

## PSYCHOPHYSICAL SCALES FOR PAIN AND SKIN CONDUCTANCE AS INDICATORS OF ACUTE PAIN IN THE NEONATE

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### Abstract

*A reliably pain measure in newborns is difficulty and diagnosis and management are obstacles in neonatal units. This study aimed to determine whether the galvanic skin response, measured by innovative equipment, the SCMS™, correlates with physiological and psychophysical scales for pain in neonates. Was also tested whether the skin conductance meets the theoretical assumptions of the Law of Initial Value and if it's adequate to explain the responses to pain stimuli in relation to physiological and psychophysical indicators. The results indicate a high sensitivity of SCMS™ for detecting pain response with precision till 15" after the noxious stimulation, validated by other measures. The measures tested varied in their efficiency in sensitivity and consistency throughout the event. In this perspective the SCMS™ has great potential for psychophysical research and clinical use on pain in neonates due to meet several characteristics for accuracy and efficiency of the measure and low operating cost.*

Assessing pain in neonates, both in clinical practice and research, is difficult and challenging because individuals those do not express verbally cannot communicate robustly this subjective phenomenon (1,2). Older children and adults able to express verbally the pain are primarily assessed using self-report, considered the gold standard for this (3). In the recent past, infants were seen as insensitive to pain for not having the central nervous system mature enough to handle the pain and being unable to interpret or remember that (1). Over the past 30 years, knowledge of the pathophysiological mechanisms of pain in newborns achieved significant progress. There is evidence that the fetus in the first half of pregnancy, and newborn are capable of feeling pain, reflected by increases in heart rate, cortisol and beta-endorphin blood levels, as responses to activation of the autonomic nervous system (2). This perception would be an inherent quality of life that appears early in ontogeny, and serves as a signalling system to tissue damage.

The pain perception is multidimensional and varies in quality, intensity, duration, location and symbolic image in accordance with the characteristics of each individual. Factors such as age, prior pain experience, cognition, learning, psychomotor stage, underlying disease, use of sedatives and analgesics, family conditions and cultural patterns may alter its expression and is therefore difficult to quantify and qualify it in neonates both healthy term and preterm infants (2).

Measurements of pain are classified as self-report, behavioural, physiological and bio-behavioural. Faced with the impossibility of self-reports in children who are unable to express verbally, behavioural indicators, physiological and bio-behavioural, alone or combined, form the basis for measures of pain (1,2). Facial expression, crying, and motor activity are behavioural indicators of pain used over these children, especially preterm and full term, although the neurological immaturity, the severity of disease or drug use may influence the expression of pain. Here the challenge is to distinguish the painful manifestations of other

behaviours such as restlessness and hunger. For them, were developed measures consisted of indicators of one-dimensional or multidimensional nature (1,2,4).

There are currently available, at least four-dimensional scales. One of the most sensitive and specific is the Neonatal Facial Coding System (NFCS), valid for premature infants with gestational ages above 25 weeks and full term neonates. It includes ten different facial behaviour: prominent forehead, narrowed palpebral fissure, deepening of the nasolabial furrow, open mouth, vertical and horizontal stretch mouth, trembling of the chin, tongue protrusion and tension (2,4,5). Multidimensional measures are made up of different behavioural domain (multidimensional scaling) or behavioural and physiological indicators (composite scales), the most used to assess pain in neonates (1,2). Among them, stands the Neonatal Infant Pain Scale (NIPS), which assesses facial expression, crying, breathing, movement and awakening (2,6). Another scale, the Premature Infant Pain Profile (PIPP), is composed of three indicators of behaviour, two physiological indicators (heart rate and pulse oximetry) and two contextual indicators (gestational age and behavioural state) (2). The Comfort scale is also a composite scale and has been validated for use in babies ventilated and not ventilated. It assesses the state of alert, calm and agitation, respiratory response, crying (not valid for ventilated), physical movement, muscle tone and facial tension (2,7).

