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Original Article

Effects of acupressure, manual acupuncture and Laserneedle® acupuncture on EEG bispectral index and spectral edge frequency in healthy volunteers

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Summary

Background and objective: The main purpose of this study was to investigate the effects of sensory (acupressure and acupuncture) and optical stimulation (Laserneedle® acupuncture) on electroencephalographic bispectral index, spectral edge frequency and a verbal sedation score.

Methods: Twenty-five healthy volunteers (mean age ± SD: 25.5 ± 4.0 yr) were investigated during the awake state. The acupuncture point Yintang and a placebo control point were stimulated. The study was performed as a randomized, controlled and partly blinded cross-over trial.

Results: Bispectral index and spectral edge frequency values both decreased significantly ($P < 0.001$) during acupressure on Yintang to values of 62.9 (minimum 35) ± 13.9 bispectral index and to 13.3 (minimum 2.9) ± 8.1 Hz (spectral edge frequency right) and 13.8 (minimum 2.7) ± 7.3 Hz (spectral edge frequency left), respectively. Bispectral index was also significantly ($P < 0.05$) affected by Laserneedle® acupuncture and acupressure on the control point but the changes were not clinically relevant, 95.4 ± 4 and 94.2 ± 4.8, respectively. All interventions significantly (Yintang: $P < 0.001$; control point: $P < 0.012$) reduced verbal sedation score.

Conclusions: The study highlights the electroencephalographic similarities of acupressure induced sedation and general anaesthesia as assessed by bispectral index and spectral edge frequency.

Keywords: ACUPRESSURE; ACUPUNCTURE; ELECTROENCEPHALOGRAPHY, bispectral index, spectral edge frequency.

Noninvasive bioelectrical neuromonitoring is gaining more and more attention in anaesthesia and critical care [1,2]. The bispectral index (BIS) and the spectral edge frequency (SEF) are important numerical descriptors of the electroencephalogram (EEG) and both are mainly used for assessing depth of anaesthesia [3]. If anaesthetists rely on BIS and SEF to detect awareness, then it is very important to exclude other influences that could give false readings. It is known that a number of environmental and physiological factors may affect BIS performance. Recently it has been reported that nonpharmacological interventions such as acupressure can also reduce BIS values significantly [4].

This study is a randomized, controlled and partly blinded (Laserneedle® acupuncture; LASCO Int. Medical Mark. AG, Basel, Switzerland) cross-over trial intended to investigate the effects of three nonpharmacological interventions (acupressure, manual needle acupuncture and Laserneedle® acupuncture) on two processed EEG variables (BIS and SEF) and a verbal sedation score (VSS) in healthy volunteers.

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Methods

Subjects

The study was approved by the Ethics Committee of the University of Graz (13-048 ex 02/03). Written informed consent was obtained from each subject. We studied 25 healthy volunteers (mean age ± SD: 25.5 ± 4.0 yr, range 21–39 yr; 15 females, 10 males; height 173.5 ± 9.3 cm; body weight 69.1 ± 16.1 kg). None of the subjects had neurological or psychological disorders and they were not taking any medication. They were partly informed about the nature of the investigation and were paid for their participation. The investigators recording EEG and sedation data were blinded to the intervention applied to the volunteers. The subjects were not informed which of the four interventions was effectively a placebo control (acupressure on a control point).

Procedure and study design

The study was performed as a randomized, controlled cross-over trial. Four EEG electrodes (F_7-F_{pz}, F_8-F_{pz}, F_z = ground) and a noninvasive blood pressure cuff were attached to the volunteers after they arrived at the biomedical engineering laboratory.

Two channels of spontaneous electrical activity were recorded from EEG electrodes (Zipprep® self-prepping electrodes; Aspect Medical Systems Inc., Natick, MA, USA). The skin-electrode impedance was $<2\,k\Omega$. Low cut-off frequency was 2 Hz and high cut-off frequency was 30 Hz. The EEG was measured continuously using an Aspect A-1000® system (version 3.12; Aspect Medical Systems Inc., Natick, MA, USA).

A period of 5 min was allowed for each subject to obtain steady state BIS and SEF values. Thereafter with one of the four conditions – acupressure at the acupoint Yintang, manual needle acupuncture at Yintang, Laserneedle® acupuncture at Yintang or acupressure at a control point – was started (Fig. 1). There were three treatments and additionally to investigate a possible placebo effect, we also used acupressure at a control point.

