Modernization of Traditional Acupuncture Using Multimodal Computer-based High-tech Methods—Recent Results of Blue Laser and Teleacupuncture From the Medical University of Graz

Gerhard Litscher*

Research Unit of Biomedical Engineering in Anesthesia and Intensive Care Medicine and TCM (Traditional Chinese Medicine) Research Center, Medical University of Graz, Austria

Abstract
Basic and clinical research in traditional Chinese and Korean acupuncture has been performed at the Research Unit of Biomedical Engineering in Anesthesia and Intensive Care Medicine and the Traditional Chinese Medicine Research Center at the Medical University of Graz since 1997. This publication focuses on the latest innovative aspects that underline the further enhancement and development of acupuncture. In this context, novel biomedical and neuroscientific methods are of paramount importance for the fast and efficient modernization of the ancient Asian healing method. Traditional and future oriented acupuncture stimulation methods can be divided into manual needle, laser needle (blue, red and infrared laser light) and electrical punctual stimulation at the body, hand and ear. Special emphasis in this research article is given to totally new technical and methodological investigations, e.g. the first data published worldwide in medicine obtained with new blue laser acupuncture equipment. In this regard, critical summary and recent results from peripheral and central measurements during acupuncture stimulation using high-tech bioengineering assessment are given. In addition, we describe the first teleacupuncture performed between Asia and Europe.

1. Introduction
Acupuncture is one of the oldest medical procedures in the world. This branch of contemporary medicine has its origin in Asia and has served as the basis of medical knowledge for thousands of years.

Acupuncture aims to maintain and restore health through balancing the body’s energy system. The term acupuncture encompasses a broad spectrum of procedures including stimulation methods such as manual needle acupuncture, laser needle acupuncture or electrical acupuncture. A large number...
of empirical data is available, but the technical quantification of effects of acupuncture has only been intensified within recent years [1−10]. In this context our research group performed pioneering work and more than 200 publications were published on the topic of high-tech acupuncture within the last 12 years [see http://litscher.info and also www.pubmed.gov (Litscher G)].

The aim of this research article is to describe innovative acupuncture stimulation, i.e. the first measurements with a blue laser needle in acupuncture research. Furthermore, recording methods for quantifying specific effects of this old Asian treatment method without the loss of traditional and holistic unique characteristics are also discussed. In addition, the first teleacupuncture performed between Asia and Europe this year (2009) is described.

2. Materials and Methods

With the help of specially designed new acupuncture stimulation and measurement techniques, unique investigations were performed within this medical bioengineering study (e.g. acupuncture stimulation using blue laser). Figure 1 shows some of the computer-based high-tech methods that are used for assessment of peripheral and central effects of acupuncture in our Traditional Chinese Medicine (TCM) Research Center [1−10].

2.1. Thermography (thermal imaging)

Thermal imaging enables the measurement of healthy volunteers’ or patients’ skin surface temperature profiles without direct contact of sensors to the skin [1]. Several infrared cameras at different wavelength ranges (2−5μm and 7.5−13μm) were used for thermographic control of possible stimulation effects in our laboratory. For the present study a new FLIR i5 infrared camera (Flir Systems Inc., Portland, USA) operated at a wavelength range from 7.5−13μm. Temperature measurements were possible in the range between 0ºC and +250ºC. The data were transferred to a notebook using ThermaCAM Researchers Pro 2.8 software (Flir Systems Inc., Portland, USA).

2.2. Laser Doppler flowmetry (LDF) and laser Doppler imaging (LDI)

LDF and LDI provide non-invasive real-time measurements of local tissue blood flow. Using these types of biomedical methods, it is possible to quantify and objectify peripheral changes in microcirculation during different methods of acupuncture stimulation [2]. Flux (= product of mean blood flow velocity and concentration of red blood cells) is calculated automatically. The measurements described in this article were performed with the LDF-monitor DRT4 (Moore Instruments Ltd., Millwey, Axminster, UK). Edge frequencies were 20Hz and 22.5kHz. The temperature unit (5−50ºC) had a resolution of 0.2ºC and an accuracy of 0.5ºC. A special probe (DP3s S/N 00166, diameter 1.3mm) was designed for recordings at a distance of 1 mm to a blue laser needle and a commercially available probe (DPIT, diameter 8 mm, length 7 mm) was used for the index finger. This point was chosen as a further recording location for control purposes following previous investigations [8].

