ARTICLE

# NIR spectroscopy explores the mysteries of acupuncture

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## Introduction

Whereas initially only electrophysiologic techniques allowed non-invasive functional studies of the human brain, the advent of modern methods and systems such as functional magnetic resonance imaging (fMRI) and transcranial ultrasound Doppler sonography have increasingly improved the field of neuromonitoring over the past decade. At the same time, Traditional Chinese Medicine (TCM), especially acupuncture, has become more widely practiced in the West. The World Health Organisation has published a comprehensive list of diseases that can be treated with acupuncture.

Our research group has shown for the first time that, when particular acupuncture points are stimulated with needles or laser light, specific effects in the brain can be made objective and quantified with the new modern cerebral monitoring methods mentioned above, see Figure 1. In this article we describe systematic changes of oxygenation in the brain using regional cerebral near infrared (NIR) spectroscopy after stimulating acupuncture points according to TCM, Korean and Chinese hand acupuncture, ear acupuncture and combinations of these methods.

## Cerebral near infrared spectroscopy

The NIR spectroscopy method allows the evaluation of changes in cerebral oxygenation through the intact skull and is gaining importance in acupuncture research because of its non-invasive approach (Figure 2).[1] The NIRO 300, 200 and 100 Monitors (Hamamatsu Photonics, Japan) are new instruments in this field of research. Parameters such as changes in oxyhaemoglobin ($\Delta O_2Hb$) and desoxyhaemoglobin ($\Delta HHb$) are determined by applying the Lambert–Beer's Law principle. The systems can measure the absolute value (µmol) of changes (either positive or negative), but not the level (absolute concentration) at which these changes occur. The measurement value is zero as long as no change in concentration occurs. Placement of the sensor (emitter and NIR detectors) on the patient's head with a silicone holder is easy and reproducible (cf. Figure 2). Data output of $\Delta O_2Hb$ and $\Delta HHb$ are presented on a colour LCD display and colour printer. In addition the INVOS® NIR cerebral oximeter 5100 (Somanetics, Troy, USA) was used within this study

**Figure 1.** Exploring acupuncture: ancient ideas – modern techniques. Biomedical Engineering Lab at the Medical University of Graz.

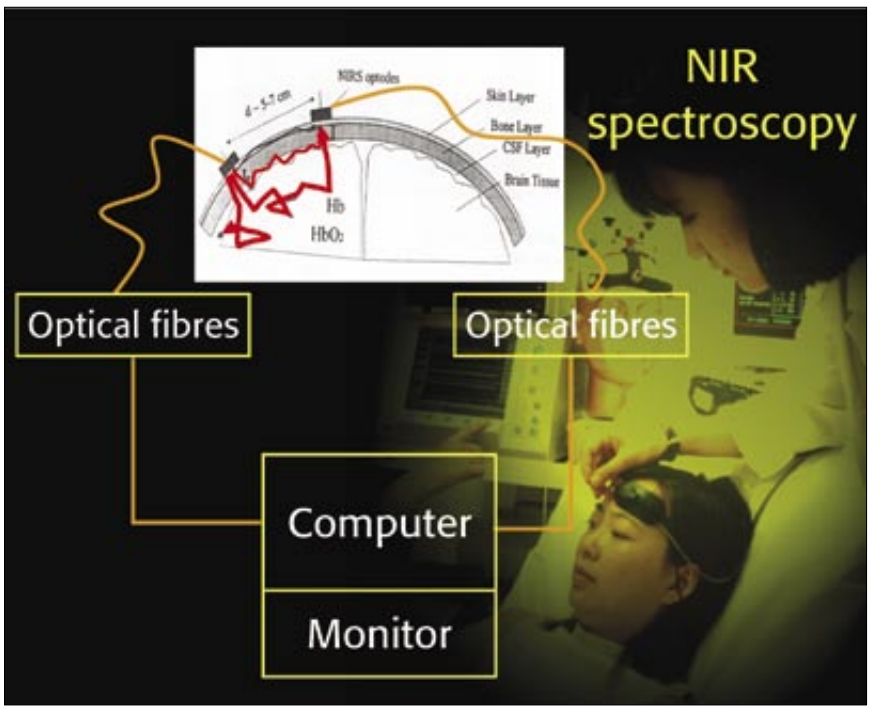


**Figure 2.** Schematic diagram showing the principles for regional cerebral NIR spectroscopy.

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**Figure 3.** Laserneedle acupuncture stimulation and recording of cerebral biosignals

before, during and after different modalities of stimulation (cf. Figure 5).