The acupoint Yintang (Ex. 1) is located midway between the medial ends of the two eyebrows at the root of the nose (Fig. 1a–c). To assess the reliability and validity of acupressure and manual needle acupuncture, pressure on the acupoint and the control point was applied by the same Chinese medical doctor experienced in traditional Chinese medicine. The thumb pressure was estimated to be about 3×10^5 Pa (mean force measured $\sim$30 N/1 cm^2; Pa = Nm^{-2}; $30/0.0001 = 3 \times 10^5$).

Manual needle acupuncture was performed using sterile single use needles, 0.30 × 30 mm (Huan Qiu; Suzhou, China). After local disinfection of the skin the needling method was oblique, in the caudal direction (0.5 cm) [5]. Stimulation for a duration of 20 s at intervals of 2 min consisted of a combination of rotating and thrusting movements using a special manual acupuncture stimulation technique (sedation method). The needle was removed after 10 min.

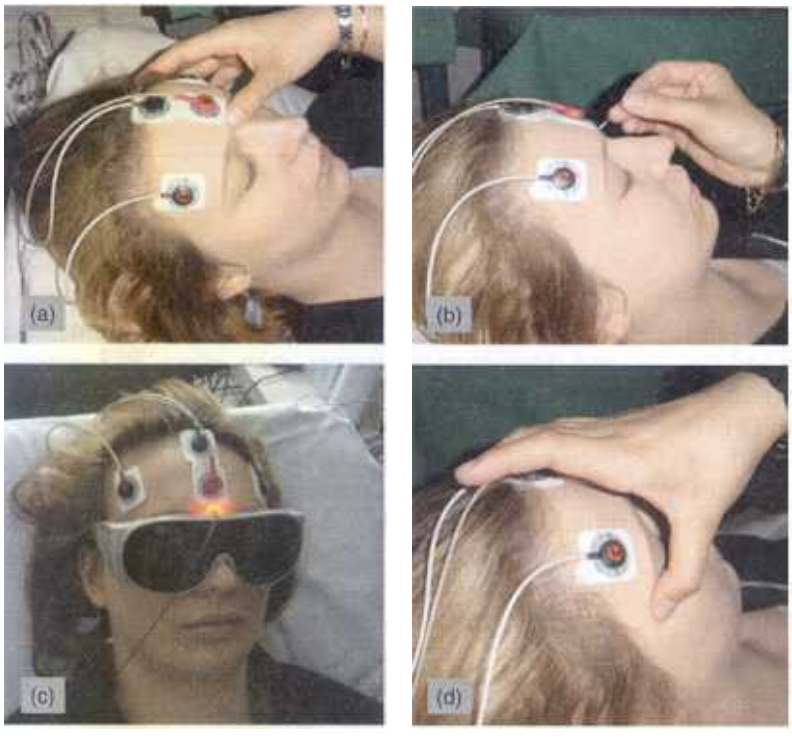

Figure 1.
Different conditions of the cross-over study design: (a) acupressure at the acupoint Yintang, (b) manual needle acupuncture at Yintang, (c) Laserneedle® acupuncture at Yintang and (d) acupressure at a control point in a 25-yr-old healthy female (with permission by the volunteer E.H.).

Laserneedle® acupuncture at the acupoint Yintang was performed using a new method for optical stimulation. This method was reported by our research group in the scientific literature in 2002 [6,7]. The Laserneedle® technique represents a new, noninvasive method for optical stimulation of acupuncture points. The laser used in this study emits red light in continuous-wave mode with an output power of 30–40 mW, which results in a radiant exposure energy of about 2.3 kJ cm^{-2} at the acupuncture point during a stimulation time of 10 min [6].

Acupressure on the control point (location: 2 cm from lateral end of the left eyebrow; Fig. 1d) was performed in similar manner as on the acupoint Yintang (duration 10 min).

All subjects had four conditions applied (Fig. 1a–d). The persons were in a semi-lying position with closed eyes. The choice of the stimulation procedure was randomized within a subject and the interval between the different sessions was at least 20 min.

Evaluation parameters

The main evaluation parameters were BIS and SEF90 during the different conditions (Fig. 1) and time intervals (Fig. 2). Measurements were made at time points a–g (Fig. 2). In any one condition we recorded BIS and SEF values continuously but sampled the data for subsequent analysis at seven points. A single reading was taken at each point. The stimulation was not stopped at the time of reading. The whole study session lasted 2–3 h. BIS and SEF90 represent single numbers, which should decrease continuously with decreasing level of consciousness (hypnosis). There are several review articles for methodological details of signal processing of BIS and SEF [3].