The group of physiological indicators of pain include: increased heart rate (HR), respiratory rate and blood pressure (1,2,5); drop in pulse oximetry (PO) (1,2,5) elevation in the blood of vasoactive substances and hormones such as epinephrine, norepinephrine, beta-endorphin, growth hormone and cortisol (1,2,8) and increased of skin conductance activity (SCA) (1,9,10). Skin conductance activity (SCA) is proposed to be a physiological measure of emotional state, validated in term newborns, infants and children undergoing mechanical ventilation, and are strongly related to behaviour and infant crying (9,10). The SCA reflects changes in secretion of the palmar and plantar sweat glands triggered by activation of the sympathetic autonomous nervous system, which in response to a stressful stimulus, secret acetylcholine at postganglionic synapses. The increase of fluctuations in numbers and range have shown a positive correlation with the physiological indicators heart rate (2), blood pressure, brain activity (11) and behavioural scales such as PIPP (10) and Comfort. They also may be interpreted as increased activity of the sympathetic nervous system, and ultimately reflect pain (9,10).

Characteristically, the behaviour of a hypothetical marker of pain, behavioural or biological, must start from the condition of a baseline followed by an acute response to painful stimuli, ending the period of recovery involving three dimensions measurable response: magnitude, variability and signal direction. In a schematic way, one can separate the components of these dimensions of pattern of pain response in five measurable characteristics: *intensity* or magnitude of response, calculated as the mean and standard deviation of the difference in score; *direction* of the curve; *reactivity* (significant change of score from baseline to the stimulus) toward the response variation (if the growth and decrease the magnitude of the response are of the same intensity); *regulation* or change in pain score for recovery; and *slope*, which reflects the trend over-regulation or down-regulation and can be calculated by linear regression coefficient (2,12).

These components of the standard quantifiers response to a painful event forms the basis for theoretical application of the Law of Initial Value (LIV), which states that the magnitude of psychophysiological response depends on the comparison with the baseline, compared to the same individual (12). No reports were found in the scientific literature regarding the conduct of studies involving LIV in skin conductance and other indicators of this research as an interpretation system of pain in neonates.

This study aims to validate the SCA measure in a group of healthy neonates in Brazil subjected to heel prick by comparing the number of waves per second and the UCA of the

waves with four behavioural indicators (range one-dimensional and three composite scales) and two physiological indicators (HR and PO).

## Method

This is an observational, prospective study, controlled by the same individual, like before, during and after. The sample population studied consists of forty-one neonates with gestational ages between 37 and 41 weeks, apparently healthy submitted to heel for capillary blood glucose level under a doctor within 48 hours of life. They were selected for convenience, between September and December 2009, at the neonatal unit of University Hospital of Brasília, Brazil. Were excluded neonates with Apgar score less than seven at five minutes; receiving any analgesia or sedation before the heel prick, with metabolic diseases, respiratory, cardiovascular, neurological or infectious, with intracranial haemorrhage grade 3 and 4, and those with congenital cardiac malformations, pulmonary, gastrointestinal and neurological. Informed consent from a parent was obtained before inclusion of neonates in the study.

Behavioural indicators were measured through scales PIPP (2), NFCS (4), NIPS (6) and Comfort (7). The scores were calculated by two trained observers independently from the analysis of images recorded along with the values of heart rate and oxygen saturation. The images were captured by a digital camera (Sony DCR-SR47) attached to a tripod, one meter apart the neonate under natural ambient lighting and / or artificial white light, with the opening angle sufficient to visualize the baby's body born, and the pulse dosimeter. Each newborn was filmed using only a diaper, housed in an incubator (Fanem), at room temperature of 27° C.

The SCA was measured using an alternating current of 88 Hz by an electric conductance meter, the Skin Conductance Measure System or SCMS™ by Med-Storm Innovation, Oslo, Norway (12). The electrodes were fixed on the plantar surface of the left foot by means of adhesive discs, and the measure placed on the anterior third, immediately after the interdigital spaces, the counter-current in the outer lateral side of the posterior third and neutral in the lateral internal posterior third. The SCMS™ uses a computer program that records the number of waves per second and calculates the average under curve area-UCA of the waves of the periods studied.

