter is mediated sympathetically; smooth muscles are innervated by postganglionic neurons.[25,26] If stimulated, norepinephrine is released and α_1 receptors are activated, resulting in a contraction of smooth muscles in the vessel wall. A decrease in sympathetic activity produces relaxation of the wall with swelling of the vessel caused by hydrostatic pressure.[27] Thus, bilateral increase in temperature may rather be initiated by a central spinal or supraspinal sympathetic rather than a local effect.[22] This finding correlates with patients' statements of a feeling of warmth and relaxation during acupuncture.[28] If increase of surface temperature after needling is mediated by the sympathetic nervous system, it could be expected that this would be a good choice in sympathetically mediated pain. On the other hand, treatment in Chinese medicine focuses on syndromes rather than symptoms and is multimodal (*i.e.*, acupuncture is combined with *tuina*, dietetics, herbal medicine, and *qi gong*), thus further investigation on this subject is inevitable. Nevertheless, Loaiza *et al.*[29] claimed that vasodilatation is initiated by increase of nitrous oxide, although the enzyme nitric oxide–synthetase is modulated by the sympathetic nervous system as well. It is crucial to test other acupoints, closely looking at other anatomical structures that might mediate the effect described above and to correlate findings with hormone and/or endorphin levels and functional magnetic resonance imaging.

Objectively measuring the effects eases the interpretation of acquired results. Training of young acupuncturists can be improved, since they would be able to trace and visualize acupuncture effects in real time. The major problem of relying solely on patients' statements can be eliminated; therapists are often unsure whether the desired effect does not emerge because of incorrect needling or if the patient is not able to sense and respond adequately, which is eminent in patients with cognitive deficits. For needling Hegu, a specific response could be observed in this investigation; still, this needs to be verified for other acupoints. As Hegu is a major acupoint manipulated in virtually every treatment, presented findings may facilitate further research and efficacy of complementary treatments can be reconsidered.

A significant increase in surface temperature occurred as soon as the needle was inserted at the acupuncture point and persisted for 30 min, whereas needling of the cutaneous and muscular point, as well as no manipulation, resulted in a decrease. Even if it is not yet apparent precisely what the pathophysiological basis is, in future research on acupuncture, sham and true acupuncture may be discriminated more easily by a nonnoxious pain–free method. Here, investigations on the measurement of sympathetic activity (*e.g.*, hormone release, microneurography), endogenous opioid release and functional magnetic resonance imaging are necessary to evaluate the exact physiologic basis. Still, infrared thermography is a valuable tool to distinguish the effects, especially in studies with placebo needling as a control.

The authors would like to thank the reviewers for their expert guidance and Frank Kozlowski (digital artist and freelancer, Norderstedt, Germany) for his valuable aid on setting up pictures as well as digital art work.

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