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Review

Ten Years Evidence-based High-Tech Acupuncture—A Short Review of Peripherally Measured Effects*

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Since 1997, the Research Unit of Biomedical Engineering in Anesthesia and Intensive Care Medicine of Graz Medical University has been dealing with the demystification of acupuncture and examining, using non-invasive methods, how different stimulation modalities (manual needle acupuncture, laserneedle acupuncture and electro acupuncture) affect peripheral and central functions. Laser is also an important instrument for acupuncture. One only needs to mention the treatment of children or of patients with needle phobia. The laserneedle acupuncture, which was examined scientifically for the first time in Graz, represents a new painless acupuncture method for which up to ten laserneedles are glued to the skin, but not stuck into it. This first part of the short review article summarizes some of the peripherally measured effects of acupuncture obtained at the Medical University of Graz within the last 10 years.

Keywords: complementary medicine – integrative medicine – laserneedle acupuncture – traditional Chinese medicine

Introduction

Traditional chinese medicine (TCM), especially acupuncture, has made many important contributions to the medicine of the world. In China and neighboring countries and regions, it has served as the basis of medical knowledge for thousands of years (1). A large number of empirical data is available, but the technical objectivation of effects of acupuncture has been intensified within the last years. Using needle, laserneedle or electrical stimulation and modern biomedical techniques, changes in peripheral and cerebral activities can be quantified (2–9). Some of the methods that are used for the assessment of peripheral (present part of the review article) and central (second part of the review article) effects in acupuncture research can be seen in Fig. 1.

In the following first part of this review lecture, some of the results obtained in the research of peripheral effects of acupuncture are described. In all investigations mentioned in this article, the test persons were informed about the procedure and gave their consent and were not under the influence of medication at the time of measurement. The studies were approved by the Ethics Committee of the Medical University of Graz.

Thermography

Thermography enables the measurement of patients' or healthy volunteers' skin surface temperature profiles without stress caused by direct contact of probes to the skin. Therefore, thermography is also a useful method for evaluating peripheral effects of acupuncture.

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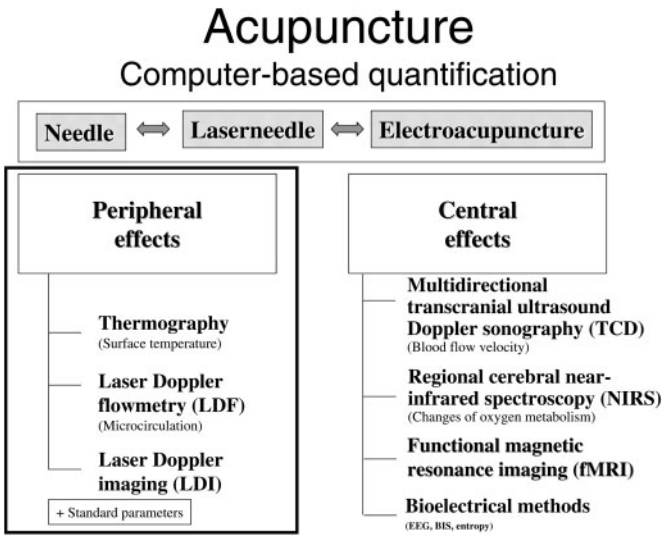

Figure 1. High-tech biomedical methods for computer-controlled quantification of peripheral and cerebral (second part of this review article) effects of acupuncture.

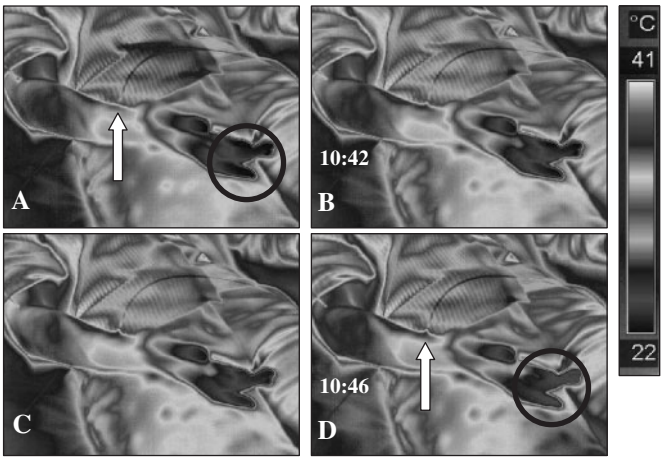

Figure 2. A characteristic example of significant initial increase in peripheral temperature during laserneedle acupuncture in a young female. Note the difference between (**A**) and (**D**) on the index finger is about +2.1°C.

