

Commentary

The painful truth: A review of the clinical use of skin conductance monitoring for postoperative pain assessment

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Accurate assessment of pain intensity remains a critical aspect of successful pain management. Currently, the most widely used method of assessment involves various self-report scales (Williamson & Hoggart, 2005). Self-report scales rely on a cooperative, reliable patient and therefore are of limited use with unconscious, preverbal or cognitively impaired individuals. For verbal children, there are over 30 pain scales available, each with their cognitive, social and developmental limitations (Stinson et al., 2006). In preverbal children, pain assessment relies on the use of observational scales to determine pain intensity (von Baeyer & Spagrud, 2007). Limitations of such observational scores include subjectivity, with observations easily confounded by behaviors related to fear or anxiety, and age and context specificity (procedural, postoperative, etc.). Given the numerous limitations of these observational assessments, an objective pain scale that is independent of subjective interpretation certainly sounds attractive. But is it realistic?

The search for an objective measurement of pain is not new. A number of objective measures have been investigated from heart rate variability (Pomfrett, 1999) to even more sophisticated measures such as functional magnetic resonance imaging (fMRI; Wartolowska, 2011). Unfortunately, as of yet, none have been able to replace subjective self-report scales.

Skin conductance monitoring has been used in a number of scientific experiments, primarily in the field of psychology (Critchley, 2002). Experiments

using galvanic skin responses in order to objectively measure pain have been conducted since the 1950s (Korotkov, 1953; Nisbet et al., 1967; Pakhomov & Ivanov, 1969). A study by Savino et al. (2013) is the most recent in number of studies attempting to use the latest in skin conductance technology as an objective measure of pain.

This commentary will review the clinical use of skin conductance as an objective measure of postoperative pain and discuss the current state of research as well as its limitations.

Background on skin conductance

The underlying theory for the use of skin conductance as a measure of pain is that pain activates the sympathetic nervous system. Activation of the sympathetic neurons associated with the eccrine sweat glands results in perspiration. When an electrical current is applied along the skin's surface, an increase in conductance can be measured (in microsiemens, μS) in proportion to the amount of sweat produced.

Early studies showed a poor correlation between absolute skin conductance and pain due to wide variability in the amplitude of skin conductance. Therefore current research uses a modified measurement, the number of fluctuations in skin conductance per second (NFSC), which some studies have shown to correlate better with pain assessment (Storm, 2008).

The Med-Storm Pain Monitor System™ (also known as Med-Storm Stress Detector or skin conductance algometer; www.med-storm.com) is

one of the most commonly used skin conductance monitors currently being used for pain research. The device uses three adhesive electrodes attached to the palmar or plantar surface of the subject to measure skin conductance in real time. Software then integrates the raw data to display various measures such as conductance (μS), or NFSC during a given sampling interval (Storm, 2008).

Current research

There have been numerous studies on skin conductance throughout the age spectrum of neonates to adults, including during intraoperative and perioperative periods (see Table 1 for details). To date, there are no studies to show that clinical therapy guided by skin conductance measurements improves patient outcomes. The available studies attempt to correlate NFSC with various self-report pain scales. Results have been mixed, with authors describing both positive (Ledowski et al., 2006; Ledowski et al., 2007; Hullett et al., 2009) and negative (Ledowski et al., 2009; Choo et al., 2010; Czaplík et al., 2012) results.

There are numerous possible reasons for the variability in results, which will be discussed further.

Sampling interval. As previously mentioned, there is a poor correlation between pain and absolute skin conductance and thus the NFSC during a given sampling interval is used. In general, most of the studies with positive results have used a very short sampling interval of 5-15 seconds, whereas studies using longer sampling intervals of 30-60 seconds have produced negative results. This is surprising, as one would expect clinically significant pain that warrants intervention to last longer than 60 seconds. This may suggest that artifacts, which are likely to have a bigger influence in a shorter sampling interval, may influence the final measure.

Cut-offs. The manufacturer recommended cut-offs for the Med-Storm Pain Monitor are shown in Table 2.

These values appear to be loosely based on the study by Ledowski et al. (2007). The various studies have used different cut-off values for NFSC to suggest different levels of clinically significant levels of pain. Lowering the cut-off value improves sensitivity but sacrifices specificity.