## Laserneedle acupuncture

Laserneedles allow the stimulation of appropriate acupoint combinations simultaneously and with higher radiation doses and therefore represent a new non-invasive optical stimulation, which is described for the first time in reports in the scientific literature by our research group (Figure 3).[2–7] In previous studies we were able to demonstrate that cerebral responses of laserneedles are equivalent to needle acupuncture (see Figure 4).

The laserneedles used in this study emit red light in continuous wave (cw) and pulsatile modes with an output power of 30–40 mW per laserneedle, which results in a radiant exposure energy of about 2.3 kJ cm$^{-2}$ at each acupuncture point during a treatment time of about 10 min.

## Healthy volunteers and acupuncture

We report in this article about the investigations of two male infants (three-and-a-half and nine years of age) and of 328 measurements on 88 healthy volunteers (50 female, 38 male), mean age 25.7±4.0 ($\bar{x}$±SD) years (19–38 years).[5] All persons gave their written consent and the ethics committee of the Medical University of Graz approved the study protocols.

A maximum of seven acupuncture points using different measurement series (needle acupuncture and laserneedle acupuncture) were investigated. The acupuncture scheme included two acupuncture points from TCM: Zanzhu (localisation: at the medial end of the eyebrow, perpendicular to and above the inner corner of the eye, at the foramina of the supraorbital nerve; needling: perpendicular 0.5–0.8 cun) and Yuyao (localisation: at the middle of the eyebrow, perpendicular and above the pupil; needling: inclined 0.3–0.5 cun). In addition, two ear acupuncture points (eye and liver; needling: inclined 0.3 cun) and two eye acupuncture points from Korean hand acupuncture (E2; needling: perpendicular 0.1–0.2 cun) and one acupuncture point from Chinese hand acupuncture (Yan Dian: on the ulnar side of the middle phalanx of the thumb; needling: inclined 0.2 cun) were included in the study.[2,3,5]

Possible responses in NIR spectroscopy parameters after needling and stimulating of a placebo point (localisation: lateral from the radius 6 cun above the horizontal fold of the wrist exactly on the radial ledge, lateral from the pulmonary meridian) were tested.

The different acupuncture schemes were applied alone and in combination, since preliminary studies indicated that the selection of different combinations also results in different effects in the cerebral parameters to be measured (e.g. blood flow velocity in the ophthalmic artery).[2–4]

Acupuncture points were needled with single-use needles after local disinfections