Figure 1  High-tech multimodal biomedical methods for computer-based stimulation and quantification of peripheral and central effects of acupuncture used at the TCM Research Center Graz at the Medical University of Graz, Austria.
2.3. Multidirectional functional transcranial ultrasound Doppler monitoring (fTCD)

New constructions from the Medical University of Graz can be used for evidence-based computer-controlled acupuncture. With these new methods and concepts, reproducible effects of needle and laser needle acupuncture stimulation in cerebral blood flow velocity can be quantified for the first time [3] (see Figure 2).

2.4. Cerebral near infrared spectroscopy (NIRS)

Near infrared spectroscopy is used to measure regional changes in oxyhemoglobin and deoxyhemoglobin non-invasively and continuously. Because of its non-invasive approach, the NIRS method allows the evaluation of cerebral oxygenation through the intact skull and is of great importance in modern acupuncture research [5].

2.5. Teleacupuncture and heart rate variability (HRV)

Heart rate variability is measured as the percentage change in sequential chamber complexes (RR-intervals) in the electrocardiogram (ECG) which is controlled by the blood pressure control system, influenced by the hypothalamus, and, in particular, controlled by the vagal cardiovascular center in the lower brainstem [7]. In the first teleacupuncture pilot study, 24-hour ECG recordings performed at the China Academy of Chinese Medical Sciences in Beijing are presented. The ECG was recorded with a sampling rate of 4096 Hz using a system partially developed in Austria (Medilog AR 12, Huntleigh Healthcare, Cardiff, UK).

2.6. Acupuncture and other innovative stimulation methods (laser needles)

Besides manual needle acupuncture, laser needle acupuncture is a new optical method for stimulating different acupoints. The painless laser needles developed in 2002 [11] used continuously emitted or frequency-modulated laser light at wavelengths of 685 and 785 nm (red and infrared laser light). The output power was about 30–40 mW per laser needle. Stimulation time was 10 minutes, resulting in an energy density of approximately 20 J/cm² at each laser needle. Further methodological details are summarized in several publications [11–13] and also in a scientific book, published in Korean [14]. Painless blue laser light (wavelength: 405 nm; output power: 110 mW; diameter: 500 μm; activation: 10 minutes) was used for the first time in this scientific acupuncture study (Figure 3).

2.7. Subjects

Using the different methods described above, more than 400 volunteers and patients (suffering from pain, eye diseases and other age-related diseases) were investigated at the Medical University of Graz. For example, NIRS measurements were successfully used in 88 healthy volunteers with a mean age of 25.7 ± 4.0 years (x̄ ± SD; range 19–38; [15]).

Within the following result section, hitherto unpublished examples from acupuncture measurements
using blue laser will be presented. The aim of the present study was to investigate specific temperature and microcirculation effects of blue/violet laser acupuncture by stimulating the acupoint Hegu (LI.4), using a continuous beam. The changes of temperature and blood circulation were quantified in the area around this acupoint (distance: 1 mm) and at the fingertip of the index finger before, during and after stimulation in 15 healthy volunteers (mean age: 27.9 ± 5.6 years, range 22–35 years; 11 females, four males). Infrared thermal imaging (see 2.1) and a laser Doppler system (see 2.2) were used. This study was approved by the local ethics committee and written informed consent was obtained from all participants.

2.8. Statistical analysis

Flux and temperature data were graphically presented as box plots. Data were compared using paired t-test using SigmaStat software (Jandel Scientific Corp., Erkrath, Germany). Changes were considered significant at a p value < 0.05.