For some of our investigations, the Agema ThermaCAM^{TM} P640 infrared camera system (Flir Systems Inc., Portland, USA) was used. The camera operates at a wavelength range from 7.5–13 μm.

The painless laserneedles used emitted continuous laser light at a wavelength of 685 and 785 nm. The output power is about 30–40 mW per laserneedle. Stimulation time was 10 min resulting in an energy density of 2.3 kJ cm^{-2} at each laserneedle. Further methodological details are summarized in three books and several publications (7–14).

In Fig. 2, a typical example of thermographic evaluation of peripheral effects of acupuncture is given. The two acupoints Neiguan (Pe.6) and Quchi (LI.11) were used for this study. Thermography in combination with acupuncture and meridians has been described in several articles recently (2, 15–22).

Laser Doppler Flowmetry and Laser Doppler Imaging

Laser Doppler flowmetry (LDF) is a technique used for investigating changes in microcirculation. It allows objectifying circulation within the microcapillary range without strongly influencing tissue structures. This principle is based on the Doppler shifting of light when light hits moving particles (erythrocytes) (23). LDF is particularly suitable in the field of pharmacology for comparison of measures that influence circulation, for controlling transplants and flaps in plastic surgery and for objectifying and classifying the stages of disease in angiological and dermatological research and industrial medicine (24). In addition, Flux (product of mean blood flow velocity and concentration of red blood cells) and the concentration of moving particles (erythrocytes) in the measurement volume are calculated.

The measurements described in the following were performed with the LDF-monitor DRT4 (Moore Instruments Ltd., Millwey, Axminster, England). Probe output was defined with 1 mW. Edge frequencies were 20 Hz and 3 kHz, 15 kHz or 22.5 kHz. The temperature unit (5–50°C) had a resolution of 0.2°C and an accuracy of 0.5°C. The results documented in Figs 3 and 4 were obtained with the DPIT probe (diameter 8 mm, length 7 mm).

The 'PIM II' laser Doppler imaging (LDI) perfusion measurement system from Lisca AB (Linköping, Sweden) includes a scanning head, an optoisolator unit, an AD converter and a computer. The scanning head comprises a laser unit, an optical system for gradual scanning and an optode detector unit. The optode isolator unit includes circuits for signal evaluation, stepper motor drive and circuits to guarantee galvanic isolation between the scanning head and the computer (25).

Twenty-two healthy volunteers were investigated within an LDF study (12 females, 10 males), mean age of 24.4 ± 2.6 years (21–29 years) (7, 8). After a resting period of 10 min, continuous measurement of microcirculation parameters and temperature was started. After reaching 'steady-state' conditions, the acupoint Hegu (LI.4) at the right hand was stimulated with a laserneedle.

The laserneedle was fixed to the skin at the acupuncture point with adhesive tape, after previously cleaning the skin with alcohol. The laser Doppler probe was applied at a distance of 1 cm from the laserneedle. Temperature at the measurement site and room temperature were determined for comparison.

Figure 3 summarizes the results of the three parameters Flux, hand and room temperature at the different

