Skin conductance and the stress response from heel stick in preterm infants

H Storm

Abstract

Aim—To evaluate whether spontaneous skin conductance activity is an objective method for measuring the stress response to painful stimuli in premature infants. The number and amplitude of the waves and the baseline increase with the activity of the sympathetic nervous system.

Methods—In 20 preterm infants of gestational age ≥ 29 weeks, behavioural state and spontaneous skin conductance activity variables were measured for three minutes before, during, and for three minutes after heel stick.

Results—The number of waves (p < 0.001), the amplitude of the waves (p = 0.001), and the level of the behavioural state (p < 0.001) increased during heel stick, and then decreased to levels found before the procedure. The baseline increased both during (p < 0.001) and after heel stick (p < 0.001), compared with levels before.

Conclusion—Spontaneous skin conductance activity reflects the stress response to heel stick in premature infants at least 29 weeks of gestational age.

Keywords: arousal; heel stick; premature infants; skin conductance activity; stress; pain

Skin conductance activity measures the activity of the sympathetic nervous system and the properties of the skin. In premature infants, the mechanisms for communicating pain or stressful situations through facial expressions are not well developed because of their immature nervous and musculoskeletal systems. An increase in heart rate and blood pressure and a fall in oxygen saturation may also follow pulmonary and cardiovascular diseases. Therefore a more objective method of assessing pain or stressful situations should be developed.

The laser Doppler, the galvanic skin response (measuring changes in the baseline), and palmar water vaporisation methods have been unsuccessful for evaluating pain in premature infants because of artefacts in the laser Doppler method and the low sensitivity of the other two methods. In full term infants, a fall in vagal tone measured by changes in respiratory sinus arrhythmia has been used to evaluate pain. However, respiratory sinus arrhythmia is poorly developed in premature infants.

In this study, the stress response to heel stick was measured with a sensitive apparatus developed to measure skin conductance. Skin conductance activity has been validated as a physiological measure of the emotional state in full term babies and has been found to be closely related to their behavioural state and crying. Skin conductance activity measures changes in the palmar and plantar sweat glands. These changes in conductance are due to the activity of the sympathetic nervous system, which responds to the emotional state by secreting acetylcholine in the postganglionic synapses. Each time this part of the sympathetic nervous system is activated, the palmar and plantar sweat glands are filled, and a spontaneous wave of skin conductance occurs.

The number and amplitude of the waves increase with increased activity in this part of the sympathetic nervous system. The baseline, defined as the mean skin conductance level, is associated with both the sympathetic nervous system and the properties of the skin. The specificity of this method is based on the stimuli that induce the stress response. In this study, the stress response is induced by painful stimuli.

The purpose of this study was to investigate whether spontaneous skin conductance activity can be used to measure the stress response to heel stick in premature infants, and to investigate how postnatal age, gestational age, and the number of previous blood samples taken influence the stress response measured in terms of skin conductance activity.

Methods

SUBJECTS

Twenty premature infants were recruited from the Section of Neonatology, Department of Paediatrics, the National Hospital, Oslo. Infants who were healthy, without fever, not suffering from intraventricular haemorrhage, had not received analgesics or sedatives within the past 48 hours, and not exposed to nasal continuous positive airway pressure intervention were eligible for participation in the study. There were 13 girls and seven boys. The infants were born between 29 and 35 weeks (median 33 weeks) gestational age and at the time of the...
study were between 1 and 25 days postnatal age (median 7 days). None had reached 37 weeks corrected gestational age. Median weight at birth was 2000 g (range 1282–2550), and at the time of participation in the study the median weight was 1930 g (range 1190–2390). Five minute Apgar scores had a median of 8.5 (range 7–10). To investigate how the number of previous heel sticks influenced the skin conductance activity variables, the number of times doctors had previously ordered blood samples for the infants were examined. It was between 0 and 35 times (median 11). If only a blood glucose test had been ordered, this was not included because the tissue injury made to obtain blood for this test is only minor. Skin conductance activity was measured when the infants were exposed to heel stick for routine blood sampling. Informed parental consent was obtained before inclusion of an infant in the study. The international ethics committee approved the study.

APPARATUS
Skin conductance activity was measured by alternating current at 88 Hz. Low frequency electrical conductance reflects the ionic conduction in the stratum corneum, which is largely determined by sweat duct filling. A frequency of 88 Hz is sufficiently high to reduce the requirements for low electrode polarisability considerably, but also low enough to ensure minimal influence from layers other than the stratum corneum. An applied voltage of 50 mV and a three electrode system were used. The three electrode system comprises a measuring electrode, a counter current electrode, and a reference voltage electrode, which ensures a constant applied voltage across the stratum corneum beneath the measuring electrode.

The apparatus (fig 1) conforms to the safety regulations given in IEC 60601. Beckman electrodes (Sensormedics, Iorba Linda, California, USA) were used. The electrodes were attached to the skin by disks of double sided adhesive tape from 3M, Minneapolis, Minnesota, USA. Conductive paste from the National Hospital Pharmacy, Oslo, Norway, containing 6 g hydroxyethylcellulose 700, 0.58 g NaCl, 0.1 g methylparahydroxybenzene, 0.1 g propyipara hydroxybenzene, 2 g alcohol 96%, distilled water up to 100 g, was used to improve electrode conductance.