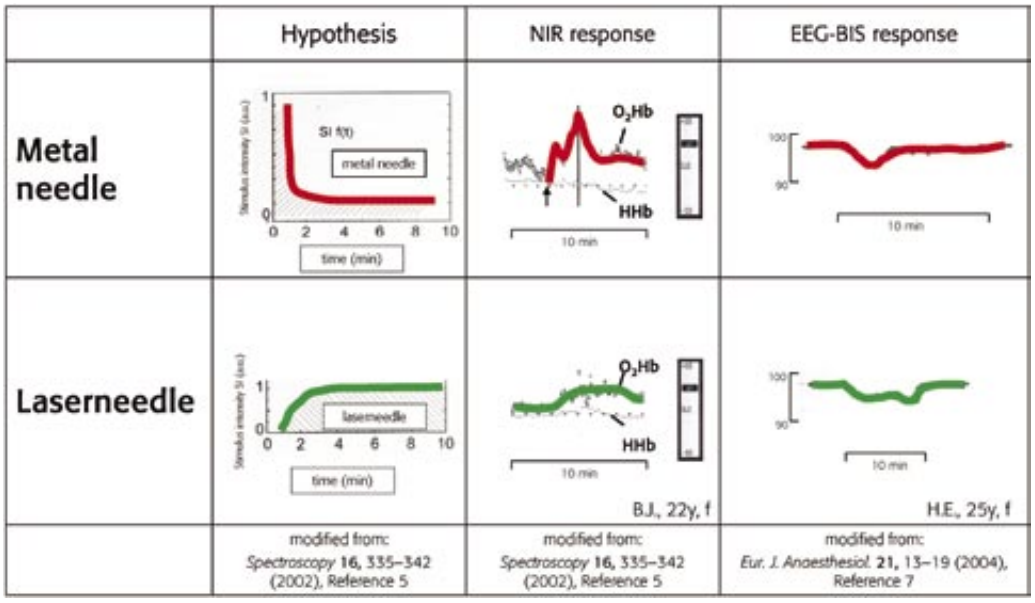


**Figure 4.** Stimulus intensity (SI) as a function of time. From left to right: hypothesis, real measured cerebral reaction of NIR spectroscopy measurement parameters $O_2Hb$ (oxyhaemoglobin) and HHb (desoxyhaemoglobin), and bioelectric response (BIS = Bispectral index). Figure modified from References 5 and 7.

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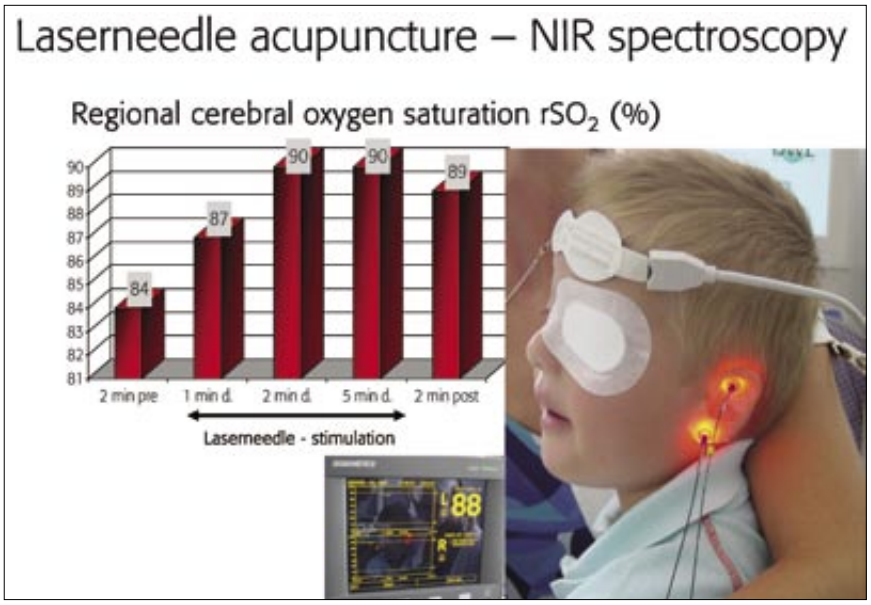


**Figure 5.** Regional cerebral oxygen saturation ($rSO_2$) in a three-and-a-half year old infant 2 min prior to (pre), during (d) and 2 min after (post) laserneedle stimulation.