3. Results

3.1. Specific effects of cerebral blood flow velocity during acupuncture

The stimulation of acupuncture points, which according to traditional Chinese medicine improve vision [Zanzhu (UB.2), Yuyao (Ex.3), Sizhukong (SJ.23), Tongziliao (GB.1), Yanglao (SI.6) and Guangming (GB.37)], led to an increased blood flow velocity in the ophthalmic artery. Apart from the blood flow velocity the regional cerebral oxygen saturation also changed. The stimulation of points, which according to TCM are to increase brain function, generally leads to a significant increase in the flow velocity of the middle cerebral artery [3,11,15].

3.2. The first results using the “blue laser acupuncture needle”

The first investigations of blue laser stimulation yielded very interesting results. Eighty percent of the subjects felt the stimulation performed on the acupoint similar to deQi-sensation. In contrast, using red or infrared laser stimulation 5 to 10% of the subjects reported immediate deQi-sensation. There were significant increases in temperature ($p \leq 0.001$) and flux ($p \leq 0.001$) during blue laser acupuncture at the acupoint Hegu (LI.4; Figure 4). Five minutes after acupuncture, flux at this location was still significantly increased ($p \leq 0.001$), temperature showed values similar to baseline ($p = 0.185$). There was no significant effect in temperature and flux at the tip of the index finger (Figure 5).

3.3. The first teleacupuncture

The aim of this biomedical pilot study was to investigate teleacupuncture using computer-controlled HRV analysis in the time and frequency domain over long
distances (transcontinentally) using common internet connections (Figure 6). As modern internet connections allow a transfer of more than 100 Mbit/s, even the real online transfer of a high-resolution ECG signal with an adequate sampling rate should not be a problem in the future. The raw data were transferred via internet to the TCM Research Center of Graz in Austria from the patients’ site computer in Beijing to the control site computer in Graz (distance: 7,650 km). Data analysis of different parameters of heart rate and HRV in the time and frequency domain [7] was performed instantly for control of possible therapeutic effects of acupuncture. The acupuncturist and the monitoring expert were informed about the findings immediately and the success of the therapy could be demonstrated objectively. The example in Figure 6 shows the first teleacupuncture measurement.

4. Discussion

4.1. Modernization of acupuncture using high-tech methods

Acupuncture is gradually gaining prominence as a health care modality in the modern world. The growth in popularity of such an ancient practice is a noteworthy phenomenon. Within the past century, scientific and technological progress has truly revolutionized Eastern and Western experimental and clinical medicine. This century was certainly the most innovative phase in medical history. Our research group has made various efforts within the last 12 years to modernize acupuncture, one of the most spectacular of Asian medical procedures. For this reason we have developed and scientifically investigated new stimulation and measurement methods for quantifying the effects of acupuncture [1−16] and moxibustion [17]. We used manual needle acupuncture, laser needle acupuncture and electrical methods for the application of stimuli at acupoints [18]. The usage of advanced exploratory tools such as multidirectional transcranial Doppler ultrasound sonography [3,9,11], cerebral near infrared spectroscopy [5,9,15], functional magnetic resonance imaging [4], different bioelectrical methods [6,9,19–21] and other highly sophisticated biomedical equipment, provides revealing insights. The obtained results are absolutely necessary for the acceptance of acupuncture by the Western medical community. Using these new techniques, the first double-blind studies in acupuncture research using painless laser needles and the first transcontinental multi-center studies in this area of modern research have already been performed [1−10,17,22,23].

Back in 1997, our interdisciplinary research group from the Medical University of Graz was able to scientifically prove that manual needle acupuncture can increase blood flow velocity in the brain [24,25]. The computer- and robotic-controlled biosensors...
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and probes integrated in a special measurement helmet, coupled with light, ultrasound and highly sensitive bioelectrical monitoring methods yielded reproducible results indicating that the blood flow velocity in the middle cerebral artery is higher, and the oxygen supply in the brain is increased by acupuncture in healthy volunteers [3,5,25].

In 1998, a further step for validating the old Chinese treatment method was achieved. In tests with healthy volunteers, proof that acupuncture leads not only to general changes in blood flow velocity in the brain but also to specific changes (i.e. different regional localization) could be documented. Thus, stimulation of distant acupoints on the hand and foot, which according to TCM are often connected to the optical system, lead to an increase in blood flow velocity in the cerebral artery responsible for vision. At the same time, the blood flow velocity in other cerebral arteries remained nearly unchanged. Comparative investigation of other acupoints of the foot did not show changes in blood flow velocity in this particular cerebral artery [3,5].

