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Assessment of pain in critically ill children. Is cutaneous conductance a reliable tool?☆

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ABSTRACT

Purpose: The purpose of this study is to assess the usefulness and accuracy of skin conductance (SC) as a tool to evaluate the level of sedation and pain in pediatric critical patients during painful procedures and to compare it with hemodynamic variables, clinical scales, and bispectral index (BIS).
Materials and methods: This is a prospective observational study in 61 critical children undergoing invasive procedures. Hemodynamic data (heart rate and arterial blood pressure), clinical scales punctuation (Ramsay, COMFORT, and numeric rating pain scales), BIS, and the number of fluctuations of SC per second were collected before, during, and at the end of the procedure.
Results: The mean age of the patients was 42.9 (range, 1 month to 16 years). Seventy-two point six percent were postcardiac surgery patients. Nonmuscle-relaxed patients showed a moderate increase in heart rate ($P = .02$), numeric rating pain scales ($P = .03$), and Ramsay scale ($P = .002$). The number of fluctuations of SC per second increased significantly during the procedure (basal, 0.1; maneuver, 0.2; $P = .015$), but it never reached the level considered as pain or stress nor did it precede clinical scales or BIS. None of the variables studied showed a significant change during the procedure in muscle-relaxed patients.
Conclusions: Skin conductance was not found to be more sensitive or faster than clinical scales for the assessment of pain or stress in critical children undergoing painful procedures. Skin conductance was not useful in muscle-relaxed children.

1. Introduction

Children admitted to a pediatric intensive care unit are commonly subjected to painful procedures and stressful situations that require the administration of sedative and/or analgesic drugs [1].

The management of sedation in these patients is difficult because sedative drugs have a narrow therapeutic window, and patients frequently have altered mechanisms of hepatic and renal clearance and because critically ill children cannot adequately verbalize the intensity and site of pain and have more tolerance and physical dependence than adults [2].

Anatomic and neurochemic pathways for the transmission of pain are developed at birth, and children can respond to it with physiologic, metabolic, hormonal, and behavioral changes. Pain causes hemodynamic instability, hypoxemia, and it increases intracranial pressure. On the other hand, excessive sedation can cause cardiac and respiratory depression, an increase in the duration of mechanical ventilation and abstinence syndrome [3,4].

Continuous monitoring of the level of sedation or pain in critically ill children is imperative during painful procedures, to find the right balance between being without discomfort and not being oversedated [5].

Several methods have been used for the evaluation of the level of sedation in critical patients, although no criterion standard exists [3,6]. Hemodynamic variables, clinical scales, and analysis of the electroencephalogram [1](EEG) are the most widely used methods [2]. However, these methods have some limitations. Hemodynamic parameters are influenced by the volemic status of the patient, drugs, and the autonomous nervous system [7,8]. Sedation scales are subjective methods and cannot be applied in profoundly sedated or muscle-relaxed patients [6,9]

In the last years, new methods based on the analysis of the EEG have been developed. Bispectral index (BIS) is a noninvasive method that assesses the level of consciousness of the patient by analyzing the frequencies of the EEG waves. Although it has been proven to be a useful

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[1] EEG: electroencephalogram; [2] BIS: biespectral index;[3] NFSC: number of fluctuations of skin conductance per second; [4] SRPS: Faces Pain Scale-revised; [5]HR: heart rate; [6]SBP: systolic blood pressure; [7]DBP: diastolic blood pressure; [8]RR: respiratory rate.

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method in critical patients, it also has some limitations: several clinical conditions and electronic devices like pacemakers could induce artifact signal pollution [2,10-13].

Skin conductance (SC) is a noninvasive method for the evaluation of pain or stress [5,14,15]. Pain or stress produces an increase in subcortical and cortical activity, which generates a sympathetic download that releases acetylcholine that acts on the muscharinic receptors, which stimulate sweat gland secretion, resulting in changes in SC [14]. The peak of the SC appears 1 to 2 seconds after a stimulus and is, in theory, independent of temperature, muscle relaxation, sympathomimetic drugs, or changes in the volume status of the patient.

Skin conductance seems to be useful for monitoring the level of sedation or pain in preterms and infants [16,17], postsurgical patients [18], children with minor injuries [19], with mechanical ventilation [5], and critically ill adult patients [20]. However, there are few data related to the usefulness of this device in critically ill children [5], and there is not much experience in muscle-relaxed patients.

The purposes of this study were to evaluate the usefulness and accuracy of this device for the assessment of the level of sedation and analgesia during painful procedures in a pediatric critical care unit; to compare this method with hemodynamic variables, clinical scales, and BIS during painful procedures; and, finally, to determine the usefulness of SC in pediatric muscle-relaxed patients.

2. Material and methods

2.1. Participants

We conducted a prospective, observational study, which included critically ill children aged from 1 month to 16 years undergoing a painful technique.

Painful procedures included arterial or central venous line catheter insertion, urinary tract catheterization, insertion of a nasogastric tube, tracheal aspiration, pleural catheter removal, left atrial pressure catheter removal, lumbar puncture, or sternal closure.