After 5 min of stimulation (Fig. 2d) the subjects were asked to move their right hand to clarify that they were awake and not asleep. In addition, before and after each stimulation mode the persons were asked to score their stress and tension based on a VSS from 0 (no stress) to 10 (maximum stress) [4]. Heart rate (HR) and noninvasive blood pressure (BP) were also recorded before and after acupressure stimulation at Yintang (measurement points: min before and 1 min after 'g' (*cf.* Fig. 2)).

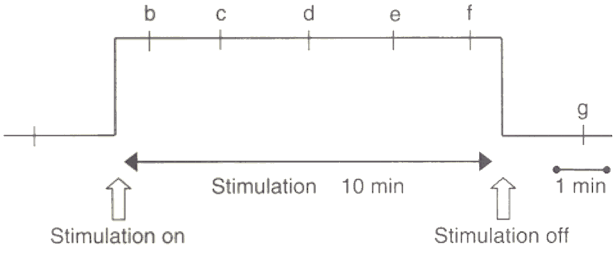

Figure 2.
Stimulation procedure and different measuring points before (a) during (b–f) and after (g) stimulation.

Statistical analysis

The BIS and SEF data were tested with analysis of variance (one-way repeated measures ANOVA; similar data were found to be normally distributed in previous investigations) using SigmaStat® (Jandel Scientific Corp., Erkrath, Germany). Dunnett's method was used for *post hoc* analysis; VSS data were compared using paired *t*-test. The results were graphically presented as box plots (BIS and SEF) and as scatter plot (VSS). Changes were considered significant at $P < 0.05$.

Results

All subjects completed the study. Figure 3 shows the decreases of BIS values during acupressure applied to the acupoint Yintang in all 25 healthy volunteers.

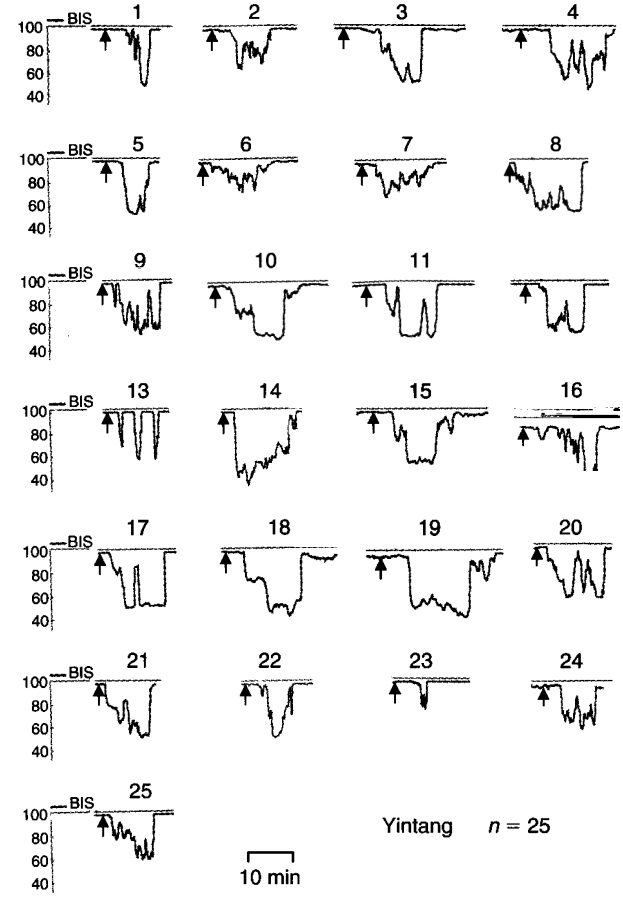

Figure 3.
The trend of BIS values of 25 healthy volunteers (1–25) before, during and after acupressure performed on the acupoint Yintang. All subjects were awake. Note the significant decrease (minimum BIS = 35; no. 14) due to acupressure.