The physiological indicators were obtained from HR and PO, using the device DX 2515 (Dixtal) and observed visually on the monitor, the images captured during the periods of record. The pictures of the newborns were observed for nine minutes, divided into three periods: three minutes earlier, considered the baseline (period before); three minutes during lancing, compression bandage and, considering the painful stimulus (period during); three minutes after the end of the period, considered as the recovery period (period after).

## Results

The PIPP scale, showed no agreement between observers and agreement during the period was low, although significant, for the period after, and is therefore discarded in this study. The skin conductance showed that the number of waves per second and the UCA were different between the periods before, during and after, with Friedman test ( $\chi^2 = 13.07$   $p = 0.001$  and  $\chi^2 = 7.02$   $p = 0.03$  respectively). For the physiological variables (maximum HR, minimum PO) and behavioural (Comfort, NFCS and NIPS scales), there were statistically significant differences between the values, considering the three periods studied (Table 1).

Table 1. Mean values, minimum and maximum activity of skin conductance, the physiological and behavioural scales in the range of 15 seconds for the periods before, during and after the heel puncture in newborns at term apparently healthy.

Measures	Before	During	After	<i>p</i>
Number of waves / sec	0,14 (0-1,0)	0,34 (0-0,93)	0,17 (0-0,67)	0,001
Area under curve (μS)	1,18 (0-11,40)	4,28 (0-67,20)	5,85 (0-111,20)	0,03
Maximum Heart Rate (bpm)	139 (112-160)	149 (119-185)	139 (119-168)	0,001
Minimum pulse oximetry (%)	94 (87-98)	92 (80-98)	93 (66-98)	0,004
Comfort scale	12,1 (6-28)	23,39 (17-30)	13,12 (6-27)	0,000
NIPS scale	2,37 (0-7)	5,54 (1-7)	2,41 (0-7)	0,000
NFCS scale	2,05 (0-7)	6,22 (4-7)	5,12 (0-8)	0,000

There was no correlation between the ASC (number of waves / second and under curve area), the HR and PO physiological indicators and Comfort, NFCS and NIPS behavioural scales for the periods before, during and after. All measures meet the components intensity, reactivity and direction of the psychophysical characteristics of a measure. The regulatory component was confirmed in all measures analyzed for 15 seconds, except in under curve area. Regression analysis, as used to analyze the slope of the curve between the periods during and before, the fifth component of the Law of Initial Value, was satisfactory only for the variables PO ( $R = 0.677$ ,  $p = 0.000$ ), scales Comfort ( $R = 0.486$ ,  $p = 0.045$ ) and NIPS ( $R = 0.438$ ,  $p = 0.013$ ). The differences were significant among during and before to the variables number of waves, UCA, HR, PO and Comfort, NFCS and NIPS scales (Table 2).

## Discussion

In this study, was found significant increase in the number of waves per second and under curve area in the period during compared with the period before the procedure, the same performance obtained for HR, PO and behavioural scales (Table 1). For Storm, the number of waves and the under curve area of the waves depend on the intensity of the force applied during the noxious stimulus (9).

The increase in HR, analyzed separately, is considered an indicator of low specificity for the diagnosis of pain subject to variations paradoxical forward to noxious stimuli. In this study, was observed a significant increase in maximum heart rate at the period during compared to the period before the painful stimulus (Table 1).

Table 2 - Differences in during-before, after-during and after-before the skin conductance activity, indicators of physiological and behavioural scales in newborns at term, apparently healthy submitted to heel.

Measures	During-Before	After-During	After-Before
Number of waves/sec	0,2(-0,23—0,96)**	-0,17(-0,86—0,4)**	0,02 (-0,47—0,40)
Area under curve (μS)	3,09(-8,64—66,33)*	1,57(-9,99—44)	4,67(-11—110,33)
Maximum Heart Rate	9,72(-39—52)**	-9,71(-45—21)	0,21(-36—37)
Minimum oximetry (%)	-1,68(-13—4)**	1,19(-30—14)	-0,54(-29—8)
COMFORT scale	11,29(1—20)**	-10,27(-17—1)**	1,02(-10—16)
NIPS scale	3,17(-2—7)**	-3,12(-7—2)**	0,05(-7—7)
NFCS scale	4,17(-1—7)**	-2,64(-9—2)**	3,07(-2—8)

