

# Objective assessment of pain-related stress in mechanically ventilated newborns based on skin conductance fluctuations

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## Abstract

**Background.** In the process of intensive care, neonates are exposed to stress and pain related to repeated therapeutic-diagnostic procedures. The aim of this study was an objective assessment of stress intensity pain while performing selected procedures in neonates in the intensive care unit.

**Methods.** 32 neonates, with a mean body mass of 2,495g, intubated, mechanically ventilated, and who underwent sedation and analgesia, were qualified to the study. A stress reaction to suctioning from endotracheal tube and capillary blood taking for blood gas analysis was evaluated. For the pain stress evaluation, the conductance fluctuation method was used.

**Results.** 0.20 oscillations per second during the mechanical ventilation were obtained; during the suctioning, the number of oscillations increased to 0.33. With the finger tip puncture, the number of oscillations was 0.35. The mean values obtained in the cases of suctioning and puncture differed significantly from the ones obtained at mechanical ventilation ( $P < 0.001$ ) and did not differ between one another ( $P = 0.558$ ). The oscillation proportion  $\geq 0.33 \text{ s}^{-1}$  was lowest during the ventilation and it was significantly different ( $P < 0.001$ ) from the values obtained at suctioning and finger tip puncture. There were no significant differences between these values.

**Conclusion.** Measurement of the conductivity of skin as an objective tool to measure pain and discomfort during invasive procedures in neonatal intensive care shows that, despite the use of sedation and analgesia, neonates experience discomfort associated with the selected performance of therapeutic and diagnostic procedures.

**Key words:** intensive care, newborns; intensive care, pain-related stress, monitoring, pain; monitoring, skin conductance fluctuation

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Self-reporting of pain sensations requires the ability to communicate that newborns and infants do not possess. This inability to communicate verbally does not however exclude the possibility of experiencing acute pain, its turning into chronic pain, and the necessity of its treatment [1].

The development of chronic pain in infants is most vividly described using the von Frey hair or Semmes-Weinstein monofilament test and measurements of stimuli needed to elicit a foot withdrawal response.

The available study findings have revealed shorter delays and stronger responses in infants than in adults. The delay and response may vary with the increasing number of acute pain-inducing procedures. During the ontoge-

netic development, cutaneous sensory receptors appear in the perioral area in the 7<sup>th</sup> or 8<sup>th</sup> gestational week and in the palmar area during the 10<sup>th</sup> week. The first sensory receptors in the abdominal wall are observed in the 15<sup>th</sup> week; in a 16-week-old foetus, the entire body surface is covered with them. Integration of non-verbal pain assessment tools for pre-term infants should consider their developmental immaturity, both physical and psychological, as well as the severity of disease. The perception of pain and its manifestations (e.g. by an infant) are influenced by the carer's evaluation of the phenomenon. Pain assessment tools for the youngest age group should be based on the knowledge of processing and modulating pain sensations

by the developing nervous system. An ideal instrument for pain assessment should aim at measurements of real-time pain severity, accuracy of pain assessment, promptness of response and adequate calibration. The available methods of pain assessment in newborns and infants focus on acute pain caused by stimulation, and not by damage to nerve endings. This assessment is based on the observation of behavioural changes such as facial expressions, body movements, crying and physiological reflexes including pulse, respiration rate and blood pressure. In this age group, physiological, biochemical and behavioural changes replace the subjective description of pain sensations [2].

The severity of pain in the youngest children can be assessed using various scales based on behavioural and physiological reflex indices, among them the Premature Infant Pain Profile (PIPP) [3], Cry, Requires Increased Oxygen Administration, Increased Vital Signs, Expression, Sleepless (CRIES) [4] and COMFORT scale [5]. Their limitation is the rater's subjectivity and relativity of assessment [6].