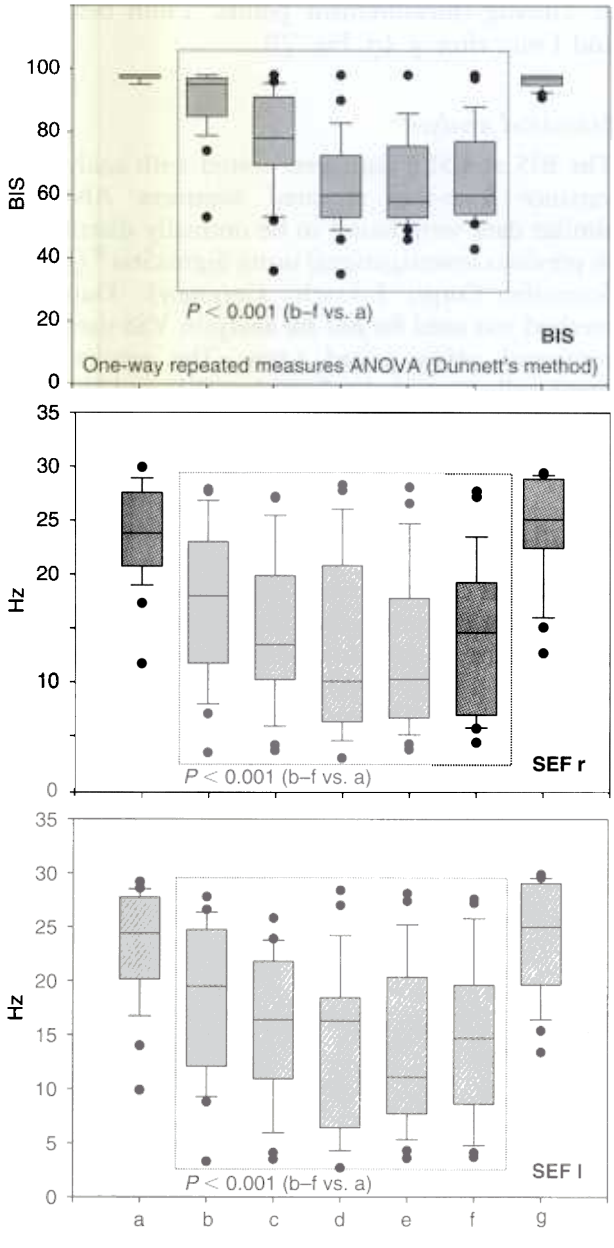

Figure 4.
Box plots of alterations of BIS and SEF values (r: right; l: left) in 25 healthy volunteers before (a), during (b–f) and after (g) acupressure (cf. *Fig. 2) on the acupoint Yintang. The ends of the boxes define the 25‰ and 75‰, with a line at the median and error bars defining the 10‰ and 90‰.*

Before the subjects were stimulated, their mean BIS values (±SD) were 97.4 (98–95) ± 1.0 and their mean SEF values (±SD) were 23.9 ± 4.1 (right) and 23.5 ± 4.9 Hz (left). The BIS and SEF values both decreased significantly ($P < 0.001$) after starting acupressure. After 5 min acupressure at the acupoint Yintang, the mean BIS values were 62.9 (minimum 35; see no. 14 in Fig. 3) ± 13.9, and the mean SEF values were 13.3 (minimum 2.9) ± 8.1 (right) and 13.8 (minimum 2.7) ± 7.3 Hz (left). The release of acupressure caused an increase in BIS and SEF back to the baseline values before stimulation (*cf.* Fig. 4).

Figure 5 summarizes the BIS and SEF results obtained during manual needle acupuncture, Laserneedle® acupuncture and acupressure on the control point. Significant ($P < 0.05$) changes were found in BIS values during Laserneedle® acupuncture (measuring points d and e; *cf.* Figs. 2 and 5) and during acupuncture on the control point (measuring points d–f). After 7.5 min Laserneedle® acupuncture at acupoint Yintang, the mean BIS values (±SD) were 95.4 (minimum 81; see Fig. 5, middle, upper panel) ± 4.1. After 5 min acupressure at the control point, the mean BIS values (±SD) were 94.2 (minimum 77; see Fig. 5, right, upper panel) ± 4.8. SEF did not show any significant alteration.

The results of the analysis of the VSS are demonstrated in Figure 6. The VSS values were significantly ($P < 0.001$) reduced after pressure application on Yintang, needle acupuncture and Laserneedle® acupuncture but also after pressure application on the control point ($P = 0.012$). Mean baseline VSS values were insignificantly lower in Laserneedle® and control conditions.