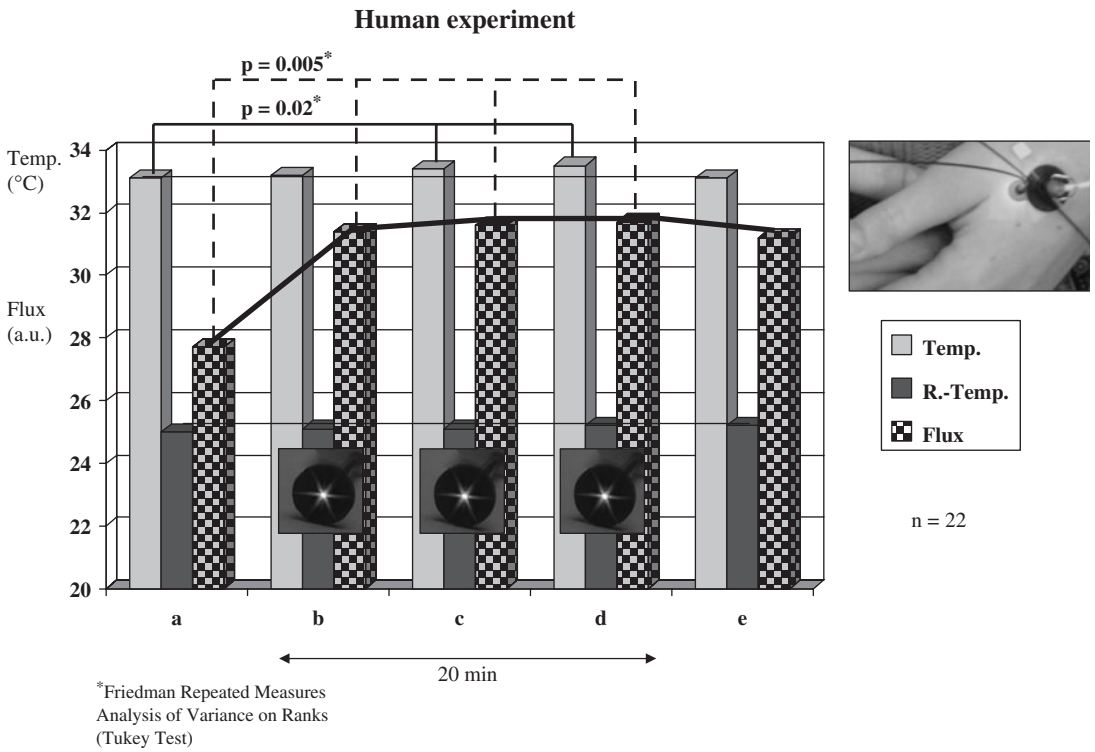

Figure 3. The results of the surface body temperature, the room temperature and Flux before, during and after laserneedle stimulation are summarized in this diagram. Flux is the product of mean flow velocity and concentration of moving red blood cells and is given in arbitrary units. Note the significant increase in the parameter during illumination. Modified from (7, 8).

measurement times. Temperatures and Flux were registered 2 min before activation of laserneedle stimulation (a), 1 min after activation (b), 10 min after activation (c), 19 min after activation = 1 min before deactivation (d) and 2 min after deactivation (e).

Observe the significant changes in Flux ($P = 0.005$) and the increase in temperature at the measurement site ($P = 0.02$). Flux was no longer significantly but still markedly higher than the initial value, even 2 min after deactivating laser stimulation (measurement time e). Temperature at the stimulation site (distance 1 cm) also showed an obvious increase, reaching its maximum at measuring time *d* (7, 8).

Measurements of microcirculation at the skin and surface skin temperature before, during and after laserneedle stimulation were also performed in animal experiments (7, 8, 14), prior to examinations in healthy volunteers. A *Sus scrofa domesticus* was anesthetized in the animal surgical unit, at the Department of Surgical Research at the University Clinic of Surgery in Graz (Fig. 4). The study was performed according to the guidelines of the Ethics Committee (animal study approval number GZ 66.010/10-BRGT/2003). Details can be found in the original publication (14) and in two books (7, 8).

Surface skin temperature and room temperature did not show any obvious changes, whereas Flux increased markedly 2 min after activation, reaching its maximum at the end of laserneedle stimulation. Thereafter, this value decreased to its initial level. The results from this animal study are comparable to the data from healthy volunteers (compare Fig. 3).

The additional examination of histological samples of pig skin revealed the following: The hematoxylin–eosin samples of the illuminated cutis did not reveal any changes in comparison with control biopsies. In particular, neither necroses of the epidermis or single keratinocytes nor changes in the endothelial cells of the dermal blood vessels were evident. No microthrombosis or extravasation could be detected (Fig. 4) (14).

Using LDI, 51 volunteers (mean age: 25.3 ± 7.6 years; 19–59 years; 33 females and 18 males) were investigated using needle acupuncture (25). The test persons were placed relaxed on a bed prior to examination. After a resting period of 10 min, continuous, non-invasive measurement of perfusion at the tip of the middle finger of the left hand was started. After reaching a 'steady-state' all patients were manually needled at the following, randomly selected acupoint (Neiguan, Pe.6) or placebo point (location: lateral from the radius 6 cun above the horizontal fold at the root of the hand) as shown in Fig. 5. According to TCM, the selected acupoint is used for treating circulatory disorders in the upper extremity.

