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Monitoring of skin conductance to assess postoperative pain intensity

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Background. Pain is known to alter the electrogalvanic properties of the skin. The aim of this pilot study was to investigate the influence of postoperative pain on skin conductance (SC) readings.

Methods. After obtaining ethical approval and written informed consent, 25 postoperative patients were asked to quantify their level of pain on a numeric rating scale (NRS, 0–10) at different time points in the recovery room. As a parameter of SC, the number of fluctuations within the mean SC per second (NFSC) was recorded. Simultaneously, the NRS was obtained from patients by a different observer who was blinded to the NFSC values.

Results. Data from 110 readings of 25 patients (14 female, 11 male; 21–67 yr) were included. NFSC showed a significant correlation with the NRS (r=0.625; P<0.01), whereas heart rate and blood pressure showed no or very weak correlation with the NRS. NFSC was significantly different between patients with no (NRS=0), mild (NRS=1–3), moderate (NRS=4–5) and severe (NRS=6–10) pain (no: 0.047, mild: 0.089, moderate: 0.242, severe: 0.263; P<0.0001). *Post hoc*, a cut-off value for NFSC (0.1) was calculated above which a pain score >3 on the NRS was predicted with sensitivity of 89% and specificity of 74%.

Conclusions. The severity of postoperative pain significantly influences SC. Using cut-off values, NFSC may prove a useful tool for pain assessment in the postoperative period.

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The correlation of neurophysiological arousal, increased sympathetic tone and changes in electrogalvanic properties of the skin were described by Wallin and colleagues.[1] Increased activity in subcortical and cortical regions of the brain as a result of arousal or noxious stimuli leads to a higher rate of firing in sympathetic, post-ganglionic cholinergic neurons.[2–4] The resulting filling of sweat glands can be measured in terms of skin conductance (SC).[5]

Storm and colleagues[6] demonstrated that the number of fluctuations within the mean SC per second (NFSC), showed a significant correlation with intraoperative noxious stimuli. The sensitivity and specificity of NFSC for detecting intraoperative noxious stimuli reached 86% when compared with a five-point clinical stress score.[6] However, there are no reports describing the performance of NFSC in the immediate postoperative period.

The aim of this observational pilot trial was to investigate potential correlations between NFSC and severity of acute pain as rated using a numeric rating scale (NRS) in the recovery room.

Methods

After approval by the Ethics Committee and obtaining written informed consent from participants, 25 patients undergoing minor elective general, plastic or orthopaedic surgery were included.

Exclusion criteria included age less than 18 or more than 85 yr, autonomic neuropathy, presence of a pacemaker,

medication with anticholinergic drugs, regional anaesthesia and postoperative analgesia by means of continuous opioid infusion.

The anaesthetic technique was provided by the attending anaesthetist as clinically required. This was not influenced in any way by the study protocol.

After arrival in the recovery room, and once able to communicate, patients were asked to rate their pain on a 0–10 NRS, with 0 representing 'no pain' and 10 'worst possible pain'.

Among patients reporting a NRS score of 3 or less, this rating was repeated after 10 min. Patients with a score higher than 3 were given a bolus of i.v. fentanyl 30 μg. This procedure was repeated every 3 min until a NRS of equal or less than 3 was achieved.

Coincident with each NRS, which was obtained by a recovery nurse blinded to the SC monitor, the NFSC was recorded as a parameter of SC by a second observer. Blood pressure (SBP) and heart rate (HR) were also recorded at the time of each NRS rating.

Data points were excluded from analysis if at the time of SC measurement patients were complaining of nausea or were actively vomiting. Postoperative nausea and vomiting (PONV) was treated with ondansetron and metoclopramide.

Patients were discharged from the recovery room after two consecutive NRS scores of 3 or less, provided that they met the standard discharge criteria.

Mean SC and NFSC were assessed using the MEDSTORM AS 2005 monitor (Medstorm Innovations, Oslo, Norway) with three single use Ag/AgCl paediatric ECG electrodes (NEOTRODE®, ConMed Corp., USA) attached to the palmar surface of the hand. The exosomatic electrodermal activity was measured in terms of conductance, which was preferred to resistance because of the parallel nature of the electric polarization and conductance in the skin.[2] The equipment used an alternating current of 88 Hz, which was high enough to reduce the requirements for low electrode polarizability, but low enough to ensure minimal influence from layers of the skin other than the stratum corneum. An applied voltage of 50 mV (highest density 2.5 μA) and a 3-electrode system (measuring, counter and reference electrodes) were used for unipolar measurement with a constant voltage applied to the stratum corneum beneath the measuring electrode. The monitor was connected to a laptop computer via a standard serial port connection to visualize and process the obtained data using a software program developed by the authors (H.S.) and modified for the purpose of the study (Asbjoern Fremming, MEDStorm Innovations; T.L.). The mean SC was given in microSiemens (μS) with a refreshing rate of 10 s. The software was able to define peaks and troughs within the mean SC to determine the amplitude of fluctuations. Any fluctuation with amplitude of greater than 0.02 μS was automatically counted. The number of these fluctuations within a second determined NFSC (Fig. 1).