In our study, the skin conductance algesimeter (SCA) was used to measure skin conductance fluctuations. This method was first presented by H. Storm and colleagues who used skin conductance to measure the sympathetic nervous system activation caused by a pain stimulus. The activation of sympathetic fibres that innervate the sweat glands induces secretion (so-called 'emotional sweating') with a simultaneous reduction in skin resistance and an increase in skin conductance. Quick absorption of the released sweat re-decreases the skin conductance. The conductance difference is read as a single oscillation having its volume (curve amplitude) and gradient (temporal distance between a peak and a valley). Pain stimuli induce a quick increase in emotional sweating and skin conductance fluctuations. When a pain stimulus withdraws, the skin conductance immediately decreases. These changes are recorded by electrodes attached to the rich-in-sweat glands of the palmar skin in adults and the plantar skin in newborns and infants. The resulting conductance fluctuations reach the central unit where they are processed and analysed. The software-transformed signal is expressed as an index (oscillations/second), which corresponds to the severity of pain-related stress (Table 1) [7, 8].

Intensive care of a newborn provokes pain-related stress associated with repeated blood sampling for gasometry and aspiration of secretion from the tracheal tube. The present study was aimed at an objective assessment of the level of pain-related stress during selected procedures in newborns mechanically ventilated in the intensive care unit (ICU).

## METHODS

The study design was approved by the Bioethics Committee of the Medical University of Silesia (Resolution No. KNW/0022/KB1/156/12 of 27 November 2012).

**Table 1.** The scale and index of pain-related stress severity in newborns/infants. According to [7] with her consent

WHITE: 0.00–0.07 impulse s <sup>-1</sup>	Calm newborn
LIGHT YELLOW: 0.14 impulse s <sup>-1</sup>	Calm newborn, slight motor activity
YELLOW: 0.21–0.27 impulse s <sup>-1</sup>	Active newborn, possible feeling of discomfort
ORANGE: 0.33 impulse s <sup>-1</sup>	Newborn probably experiences pain/discomfort, assess the situation
RED: 0.40–0.70 impulse s <sup>-1</sup>	Newborn most likely experiences pain/discomfort

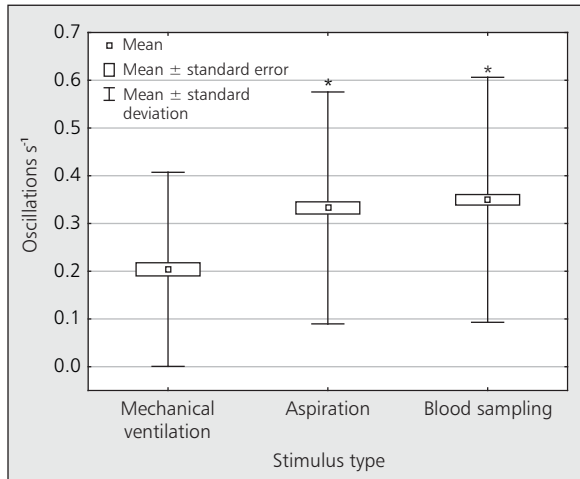
The study included 32 neonates born between the 34<sup>th</sup> and the 39<sup>th</sup> week of pregnancy (median = 36) with a mean body weight of 2,495 ± 395 g, intubated, mechanically ventilated, between the 2<sup>nd</sup> and the 6<sup>th</sup> ventilation day. The stress reaction of newborns to aspiration of secretions from the respiratory tract and to capillary blood sampling for gasometry was assessed. The newborns were sedated with the continuous intravenous infusion of midazolam (0.2 mg kg<sup>-1</sup> h<sup>-1</sup>) and fentanyl (2–3 µg kg<sup>-1</sup> h<sup>-1</sup>).

The pain-related stress was assessed using a method of skin conductance fluctuations (Med-Storm Pain Monitor, Med-Storm Innovation AS, Norway) with the number of conductance oscillations per second included. During the first 20 minutes following the placement of electrodes and connection of the SCA, the parameters of skin conductance were recorded continuously until the stabilisation of measurements. Subsequently, the initiation and completion of a procedure were determined at the defined measurement points. The duration of stimulus exposure was defined as the time from the onset of aspiration to stabilisation of measurement and from the fingertip puncture to stabilisation of measurement at the baseline level. To assess the severity of stress reactions during the procedures, two pain thresholds were accepted: the number of oscillations ≤ 0.14 s<sup>-1</sup>, which reflects the 'comfort threshold' (a child shows no pain reaction) and the number of oscillations ≥ 0.33 s<sup>-1</sup>, which indicates the pain/discomfort threshold (Table 1).