\*  $p < 0,05$  \*\*  $p < 0,01$

Several studies claim that the observation of facial expression seems to be a non-invasive indicator more sensitive and specific in assessing pain in neonates at term and preterm infants (1,2). One must also consider that crying and body language are two other indicators of the extent of behaviour with strong pain in children non-verbal or pre-verbal (1,2,4). Therefore, behavioural scales were chosen who had in common those most sensitive indicators, and if possible the both, like the scales NFCS, NIPS, Comfort and PIPP to serve as a reference in comparisons with traditional physiological indicators (HR and PO) and SCA. In this study, the scores of three scales that were used for analysis, increased significantly in the period prior to the period during the procedure, the period after returning to a level slightly higher than baseline (Table 1). However, the decrease in score of the scale of the NFCS for the period after was quantitatively much smaller than for other scales. As the scale NFCS has a greater number of components of facial expression, it can be hypothesized that facial expressions had a greater effect of discriminating in the evaluation of pain after the three minutes after the period.

This study found no significant correlation between the SCA, represented by the number of waves per second, and under curve area of the waves, the indicators HR, pulse oximetry and Comfort scale, NFCS and NIPS. The activity of skin conductance not be correlated or with other behavioural and physiological indicators, is probably because it operates in a much minor numeric scale, becoming difficult any statistical comparison and although it may have greater specificity for pain, it is proposed that the most prudent course is to evaluate it in conjunction with other measures searching for a general performance comparison than statistical correlations.

The expectation that the activity of skin conductance as physiological indicator function is the same as that governing the evaluation of other physiological and behavioural indicators described in the literature and studied in this research, namely that all function as a gauge of the emotional response of the individual to an acute painful stimulus. By using linear regression analysis of the slope of the curve, the fifth component characteristic of a physiological indicator (LVI), found statistical significance only for number of waves, PO, NIPS and Comfort scale. However, while the differences before to during, to the variables number of waves, heart rate, pulse oximetry, Comfort scale, NFCS and NIPS, were highly significant, there was not significant difference only for the under curve area.

### **Conclusion**

The increase of skin conductance to a noxious stimulus is a reflex activation of sympathetic nervous system on the sweat glands and has been interpreted as pain perception (9). The wave spontaneously generated by filling and emptying of the sweat glands is captured in the palm and sole of the foot by a device that measures the conductance in real time (9). This method of pain assessment has been tested over the past eight years and has found variable association between significant and non significant, with other physiological and behavioural parameters in various situations of acute pain and not acute, in healthy neonates at term and preterm subject to heel prick, on mechanical ventilation and underwent tracheal suction, in children from one day to 11 years and adults undergoing surgery (10).

In full term newborns subjected to heel prick, the number of waves per second, unlike the under curve area of the waves, was found to be significant for the diagnosis of acute pain during the procedure, as well as heart rate, pulse oximetry and behavioural scales Comfort, NFCS and NIPS. In neonates who do not express facial activity and motor robust for various reasons, can be a far more valuable than the others. The number of waves per second, heart rate, oxygen saturation and Comfort scale, NFCS and NIPS showed a significant change in

score from baseline when the painful stimulus, given the assumptions that form the fifth characteristic of a measure psychophysical the so-called Law of Initial Value.

In this group of cases, the number of waves per second better reflect the activity of skin conductance than the under curve area of the same, and seems to have better sensitivity to identify physiological responses to painful stimuli than other physiological and behavioural indicators. It is considered that in the context of pain research in newborn should always be assessed through a series of physiological and behavioural measures, taking into account the individual context and environment. However, both for the research and for clinical management of pain it is suggested to favour the use of non-invasive technologies and low-cost that is also more efficient in time dimension, important for the health services that manage the pain. In this sense, the SCMS<sup>TM</sup> technology meets the criteria expected by both the theoretical assumption of LVI as the replication of validation studies in other countries.

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