Statistical analysis

Given there was no comparable previous study, this was planned as a pilot trial. However, Harrison and colleagues[7] enrolled 21 infants investigating SC as a measure of pain and stress. We set the alpha error at 0.05 and the beta error at 0.2. All data were tested for normal distribution using the Komogorov–Smirnov test. ANOVA with *post hoc* Bonferroni correction was used for comparison of means. Pearsons correlation coefficient (*r*) was used to describe the correlation between NFSC and pain scores. Data are described as mean (SD).

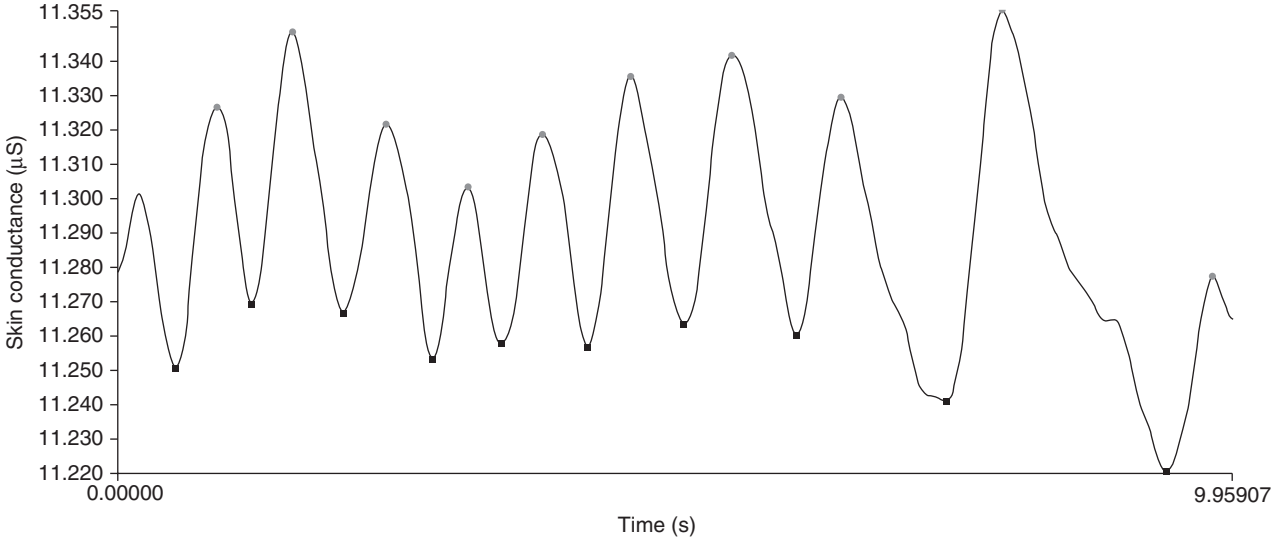

Fig 1 Screen shot from skin conductance (SC) monitor showing an increase in mean SC. Peaks and troughs exceeding 0.02 μS are marked by dots, and the number of these fluctuations per second is defined as NFSC.

Results

One hundred and ten measurements from 25 patients (14 female, 11 male; 21–67 yr) were included in the calculation. The distribution of surgical specialties included 11 general surgical patients, 9 orthopaedic and 5 plastics cases. Because the discomfort from PONV could cause an increased sympathetic tone and therefore NFSC, four readings from two patients with severe nausea or active vomiting were excluded from analysis.

The mean duration of the operation was 77 (47) min and patients were able to effectively communicate on average 7.8 (4.1) min after arrival in the recovery room. The mean time of data collection per patient was 17.5 (9.8) (range 10–43) min.

While no correlation was found between the mean SC and the NRS, the NFSC significantly correlated with the NRS rating of patients (r=0.625; P<0.01). HR showed no correlation with the values of NRS, but SBP correlated weakly with NRS: r=0.191; P<0.05.

When the pain according to the NRS values was grouped in categories of 'none' (0), 'mild' (1–3), 'moderate' (4–5) and 'severe' (6–10), the corresponding NFSC values were significantly different for each group (Fig. 2).

From our data, a cut-off value for NFSC of 0.1 was calculated to have the highest sensitivity (89.2%) and specificity (73.5%) in distinguishing pain with a NRS of >3 (moderate or severe pain) from pain with a NRS <3 (no or mild pain).