Acupuncture was performed after local disinfection of the skin using sterile one-use needles (0.30×30 mm; Huan Qiu, Suzhou, China) and triggering of the

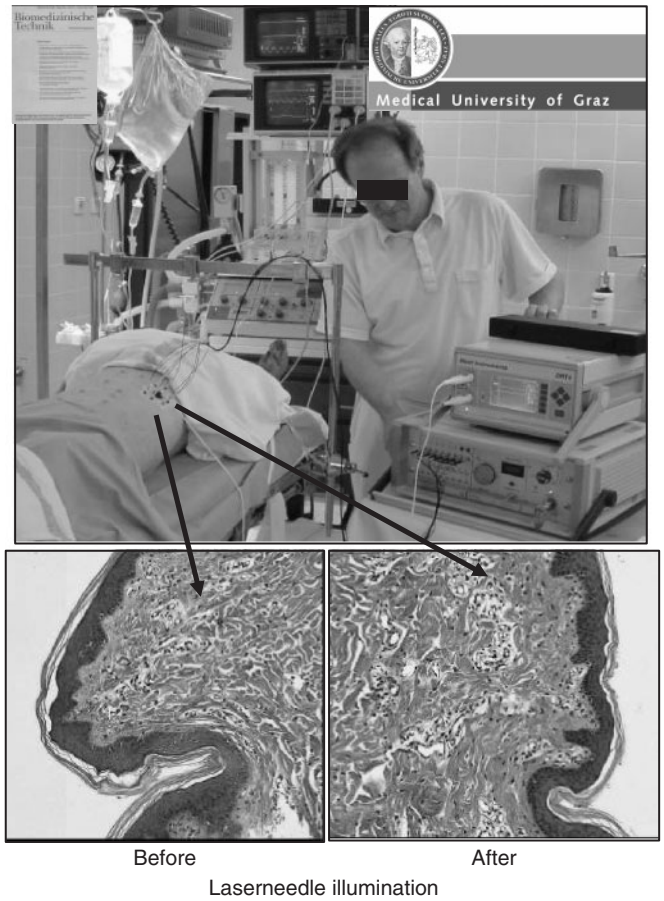

Figure 4. Animal experimental study. Results of the illuminated and non-illuminated skin. No micromorphological differences are evident [modified from (14)].

acupuncture specific De-Qi sensation. The needles were removed carefully after 10 min and the puncture site was covered with a gauze pad. The analogous procedure was performed when needling the placebo point. In each case, the second measurement was performed within an interval of 2 h to 1 day after the first measurement (25).

Specific changes in 'mean perfusion' (mean value of region of interest) measured in Volt were used as an evaluative parameter for quantifying changes in microcirculation at the finger region. Figure 6 shows the relative comparison of microcirculation-influencing procedures (acupuncture/placebo) at the tip of the middle finger in a 42-year-old volunteer. The pictures show a marked decrease in perfusion immediately after needling the acupoint and the placebo point. However, 1 min later, an obvious increase in microcirculation only occurs when the acupoint is needled.

Perfusion significantly ($P \leq 0.001$, ANOVA) decreased initially at the acupoint in 51 persons. This phenomenon was not evident to this extent at the placebo point. Thereafter, a significant increase in mean perfusion values took place in both cases after about 1 min, reaching a higher level at the acupoint than at the placebo point, as demonstrated in Fig. 6 (25).

Conclusion

Bioengineering assessment of acupuncture using new modern technologies (2–6), including neurophysiological (26) and neurobiological (27) methods, can give evidence-based insight into different effects of acupuncture in the periphery and in the brain (second part of the review article).

