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Postoperative Pain Assessment Methods for Infants and Young Children: A Review

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Abstract

Pain assessment in pediatric postoperative setting has always been challenging, due to the lack of insight about pain mechanisms in newborns, infants and young children. Several research works about this subject were conducted over the years, and such studies contradict what was postulated for many years and demonstrate that infants do feel pain stimuli, even more so than older children or adults. For this reason, it is important for health care providers to be familiar with appropriate pediatric pain assessment tools, accordingly to age, cognitive development and context of the pain. This paper will focus on the diverse available scales and parameters used, as well as their advantages and limitations. Additionally, some recent developed technologies are briefly mentioned, some of which could translate a solution for this problem in the future. We still lack a gold standard for pain assessment in all clinical settings and pediatric age groups. Self-report, behavioral and physiological scales can be used for such purpose, although none of these methods has proven to be neither superior nor demonstrated excellent accuracy. Further research is needed in order to find and validate an objective and easy to use pain assessment instrument that could become a gold standard for worldwide use. The question about the best pain assessment method for infants and young children remains unanswered, being necessary to adapt the pain assessment process to each specific child and context.

Keywords: Pain assessment; Postoperative period; Behavioral scales; Self-report scales; Physiological scales; Infants; Children

Abbreviations: FPS-R: Faces Pain Scales Revised; NRS: Numerical Rating Scales; VAS: Visual Analogue Scales; CHEPOS: Children's Hospital Of Eastern Ontario Pain Scale; OPS: Objective Pain Scale; BOPS: Behavioral Observational Pain Scale; CHIPPS: Children And Infants Postoperative Pain Scale; NCPC-PV: Non-Communicating Children's Pain Checklist Postoperative Version; INRS: Individualized Numerical Rating Scales; CAAS: Cardiac Analgesia Assessment Scale; PPG: Photoplethysmography; EDA: Electro Dermal Activity; GSR: Galvanic Skin Response; SPI: Surgical Pleth Index; PDR: Pupillary Dilating Reflex; ANI: Analgesia Nociception Index; EDIN: Échelle Douleur Inconfort Nouveauné

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Introduction

For a long period of time, it was believed newborns and infants didn't feel as much pain as older children and adults, as it was thought their nervous system wasn't completely developed yet. It is long known that peripheral nerve myelination is concluded at the time of birth. Therefore, every newborn and, subsequently, infants and children, are capable of feeling pain and of establishing *motor responses* to these unpleasant stimuli. On the contrary, the pain inhibitory pathways are undeveloped, which actually translates into a more exuberant pain sensation, due to the *overdrive* of the excitatory mechanisms. In other words, younger children may actually feel more pain in response to a lower-intensity noxious stimulus. There are increased central effects, such as tissue damaging by noxious stimuli, which may lead to long time structural and functional *damage* in pain pathways, causing chronic pain and increased sensitivity to pain stimuli later in life. Physiological responses, such as increased heart rate, blood pressure and oxygen demand, can happen at the time of the noxious stimuli and these may be detrimental to debilitated children, worsening postoperative outcomes as well as psychological adverse effects, such as fear, anxiety and depression [1-6].

On the other hand, when pain is overestimated the child is exposed to overmedication, which can potentially cause adverse effects. Postoperative pain management in children is still far from ideal. Reportedly, only 25% of children subjected to surgical procedures are pain free on the day of the intervention and 13% find themselves under severe pain. Usually, there is a tendency for *oligoanalgesia*, and lack of an implemented guideline for pain assessment is often reported as the cause, along with ineffective pain measurement tools [7-9].

When assessing pain in children, certain factors such as age, cognitive level, disabilities, type of pain and situation upon which the pain emerges must be considered [10]. Pain assessment is the first step to pain management. Currently, most health care provider's base pain assessment on behavioral and self-report pain scales, although there is no evidence that a single scale proves to be more accurate than others, giving way to worldwide discordance in actual clinical practice.