The NFSC 3 min after a bolus of fentanyl was significantly lower compared with that before administration of that bolus [0.21 (0.13) *vs* 0.27 (0.14); P<0.01]. Patients who reported an improvement of pain relief, indicated by a reduced NRS rating 3 min after administration of fentanyl, had a significantly lower NFSC compared with those without a clinical improvement [0.16 (0.13) *vs* 0.27 (0.10); P<0.01].

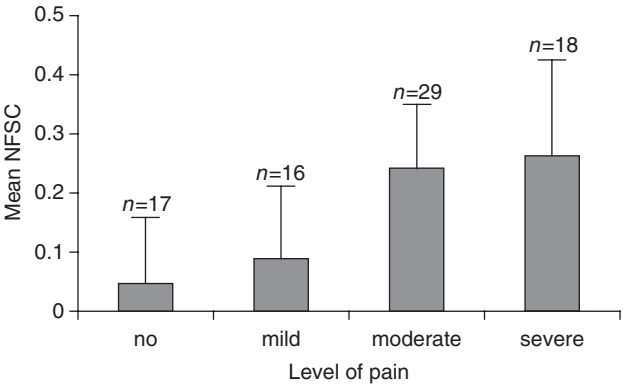

Fig 2 Mean (SD) fluctuations of skin conductance per second (NFSC) for different levels of pain, as assessed by a numeric rating scale (NRS) and categorized: no (NRS 0), mild (NRS 1–3), moderate (NRS 4–5) and severe (NRS 6–10). n=number of data points. The differences in NFSC were highly significant P<0.0001.

Discussion

In this study we demonstrated a correlation between the NFSC, a relatively new parameter of SC, and self-assessed pain measured using a NRS.

Pain is defined as an unpleasant sensation.[8] Even in fetal life noxious stimulation causes detectable stress responses,[9] but acute pain in adults is an important contributor to the postoperative stress response.[10] Therefore, the prevention and treatment of pain should not only be regarded as a basic human right, but also as a way to reduce postoperative morbidity and mortality.[10 11] Assessment and quantification of severity of postoperative pain is therefore an important component of postoperative care.[12]

A variety of score systems have been validated for this purpose, including the NRS, faces pain scale, visual analogue scale[13] or the six graded faces scale for children.[14]

Most of these systems do not work well in patients with communication difficulties, in unconscious or delirious patients or small children. In addition, pain is more than a sensation such as touch or vibration, as it is also an 'emotional experience' and by its very nature, subjective.[15]

Therefore, a parameter able to measure the stress caused by pain would be a helpful tool in the assessment of pain itself.

Monitoring SC has already been mentioned as a possible tool for this purpose more than 20 yr ago.[16] Unfortunately, the mean SC is altered significantly by the type or the actual area of placement of the electrodes and shows high inter-individual differences. This is reflected again by the lack of correlation between mean SC and NRS in our study. In contrast, NFSC is not affected by these factors and allows a better inter-individual comparison of values.

NFSC as a parameter of pain-related stress response has been published before[3] where authors found significant differences in the NFSC before and after a heel stick procedure in pre-term infants. A more recent study showed no correlation between the mean SC or the amplitude of fluctuations of SC and a painful stimulus.[7] These authors found a significant higher value for NFSC at the time of the painful procedure, when compared with both before and after the procedure and concluded that NFSC was the only parameter of SC recommended for further research.

Our study confirms a potential for NFSC to become a surrogate measure to assess the stress response to postoperative. It is in particular remarkable that low pain intensities in the range of an NRS of 0–3, commonly regarded as pain sufficiently treated, result in significantly less stress response than higher pain scores.

Post hoc, we calculated a cut-off value for NFSC, that was able to distinguish between a NRS pain score greater than

3 from a score of 3 or less, with a high sensitivity and acceptable specificity.

Our findings are supported by those of Storm and colleagues,[6] who reported a NFSC of 0.05 showed sensitivity and specificity of 86% for indicating intraoperative painful stimuli.

However, the use of SC as a correlate of postoperative pain may have limitations. Central and peripheral modulators of the autonomic nervous system, such as neuromuscular reversal agents or alpha-2-agonists, may potentially affect SC measurement. As we excluded patients receiving these drugs, we cannot comment on their effect on NFSC readings. In addition, patient factors causing discomfort such as PONV or anxiety will influence sympathetic tone. Data points from subjects with PONV were excluded. As pain perception is complex, the contribution of psychological factors is impossible to exclude. Despite these limitations, our results suggest that measurement of NFSC may have a role in assessing postoperative pain.

We conclude that changes in levels of patient-rated postoperative pain on a NRS are reflected by corresponding changes of NFSC as a parameter of SC. In contrast to the mean SC, NFSC was able to distinguish between mild and moderate/severe pain with a high sensitivity and acceptable specificity. A limitation of our study is that it presents only pilot data from a limited population and thus further research is needed to evaluate the use of NFSC monitoring in the recovery room setting.

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