HR and BP values (mean ± SD) before and after acupressure at Yintang were calculated to be 73.2 ± 12.4 beats min^{-1}, 109.8 ± 14.0 mmHg (systolic) and 69.3 ± 10.6 mmHg (diastolic), respectively. After stimulation the values decreased to 63.7 ± 11.9 beats min^{-1}, 107.7 ± 8.7 mmHg (systolic) and 66.8 ± 8.6 mmHg (diastolic), respectively.

Discussion

The BIS and the SEF are mainly used intraoperatively to monitor the hypnotic effect of anaesthetic drugs. There are several studies reported in the literature proposing target values for EEG parameters to guide the depth of anaesthesia. A number of authors have reported a low probability of recall and a high probability of unresponsiveness during surgery at a level of 60 for BIS [8,9]. BIS values <50 are described as suppressing haemodynamic responses during endotracheal intubation [10]. In an editorial of the *European Journal of Anaesthesiology*, Chan and Gin reported recently that statistically it would be extremely unlikely for a patient to be aware when BIS is <50 and, in fact, there has not been a single case of frank awareness at this level [11]. In that context, our results showed that 10 of 25 awake healthy volunteers (40%) have Yintang acupressure induced BIS values below 50, and 21 of 25 subjects (84%) below 60.

Acupressure, acupuncture, meditation, hypnosis or relaxation techniques are all considered to be forms of complementary and alternative medicine.

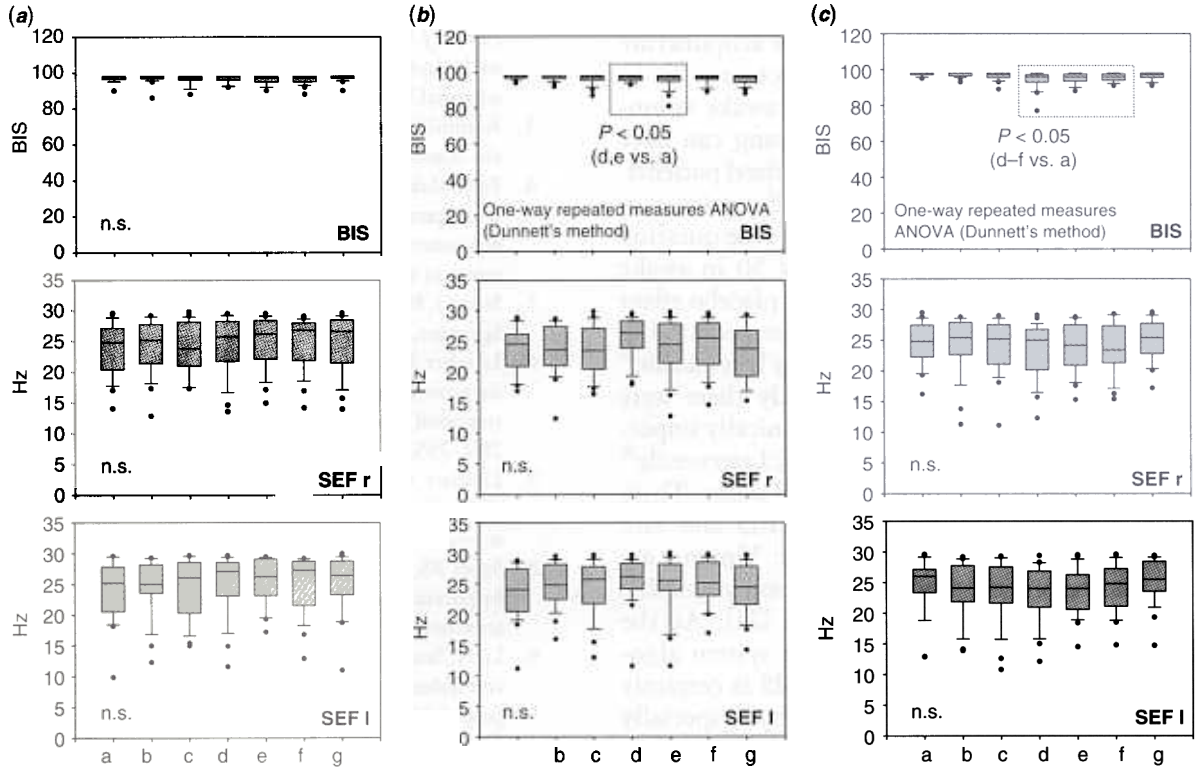

Figure 5.
Box plots of changes of BIS and SEF values (r: right; l: left) during (a) manual needle acupuncture, (b) Laserneedle® acupuncture and (c) acupressure at the control point. Further explanations see Figure 4.