The obtained data was analysed using Statistica 10 software (Statsoft Inc., Tulsa, OK, USA). The distribution of data was determined using the Kolmogorov-Smirnov test and the results were analysed by the one-way analysis of variance (ANOVA) and post-hoc Tukey HSD test. Percentages of threshold measurements were compared using the  $\chi^2$  test. Statistical significance was assumed at  $P < 0.05$ .

## RESULTS

The analysis showed 0.20 (0.18–0.23) oscillations per second during mechanical ventilation and 0.33 (0.31–0.36) oscillations during suction of secretion from the tracheal



**Figure 1.** Comparison of mean values of conductance oscillations during exposure to different stressors in mechanically ventilated neonates; \* $P < 0.05$  compared to values during mechanical ventilation

tube. Fingertip punctures during arterial blood sampling for gasometry increased the number of oscillations to 0.35 (0.33–0.37).

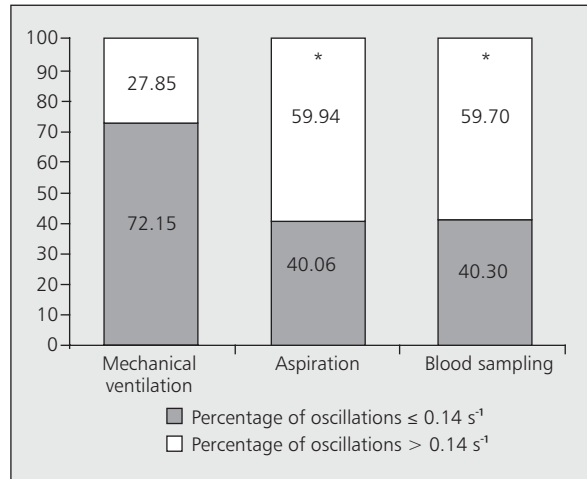
The mean values obtained during aspiration and fingertip puncture differed considerably from those observed during mechanical ventilation ( $P < 0.001$ ); the values noted during aspiration were found to be comparable to those during fingertip puncture ( $P = 0.558$ ) (Fig. 1).

The highest percentage (72.15%) of oscillation values  $\leq 0.14 \text{ s}^{-1}$  was found during ventilation. Significantly lower percentages ( $P < 0.001$ ) were observed during aspiration of secretion from the tracheal tube and fingertip puncture (40.06% and 40.3%, respectively) (Fig. 2).

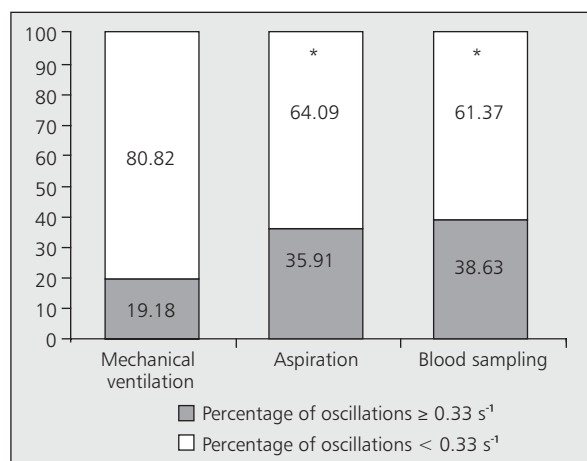
The lowest percentage of oscillation values  $\geq 0.33 \text{ s}^{-1}$  was found (19.18%) during ventilation (19.18%) and was significantly different from the results obtained during aspiration of secretion from the tracheal tube and fingertip puncture (35.91% and 38.63%, respectively). No significant differences were found between the two above results.