SOFTWARE PROGRAM
The data were stored on line using a portable computer (Compaq Armada) and were analysed off line with a software analysis package. The sample frequency was 50 Hz and the resolution was 12 bits. The software analysis program for skin conductance activity was carried out in Labview, National Instruments, USA, and was developed by us. The program recorded and counted the number of waves per second, by defining the valleys and peaks, and calculated the mean of the amplitudes of the waves and the mean baseline in the study period for the spontaneous skin conductance activity. The valleys and peaks were established when the derivative of the wave was 0. The amplitude of the wave was calculated from the bottom of the valley before the peak to the height of the peak. The slope was defined as (the mean distance of the valley to the peak)/(time to reach peak) (fig 2).

The program contained a function that enabled us to define a threshold for these values. To eliminate electronic noise, the definition of minimum amplitude was set at 0.02 µS. Moreover, to eliminate artefacts, the slope was set at less than 2 µS/second. The width of the waves was unlimited. Artefacts occurred if an electrode became detached from the skin. The method was not sensitive to movements or changes within normal room temperature. The software analysis program could also analyse smaller segments of the registered data. This function was used if artefacts were found. Moreover, in order to examine details of the registered data, a particular time period during registration could be chosen and expanded.

The apparatus and software program have been commercially developed by Med-Storm Innovation, Oslo, Norway, product number 060895.

PROCEDURE
Testing was conducted in the intensive care area or the intermediate area at the Section of Neonatology. The infants were subjected to heel lancing for routine blood collection to test for metabolic disease and physiological function. The standard protocol for sampling blood involved warming the left foot, picking it up, making a small incision with a metal scalpel (2.2 mm long and 1 mm wide), squeezing the heel, and if necessary repeating the incision to draw sufficient blood. Blood was collected for at least the following tests: haemoglobin, leucocytes, platelets, C reactive protein, Na+, K+, Ca++, acid-base.

Electrodes were fastened to the infant’s right foot 10 minutes before the heel stick was scheduled. The counter current electrode was placed on the medial right side of the foot over the abductor hallucis muscle adjacent to the plantar surface, the measuring electrode was placed midway between the first phalanx and a

Figure 1 Diagram of apparatus used to measure skin conductance activity. Reproduced with permission from Asbjørn Fremming (postgraduate thesis, Institute of Physics, University of Oslo, 1998).
p Value
Number of waves/second 0 (0.0–0.2) 0.03 (0.0–0.35)* 0 (0–0.26) <0.001
Amplitude (µS) 0 (0–0.04) 0.03 (0–0.07)* 0 (0–0.06) 0.001
Baseline (µS) 1.3 (0.7–4.4) 1.7 (0.7–4.7)* 1.7 (0.7–5.8)* <0.001
Level of behavioral state 1.8 (1–3) 3.3 (1–4)* 1.8 (1–4) <0.001

Table 1  Spontaneous skin conductance activity variables (number of waves per second, amplitude of waves, and baseline) and level of behavioral state before and during and after heel stick in premature infants

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<th>Before</th>
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<td>1.8 (1–3)</td>
<td>3.3 (1–4)*</td>
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Values are median (range).

Results

In this study a stress response to heel stick was found from 29 weeks gestational age when skin conductance activity variables were measured (fig 2).

The number and amplitude of the waves increased significantly during heel stick (p < 0.001 and p = 0.001 respectively) and then stabilised to levels found before the procedure (tables 1 and 2). The behavioural state mirrored these spontaneous skin conductance activity variables (p < 0.001) (tables 1 and 2). The baseline was higher both during (p < 0.001) and after (p < 0.001) heel stick, and differed from the other variables (tables 1 and 2). Four of the infants did not show any changes in number and amplitude of the waves during heel stick. These infants were 1, 2, 3, and 6 days old, and their gestational age was between 29 and 35 weeks. In total, there were 10 infants younger than 7 days. No correlates were found between behavioural state and the skin conductance activity variables.

There were positive significant associations between postnatal age and the number (p = 0.01, r² = 0.29) and amplitude (p = 0.004,
Monitoringskinconductanceactivityvariablesduringheelstickhadprobablyhadlessexposure toheelsticksbecauseoftheirage andthereforewerelesssensitive.

Furthermore,thesensoryneuronesinthe fetal spinal cord that respond to noxious stimuli have larger receptive fields than in adults. Diffusecentralconnectionsandlargedorsalreceptivefieldsarelikelytoleadtopoorerdiscriminationbetweennoxious andnon-noxiouseventsandpoorer spatiallocalisationbythefetus. Reducingthenociceptivenervoussignaltosthecentralnervousystem willreducetheriskofinappropriatelychangesinthenervoussystem,changesthatmayin themselvesinducepain.

The ability to evaluate the stress response to painful stimuli in premature infants is important. A controlled study showed that interventions designed to decrease the amount of sensory input and the intensity of stressful stimuli during intensive care of premature neonates were associated with improved clinical and developmental outcome. Moreover, circumcised boys showed a more pronounced pain response than other infants when they were vaccinated at 4 months of age. This implies that infants remember pain. In the short term, these behavioural changes may disrupt the adaptation of newborn infants to their postnatal environment, the development of parent-infant bonding, and feeding schedules. In the long term, experience of pain in neonates could possibly have psychological sequelae and alter sensitivity to pain or somatisation.

Monitoring skin conductance activity variables may be a useful tool for surveying stress responses to pain stimuli in premature infants. The method is easy to use, and artefacts occur only if the electrodes become detached from the skin.
increases with the number of previous blood samples in premature infants.

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