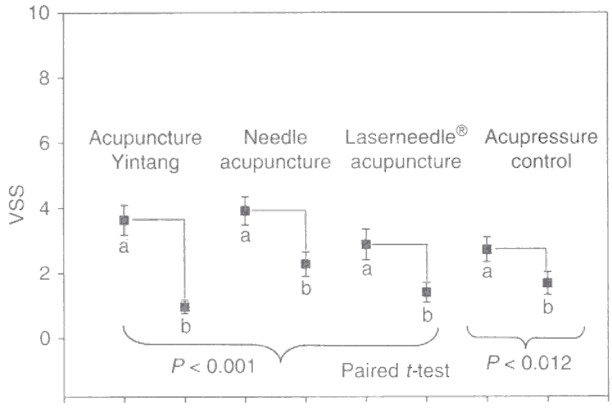

Figure 6.
Mean (±SD) values of the VSS of 25 healthy volunteers before (a) and after (b) different modalities of nonpharmacological stimulation (0: no stress; 10: maximum stress).

Acupuncture has been shown to reduce medication use in a number of trials [12]. Acupressure has been studied and offered in scientific literature as a valuable treatment in improving the quality of sleep [13]. In previous studies, it has also been shown that pressure on acupoints can decrease postoperative pain [14] and that Korean hand acupressure reduces postoperative nausea and vomiting after gynaecological laparoscopic surgery [15]. Acupressure has also been used in some other studies for prevention of emesis [16]. There are a number of theories as to how acupressure or acupuncture works. All these hypotheses show that the brain plays a key role in acupuncture and acupressure research [17–20]. Modulation of subcortical structures may be an important mechanism by which acupuncture and acupressure exerts its complex multisystem effects [20]. Demonstration of regionally specific, quantifiable acupuncture and acupressure effects on relevant structures of the human brain would facilitate acceptance and integration of these therapeutic modalities into the practice of modern medicine [17–20].

It has been shown in several publications that different narcotics have different influence on BIS and SEF [8–11,21–26]. However, nonpharmacological influences such as electromyographic activity may contribute to the low specificity of the absolute values of the electrophysiological measurement data [21]. In the majority of the cases, the BIS is falsely elevated [21]. Our results appear to confirm the results of the study of Fassoulaki and colleagues [4] who also found that acupressure on Yintang resulted in a significant and clinically relevant reduction on BIS values and they concluded that BIS is therefore of limited clinical relevance for monitoring depth of anaesthesia [22–26]. However, Fassoulaki and

colleagues [4] did consider the SEF, nor did they investigate the effects of manual needle acupuncture and the effects of Laserneedle® acupuncture.

We have shown in this study that awake volunteers subjected to acupressure at Yintang can have similar BIS and SEF values to anaesthetized patients. While it is unlikely that a patient will receive acupressure or acupuncture during surgery, the question as to what causes BIS readings below 50 in awake subjects remains. It is unlikely to be a placebo effect as we have shown in several test measurements using placebo points that BIS is not affected by Laserneedle® stimulation *per se*. In the present study there were small statistically significant but not clinically important changes with needle acupuncture, Laserneedle® acupuncture and acupressure at control point. These findings also help confirm that the BIS and SEF reductions induced by acupressure at Yintang are not a placebo effect. Reduced electromyographic levels could be partially responsible [21]. At the moment it is unclear to what degree system algorithms contribute to such findings. BIS is certainly affected by electrical activity nearby, especially diathermy. Therefore, there could also be a possibility that local movement in the region of the recording electrode might be responsible for the EEG effects observed. These are apparently less during control point acupuncture than during Yintang acupressure, where pressure is applied to a point immediately adjacent to the Zipprep® electrode. Further investigations are necessary to clarify these questions.

In conclusion, we found in healthy awake volunteers that acupressure at Yintang results in statistically significant and clinically relevant reductions in BIS and SEF while needle acupuncture, Laserneedle® acupuncture and acupressure at a control point result in statistically significant but clinically unimportant reductions. Although the validity of BIS in anaesthesia is higher than that of SEF, BIS too has to be interpreted very carefully as our results show. Our results also highlight the EEG similarities of acupressure induced sedation and anaesthesia.

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