## DISCUSSION

It has been demonstrated that mechanical ventilation constitutes a significant nociceptive stimulus in newborns despite concurrent sedation [9]. The available literature describes negative reactions to procedures performed in the ICU, including mechanical ventilation, and their consequences, i.e. increased intracranial pressure, central nervous system haemorrhage, prolonged mechanical ventilation or hospitalisation [10]. In order to avoid these negative sequels, aspiration, blood sampling and other invasive procedures should be preceded by the administration of analgesics (e.g. paracetamol) or bolus of fentanyl. According to the modern



**Figure 2.** Comparison of oscillation percentages  $\leq 0.14 \text{ s}^{-1}$  (comfort threshold) during various procedures; \* $P < 0.001$  compared to the values during mechanical ventilation



**Figure 3.** Comparison of oscillation percentages  $\geq 0.33 \text{ s}^{-1}$  (pain threshold) during selected procedures; \* $P < 0.001$  compared to the results during mechanical ventilation

approach to patient care in the ICU setting, deep sedation is increasingly being replaced by conscious sedation or sedation with preserved reflexes.

In our study, the percentage of readings higher than the pain threshold did not exceed 40% and was half that during mechanical ventilation compared to other invasive procedures such as secretion aspiration or blood sampling. Nevertheless, the presence of stimuli exceeding the pain threshold during mechanical ventilation, irrespective of their severity, indicated the invasive nature of ventilation and its indubitably negative effects on the neonate's condition. Other consequences of insufficient pain therapy include haemodynamic instability, hypoxaemia and blood pressure fluctuations that may lead to, for instance, intracranial ha-

emorrhage. Adequate analgesia may reduce the frequency of hypoxaemia incidents and oxygen demands during painful procedures in neonates treated in the ICU [11].

On the other hand, deepened sedation and reduced reactivity of the child induced by administration of higher doses of opioid analgesics prolong mechanical ventilation and affect gastrointestinal motility, delaying the introduction of enteral nutrition [12].

Our findings revealed that the highest percentage of measurements indicating well-being (72.15%) was found during uneventful ventilation (72.15%); significantly lower percentages were observed during aspiration of secretion from the tracheal tube and fingertip puncture (about 40%), which means that any invasive procedure performed with sedation, including mechanical ventilation, may provoke the sensation of discomfort, more often during additional invasive procedures. However, some studies have indicated that the values of skin conductance are individually variable at critical points and should be considered in relation to baseline values [13].

Taking into consideration both ranges of comfort and pain reactions, it is clear that the effective level of sedation and analgesia is extremely difficult to achieve, as the level of sedation adequate for a particular clinical situation has to be weighed against the adverse side effects of the agents administered. Pain and broadly understood discomfort in neonates and infants are most commonly treated using pharmacological methods [9], sometimes supplemented with other simple measures of sedation and analgesia, e.g. oral supply of glucose or feeding [14, 15].

In the scales used to date, physiological variables are considered useful indicators of pain sensations, despite the fact that the assessment of vital signs (such as heart rate, blood pressure, temperature and breathing) is often misleading as they can vary greatly in response to the disease. Haemodynamic changes are also markedly modified by drugs affecting the circulatory system and show poor specificity as indicators of sufficient levels of anaesthesia and sedation or otherwise. The method applied in the Skin Conductance Algesimeter does not depend on haemodynamic changes, ambient temperature and respiratory rhythm.

Since infants and small children do not verbalise their pain, its incidence and severity are understated; therefore, the youngest children fall into the group of increased pain risk. The assessment of pain in this group constitutes a major challenge, because evaluations based on reliable and adequate methods have to be regularly repeated to be sure that the pain has been identified and relieved. Despite a considerable number of studies describing the pain in infants, many issues related to its occurrence remain unexplained [16]. With current medical knowledge and technical possibilities, attention should be focused on designing the most effective and least

harmful model of sedation, which should be possible using novel tools for pain-related stress assessment.

## CONCLUSION

The assessment of skin conductance as an objective tool for the evaluation of pain and discomfort during invasive procedures used in the intensive care of neonates demonstrates that, despite sedation and analgesia, neonates experience discomfort related to the therapeutic and diagnostic procedures they undergo.

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