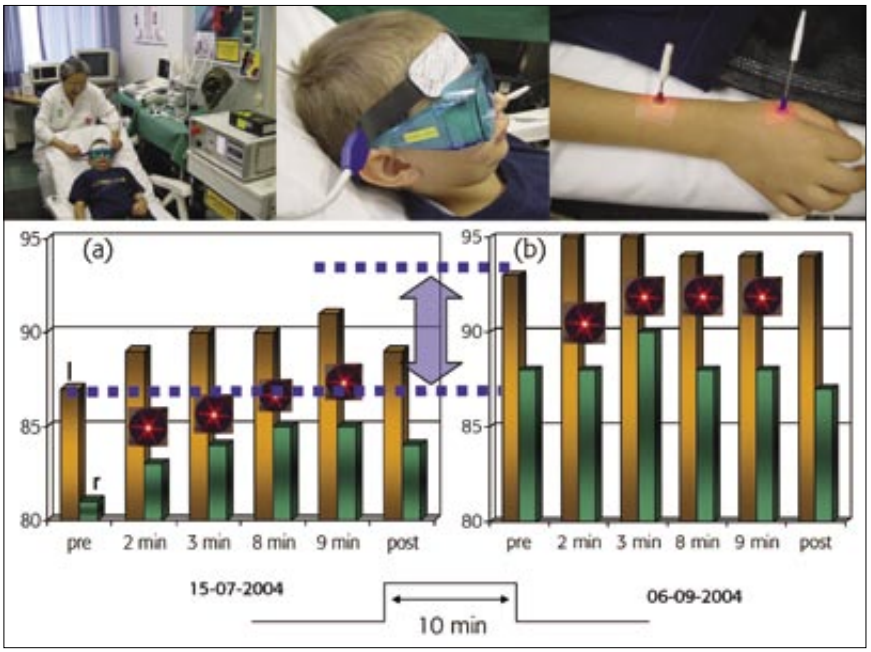


**Figure 6.** NIR spectroscopy of a nine year old infant before (pre), during (2–9 min) and after (post) laserneedle stimulation (for 10 min). The diagrams show frontal cerebral oxygen saturation values on both sides (left = 1and right = r) at the beginning of acupuncture treatment on (a) 15 July 2004 and at the end of the treatment series on (b) 6 September 2004. Note the increase in regional cerebral oxygen saturation on both sides (see arrow).

of the skin. We used three different types of needles (body: 0.25 × 25 mm, Huan Qiu, Suzhou, China; ear: 0.2 × 13 mm, European Marco Polo Comp., Albi, France; hand: 0.1 × 8 mm, Sooji-Chim, Korea). Stimulation was performed with simultaneous rotating, pulling and thrusting movements of medium intensity.

In the case of laserneedle acupuncture, the skin at the acupuncture point was cleaned with alcohol; the laserneedle was positioned at the surface of the skin and then fixated with special adhesive tape. We used the same acupuncture schemes as in the combined measurements using needle acupuncture.

During the experimental phase, the test persons were positioned in a relaxed manner on a lounge. After applying the NIR spectroscopic sensors to the frontal area of the skull, a 10 min resting period was observed. Then, either laserneedle stimulation was activated or the acupuncture needles were inserted and stimulated for 10 s. Thereafter, the laser was activated for 10 min or the needles were left alone. The maximum amplitude of $\Delta O_2Hb$ and $\Delta HHb$ (phase during acupuncture) was analysed during this period of time. Randomised selection of which technique should be started with, as well as selection of the sequence of the particular type of stimulation (body, ear, hand, combination) was done. The resting period between each investigation was at least 30 min.

## Results

Figure 5 shows a typical increase of regional cerebral oxygen saturation ($rSO_2$) values during laserneedle stimulation in a three-and-a-half year old infant after an impression-fracture and oculomotoriusparesis. The ear points Shenmen and eye were stimulated (see Figure 5).

Similar results were found in a nine year old infant with asthma. The following acupoints were stimulated using laser light: Yingxiang, Hegu, Kung Tzuei (Figure 6).

Figure 7 shows the mean values of maximum change in $O_2Hb$ parameter during and 5 min after manual needle acupuncture and laserneedle acupuncture in 88 healthy volunteers. Needling and stimulation of the placebo point does not lead to marked changes in cerebral NIR spectroscopy parameters during and 5 min after acupuncture. Manual needling and laserneedle stimulation of acupoints leads to a marked increase in $O_2Hb$ and a simultaneous decrease in HHb[5] when using the combined Korean hand acupuncture (E2) and Chinese hand acupuncture (Yan Dian), as well as TCM-body (Zhanzu and Yuyao) acupuncture, as well as combined body, ear and hand acupuncture. This effect is still