In order to provide optimal medical care to children, it is mandatory to improve the accuracy of pain assessment, by applying the best assessment tools to the patient at hand. For the reasons mentioned above, the doubt about the best pain assessment method in infants and young children remains, being the aim of this paper to review the most commonly used pain assessment tools, as well as their advantages and limitations.

Self-Report Scales

Nowadays, self-report scales are the *gold standard* for pain assessment in children over six years old, whenever its application is possible. These scales can be verbal or nonverbal. However, they always require a certain degree of cognition and communication skills, both being improved by increasing age and experience, as it depends on the child's development. As an example, facial expression scales are favored when dealing with younger children [11, 12].

The most commonly used self-report scales are the Faces Pain Scales Revised (FPS-R), Numerical Rating Scales (NRS) and Visual Analogue Scales (VAS). Table 1 *s*ummarizes the most commonly used self-repot scales. Self-Report scales' application may actually be possible by the fourth year of age. It depends greatly on the maturity of the child (both cognitive and emotional) and it can only be applied to verbal children who don't present a cognitive disability [13]. Therefore, it cannot be used as a clinical standard method for pain assessment at such young ages.

The Numerical Rating Scales (NRS) are also difficult to use with children younger than 8 years old. They demand the ability to understand numeracy and to have the skill to express oneself. Being able to count (in younger children) does not suffice, as it is also required an ability to understand quantitative significance of numbers, translating a higher level of cognitive development. Among these scales, the most commonly used is the NRS-11, scored from 0 to 10 [14]. It has also been postulated that children tend to provide a higher level of pain when using the NRS, in comparison to the VAS or the FPS-R.

The FPS-R, presents different facial expressions portraying various degrees of pain, by demonstrating different feelings, to which the children should identify themselves with (Figure 1). This method doesn't demand such a refined cognitive development, which makes it more adequate to younger children. Moreover, studies show that children favor these scales when compared to the VAS, while a study by Tovar supported the use of the FPS-R in children aged older than five, remaining the doubt about younger children and the best evaluation method [15-18].

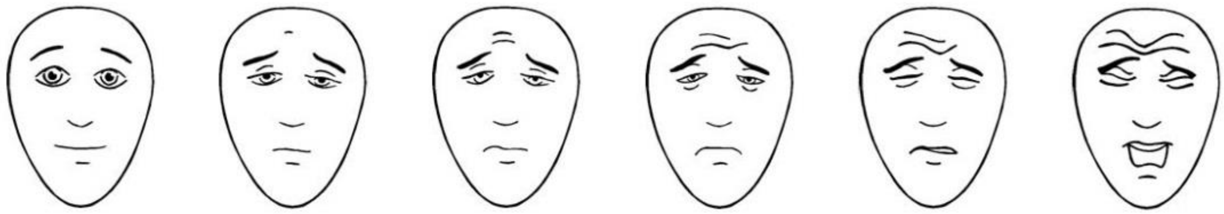

Figure 1: The Faces Pain Scale - Revised: scored from 0 to 10 (0-2-4-6-8-10) or from 0 to 5. The child must point to the face that shows how much pain they are feeling *[Copyright of the FPS-R is held by the International Association for the Study of Pain (IASP) ©2001. This material may be photocopied for non-commercial clinical, educational and research use, pending permission for journal publication at this date].*

VAS depicts a 10 cm line, representing a continuous pain dimension, either vertical or horizontal, in which the child must mark the point that corresponds to their pain. The ends of the line are the extreme limits of pain. The index of pain severity is given by the length in centimeters from the low extreme of the line to the patient's mark. They are often used in clinical practice and several studies have proven its validity and sensitivity for use in children as young as three years old [19].

When it comes to construct validity, VAS shows good to moderate correlation with other self-report pain measures, for instance with the FPS and it is the most recommended of self-report scales for children aged four to six years old, being the vertical version the most suitable [20-21].