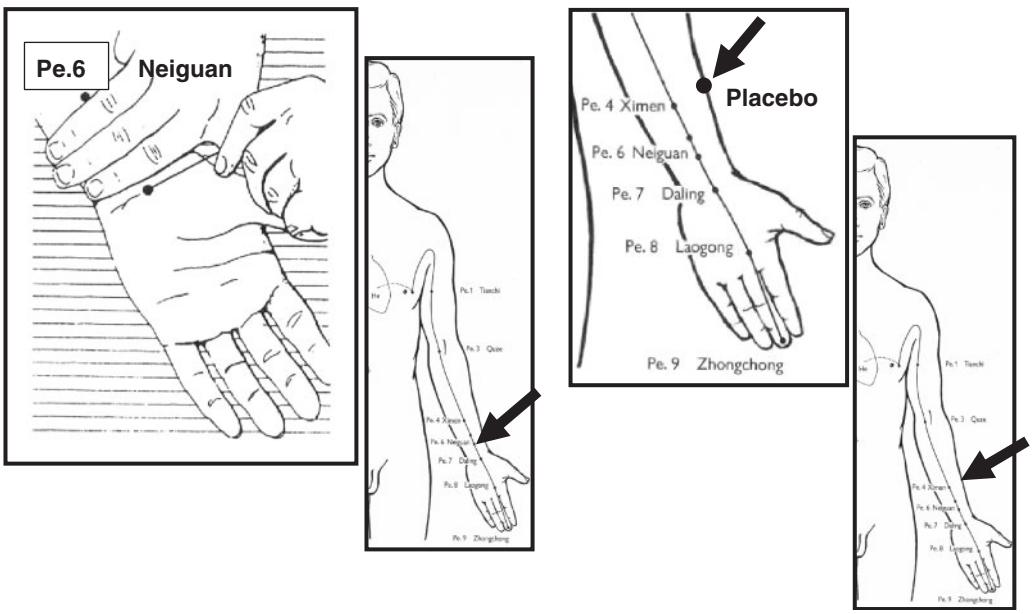

Figure 5. Acupoint Neiguan (left) and placebo point (right).

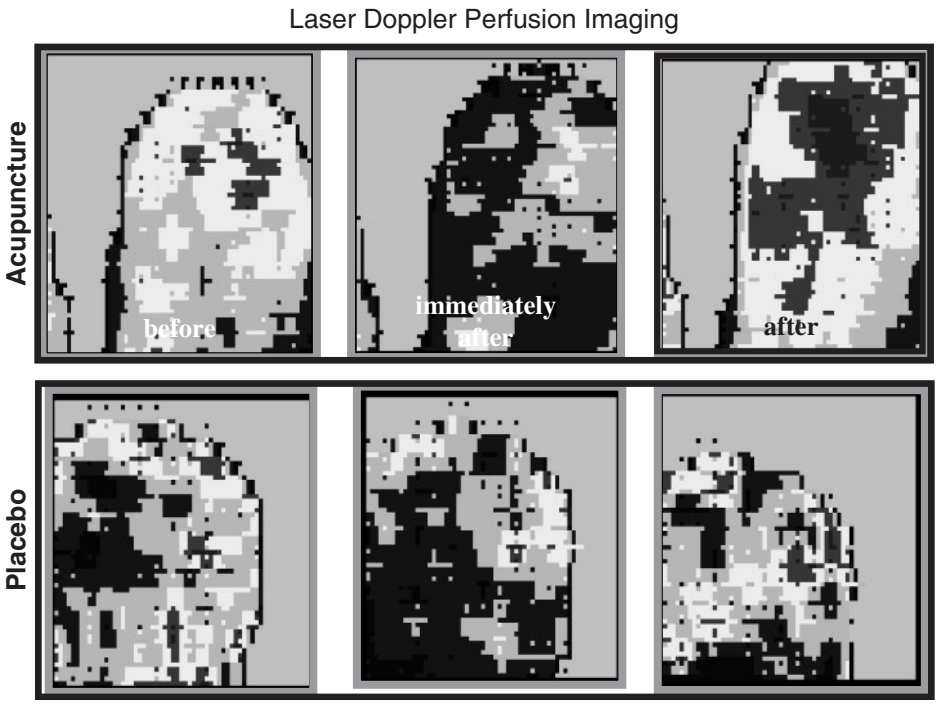

Figure 6. Significant differences were revealed in the behavior of the perfusion after the insertion and stimulation of an acupuncture needle at a real acupuncture point and a placebo point. At both the placebo point and the acupuncture point, there was initially a short-term reduction of perfusion through vasoconstriction (middle). This, however, was followed by a massive increase of perfusion at the acupuncture point, which did not occur to this extent at the placebo point (right). Modified from (25).

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