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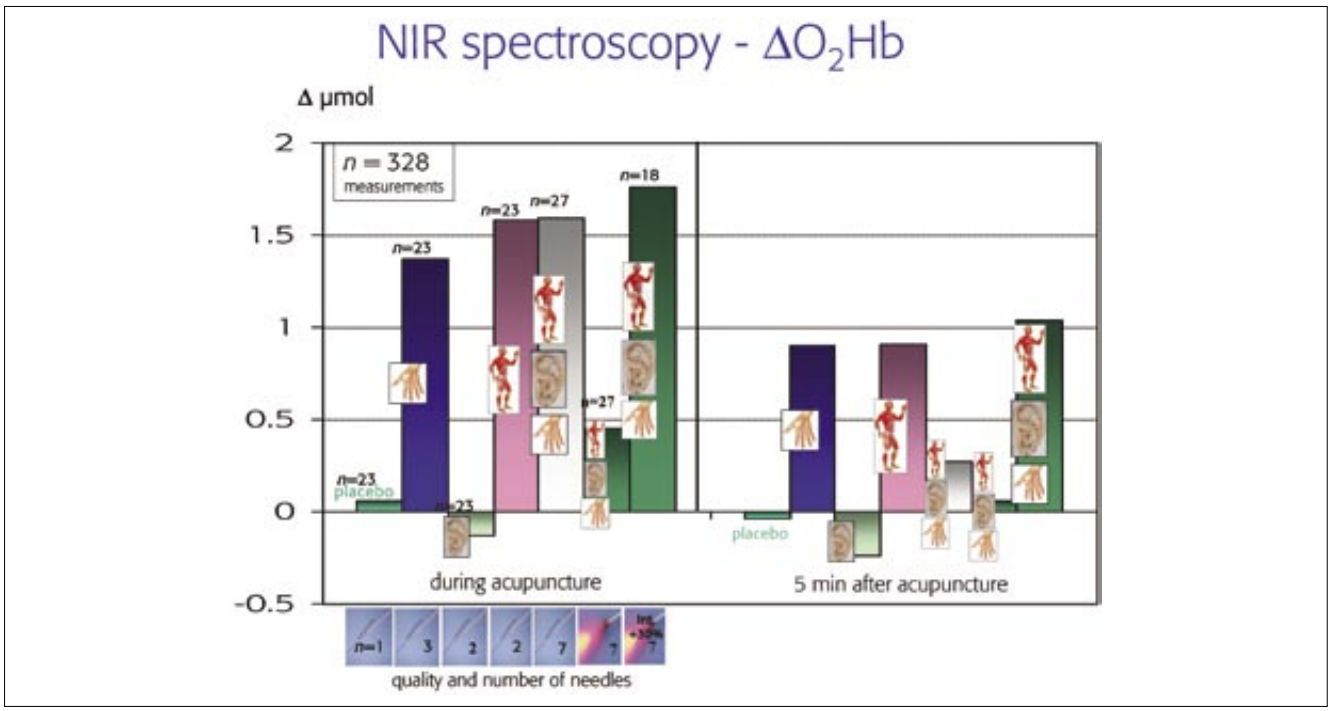


**Figure 7.** Changes in µmol of oxyhaemoglobin ($O_2Hb$) during needling of a placebo point, three hand acupuncture points, two ear acupuncture points, two acupuncture points from TCM, a combination of hand, ear and body acupuncture as well as laserneedle stimulation and an intensity-increased (+30%) laserneedle acupuncture (from left to right) during and 5 min after acupuncture.

present 5 min after removing the needles or deactivating the laser stimulation.

## Discussion

Cerebral oximetry uses NIR spectroscopy to evaluate changes in cerebral oxygenation non-invasively and continuously. Its operation relies on two basic facts. First, NIR light passes through human tissue, including bone. Second, haemoglobin is the predominant absorbing substance in the NIR range. Because haemoglobin changes colour as it binds with oxygen, evaluating the relative absorption of two or more wavelengths of light can provide information on the relative concentrations of oxy- and desoxyhaemoglobin. While knowledge of the distance over which the light passes is important, devices in use today either incorporate means to measure the light path length[8] or cancel its effect.[9]

Devices currently in use measure oxygen saturation of all the blood in the vascular bed, which is typically 70–80% venous and capillary with the remainder arterial.[10] Measurements are presented as either a saturation index ($rSO_2$) or total oxygen index (TOI). This venous-weighted average reflects change in the balance between cerebral oxygen supply and demand.

The goal of this article was to give a summary about clinical experimental studies dealing with new methods of NIR spectroscopy and optical acupuncture stimulation. Since the volunteer or patient does not feel the intervention, the different acupoints can be stimulated continuously and simultaneously. Double-blind, randomised, controlled crossover studies indicated that cerebral effects of this manner of stimulation are nearly equivalent to that of needles. The findings may be of great importance, not only for the field of spectroscopy and laser medicine but also for acupuncture research in general.

Scientists agree that the 21st century will be the century of photons, as the past 20th century was that of the electrons.[3]

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