Selective proof of the specific effects of particular acupoints regarding changes in blood flow velocity can be determined with a multidirectional probe holder. Therefore, simultaneous registration of flow profile patterns in the middle cerebral artery, supratrochlear artery and ophthalmic artery are possible (see Figure 2) [16].

More recently, laser needles for acupuncture are applied at the skin but are not inserted into the skin. This non-invasive, painless laser stimulation can induce reproducible peripheral and specific cerebral changes. These changes are expressed by the shifting of different parameters such as cerebral blood flow velocity (compare 3.1). The effects of the red and infrared laser needles could
be objectified and quantified using modern neuromonitoring methods described in the methods section. Thus far, about 200 scientific studies and six books have been published regarding High-Tech Acupuncture (Computer-Controlled Acupuncture®) by our research group. Some of the research in the field of high-tech acupuncture is illustrated in the spectrum of methods in Figure 1.

4.2. “Blue laser acupuncture”

In this research article, the first medical data in acupuncture research obtained with a blue laser beam are presented. This kind of laser is new and has only been used in industrial applications (Blu-ray disc) and in only a few medical procedures [26,27]. There are currently no published data available in medical acupuncture (www.pubmed.gov).

Many people nowadays are fascinated by the term laser. Innovation and laser have nearly become synonyms. Laser is also an important instrument for acupuncture. One only needs to mention the treatment of children or of patients with needle phobia. In this way, individual combinations of acupuncture points can be stimulated simultaneously according to TCM. In the context of double-blind studies (neither the acupuncturist nor the patient knew whether the stimulation was activated or deactivated) effects in the brain could be demonstrated in a reproducible manner for the first time [13,14].

Blue laser light with a wavelength of 405 nm, which appears to the eye as violet, may represent a new approach to high-tech acupuncture research. First results, as shown in this manuscript, are promising. Although the blue laser does not have the same penetration depth as the red and infrared laser (blue: approximately 2 mm vs. red/infrared: 2–3 cm [13,14]), the evoked deQi-sensation, which is a prerequisite for effective acupuncture stimulation, may warrant the future use of blue lasers in acupuncture research. Further studies using this new kind of technology in medical research are in progress.

4.3. The first teleacupuncture

Telecommunication technology includes the assisted transmission of signals and biological data over a distance. In this context, telemedicine like telesurgery and also teleanesthesiology have become more interesting [28]. However, teleacupuncture has not yet been performed.

The first realization of teleacupuncture demonstrates that automated teletherapeutic procedures can be performed even over a long distance.
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acupuncture research. The ability to heal illnesses with laser light acupuncture with a wavelength of 405 nm may also represent a new approach to high-tech acupuncture research. The ability to heal illnesses and relieve pain with teleacupuncture is no longer a future vision. It has already become reality.

Acknowledgments

The author thanks Ms. Lu Wang, MD LA for performing acupuncture and Ms. Ingrid Gaischek, MSc, for her valuable support in data registration and analysis. Both of these contributors are from the Research Unit of Biomedical Engineering in Anesthesia and Intensive Care Medicine and the TCM Research Center Graz, Medical University of Graz.

The study was supported partially by the Zukunftsfonds of the Styrian Government (project 4071) and is part of the project “Bioengineering and clinical assessment of high-tech acupuncture: a Sino-Austrian research pilot study”, supported by the Austrian Federal Ministries of Science and Research and of Health and the Eurasia Pacific Uninet.

The following scientists delivered valuable contributions: Weibo Zhang (Beijing, China), Seung-Ho Yi (Seoul, Korea), Lu Wang (Graz, Austria), Tao Huang (Beijing, China), Ingrid Gaischek (Graz, Austria), Zheng Xie (Beijing, China, and Graz, Austria), Jan Valentini (Beijing, China, and Graz, Austria). The author wishes to sincerely thank everyone.

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