Confounding variables. Initial studies of the NFSC variable suggested that it was fairly robust,

Table 1
Summary of selected clinical trials using skin conductance fluctuations to assess pain in awake postoperative patients

Study	Ledowski et al., 2006	Ledowski et al., 2007	Hullett et al., 2009	Ledowski et al., 2009	Choo et al., 2010	Czaplík et al., 2012
N	25 adults	75 adults	165 children	100 adults	90 children	44 adults
Age range (years)	21-67	19-81	1-16	18-32	7-17	>18
Self-report pain scale cut-off	NRS >3	NRS >3	VAS >3	NRS >5	NRS >3	NRS >2
NFSC Cut-off	0.10	0.10	0.13	0.10	0.2	>0.13
Sensitivity	89.2%	88.5%	90.4%	58%	51.9%	77.9%
Specificity	73.5%	67.7%	64.5%	61%	78.4%	41.2%
Sampling period	Not reported	5s	15s	5s	60s	60s
AUC	Not reported	75.5%	82%	Not reported	62.3%	Not reported
Correlation (<i>r</i>)	0.625	0.477	Not reported	0.165	0.21	0.571

Note. NRS = Numerical Rating Scale. VAS = Visual Analog Scale. AUC = Area under receiver operator curve. Correlation = correlation between NFSC and self-report pain scale.

Table 2

Pain intensity scores assumed to be associated with values of NFSC, from the Med-Storm Pain Monitor™ User Manual, p. 22

Number of fluctuations in skin conductance per second (NFSC)	Corresponding pain intensity score (Visual Analog Scale, 0-10)
0.00-0.07	No pain
0.13-0.21	1-3
0.27	4-5
0.33	6-8
0.40-0.70	8-10

Note. No directions are given for interpretation of overlapping or missing values.

being resistant to external factors such as external temperature, neuromuscular blockade and adrenergic agonists (Storm, 2008). However it can be influenced by a number of confounders discussed below.

Movement artifact. Movement artifacts have repeatedly been reported to be a significant confounder (Storm, 2008). This could partially explain the observation of poor results with longer measurement times. However, this poses a significant practical problem in being able to obtain a reliable measurement in a noncooperative, nonverbal patient in pain.

Temperature. A study by Valkenburg et al. (2012) found a direct correlation between skin temperature and NFSC in the absence of clinically significant pain, suggesting that skin temperature autoregulation could confound skin conductance results in some settings.

General arousability response. Given the numerous functions of the sympathetic nervous system, it is not surprising that activation can occur from numerous stimuli unrelated to pain. It was noted by Czaplik et al. (2012) that NFSC values seem to fluctuate quite frequently, making it difficult to identify and document a predominant value. They also reported that increases in NFSC were observed by simply speaking to the patient to assess pain intensity. Choo et al. (2010) also reported a significant increase in NFSC during subject responses to pain scale assessment, again suggesting a general arousability response. This

certainly could explain the observations of Savino et al. (2013) where a significant rise in NFSC occurred during heel lancing, but then promptly returned to baseline.

Objective measurements for subjective symptoms

Over fifty years ago, Henry K. Beecher, anesthesiologist and pioneer in pain research and medical ethics, noted the challenges associated with developing objective measures of subjective phenomena in clinical practice (Berde & McGrath, 2009). Perhaps there is another reason that a reliable objective measure of pain has not yet been discovered. All of the current research of objective measures of pain use self-report scales as the standard for comparison and thus can only at best show equivalence. If an objective scale cannot be shown to be superior, can it be shown to be more reliable? Here again, the available evidence is lacking and as we have discussed, there are a number of confounders that compromise its reliability.

The International Association for the Study of Pain (Merskey et al., 1994) states that pain is always a subjective experience. If we accept that pain is a subjective experience, then arguably it seems logical that it would be best assessed with a subjective measure whenever possible.

Conclusions

There is currently a lack of evidence to recommend the use of skin conductance for the assessment of pain. Due to the variability in results, it would not be prudent to use skin conductance to guide therapeutic interventions for pain at this time. Further research and optimization to identify an optimal sampling interval, minimize the influence artifacts caused by movement and general arousal are needed to improve the specificity of skin conductance as a measure of pain. An objective measure of pain remains elusive and will likely remain so for quite some time.

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