Approval was obtained from the institutional review boards of the hospital, and informed consent was obtained from the parent or legal guardian of each child enrolled.

Patients were excluded if they were being treated with anticholinergic drugs (high-dose atropine or neostigmine) or sympathetic central nervous system inhibitors (ie, clonidine), if they had a peacemaker or defibrillator, or if they rejected to participate in the study.

2.2. Test methods

After being included in the study, a BIS XP 3.4 monitor (Aspect Medical Systems, Newton, MA) was settled. Frontal sensors with 3 ZIP Prep pediatric electrodes in children younger than 1 year and Quatro ZIP Prep electrodes in children older than 1 year were used. The BIS monitor was connected to a Philips Intellivue MP70 monitor.

Skin conductance was analyzed by a Med-Storm monitor (Med-Storm Innovation AS, Oslo, Norway). This device measure real-time changes in SC due to pain or stress by analyzing the peaks or number of fluctuations of SC per second (NFSC) and the relative area under the curve [21]. An *NFSC peak* is defined as minimum followed by a maximum in conductance values Micro Siemens (μS) [5,21]. The system can measure conductance values in the range of 1 to 200 μS, with a noise level below 0.002 μS and has error detection that provides a warning about electrode looses or external interferences [21].

An applied voltage of 50 mV and a 3-electrode system (Sensormedics, CA, Oslo, Norway) were used. The 3-electrode system comprised a measuring electrode (M), a countercurrent electrode (C), and a reference voltage electrode (R), which ensured a constant applied voltage across the stratum corneum. The electrodes were settled on the soles in children younger than 1 year and on the palms in older children to improve the quality of the signal, as older children have a thicker sole corneal stratum than infants. The electrodes were placed according to the Edelberg guidelines for the placement of electrodes to obtain the most sensitive measurement [14].

According to the specifications of the manufacturer, a value greater than 0.21 peaks per second was considered to be as pain or discomfort.

2.2.1. Clinical scales

Anxiety and pain were measured by the Modified Ramsay scale, COMFORT scale, and self-report pain scale (SRPS) (Faces Pain Scale-Revised in infants and children after receiving sedatives and color rating scale for conscious children). Modified Ramsay scale is an 8-point scoring system, which quantifies the level of sedation [22] and has been used to evaluate the level of sedation during the performance of procedures in critically ill adults and children [2,3,6,22]. This scale is scored from 1 (patient anxious and agitated or restless or both) to 8 (no response to any stimulus including pain).

The COMFORT scale is a useful score to measure the levels of stress in critically ill children requiring mechanical ventilation [23]. It evaluates 8 parameters, scoring between 1 and 5 points each.

2.3. Protocol

Previous to the procedure, heart rate (HR [beats per minute]), systolic (SBP [millimeter of mercury]) and diastolic arterial blood pressure (DBP [millimeter of mercury]), and respiratory rate (breaths per minute) were recorded as well as the punctuation in clinical scales, BIS, and NFSC. All these measures were repeated during the procedure and 5 minutes after the procedure. Maximum registered values of the procedure were recorded and considered for analysis.

The basal pharmacologic sedation-analgesia treatment (type and dosage) of the patient as well as the additional doses needed to achieve a good level of analgesia was also recorded. The administration of additional doses was at the discretion of the attending physician based on the clinical status of the patient.

2.4. Statistical methods

Data were analyzed with SPSS software version 18.0. The evolution of hemodynamic parameters, clinical scales, BIS, and NFSC were analyzed using the Wilcoxon test. Correlation between variables was estimated using the Spearman rank correlation coefficient (ρ).

3. Results

Sixty-one patients were included in the study. The mean age was 42.9 $\pm$ 56.5 months. Children were diagnosed as postcardiac surgery in 72.6%, respiratory failure in 9.7%, neurologic disease in 6.5%, oncology patients in 6.5%, sepsis in 3.2%, and others in 1.6%.

The most common procedure was pleural or atrial left pressure catheter removal (37.7%), followed by arterial or venous canalization (27.8%), tracheal tube aspiration (18%), nasogastric or urinary tract tube insertion (9.8%), lumbar puncture (4.9%), and chest closure in a cardiac patient (1.6%).

Continuous midazolam infusion was used in 42% of patients (mean dose, 1.5 $\pm$ 2.4 μg/kg per minute), fentanyl infusion in 61% (mean dose, 1.0 $\pm$ 1.2 μg/kg per hour), remifentanil infusion in 6% (mean dose, 0.05 $\pm$ 0.2 μg/kg per minute), and propofol infusion in 22% of patients (mean dose, 0.6 $\pm$ 1.3 mg/kg per hour). Fifteen patients received continuous muscle relaxation with vecuronium (mean dose, 0.13 $\pm$ 0.1 mg/kg per hour).

3.1. Evolution of hemodynamic parameters, clinical scales, BIS, and NFSC variables

The evolution of hemodynamics, clinical scales, BIS, and NFSC in basal situation, during the procedure and at the end of the procedure is registered in Table 1. The NFSC evolution is represented in Figure 1.