According to Birnie [11], the Numerical Rating Scale (NRS-11), the revised Faces Pain Scale (FPS-R) and the Color Analogue Scale (CAS) (a specific type of VAS, where 0.25 cm intervals are colored with a gradual color scheme from white to red, filling the 0 to 10 cm line [22], exhibited in Figure 2 [23]) are recommended for acute pain, showing better performance than the other analyzed self-report scales.

According to Baeyer [24], the revised Faces Pain Scale can be used for children as young as 4 years old, and the CAS starting from five years old.

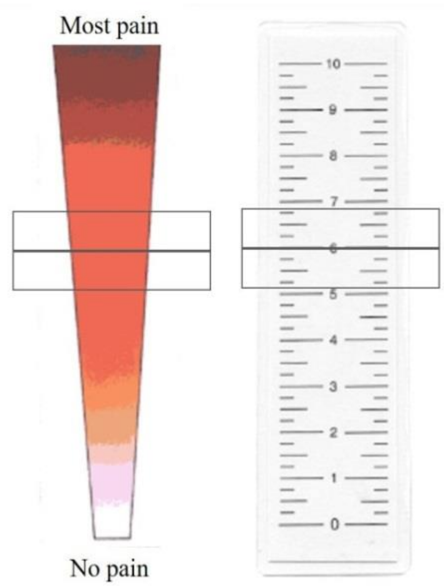

Figure 2: Color Analog Scale (CAS), with the permission of Kathy Speechly. It depicts a band, 10 cm of length, with a gradual color pattern, going from dark red to white [23].

However, these tools didn't provide strong results for their use in postoperative or chronic pain settings. Moreover, there wasn't any self-report scale reliable enough to measure pain in children younger than six years, which is also proved by further studies.

All the self-report scales share a common problem, which lies on the child's understanding of which level of pain they are feeling. Indeed, when facing the task of choosing a face, a number or a point in the crescendo line of pain, they are told which extremity is "no pain at all" and the other "the worst pain imaginable". What happens is that the amount of pain the children have experienced previously in their lives will determine the way they choose the level of the present noxious feeling. It is known, for instance, that *hospitalized children* describe pain differently from the others, for instance, they are more likely to cry and to describe pain in combination with fear and tension [25]. Therefore, it may not correctly reflect the true intensity of the pain.

Furthermore, younger children (below five years of age) show a tendency to choose the extremes of the scales. This happens due to the fact that they don't understand the scale as being gradual but dichotomous [26]. Although these scales are largely used in most clinical settings, their accuracy doesn't seem to be as good in post-operative and chronic pain situations. In fact, for these specific settings, there are only weak recommendations considering the use of self-report tools. Also, no self-report measure is ultimately recommended for children younger than six years of age [14], which makes the problem of accurate pain assessment in this age group stand.

Tool	Age Group	Advantages	Disadvantages	Observations
Self-Report Scales	Recommended>6 years	Greater accuracy than the tools. Quick assessment time.	Requires cognition and communication skills (not applicable to young or disabled children)	Preferred pain assessment method
NRS	>8years	Simple and easy to use scale	Demands higher cognitive skills. Only possible to use with older children	Preferred tool for older children
FPS-R	>5 years	Children reportedly favor this scale. More intuitive and easy to understand by younger children	Not enough evidence for its use below age of 5. Limited for children with cognitive or visual impairment	Conforms closely to a linear interval scale
Vas	≥3 years	Potentially applicable to younger children. Continuous pain dimension	Only good moderate correlation with FPS	Vertical version is preferred

Table 1: Summary of Self Report Scales and their main advantages and disadvantages. NRS: Numerical Rating Scale, FPS-R: Faces Pain Scale revised, VAS: Visual Analog Scale.

Behavioral scales

No behavioral pain assessment system has yet been universally accepted in clinical practice, due to contradictory findings about their specificity, sensitivity, reliability or validation. Another reason frequently pointed out, is the lack of *feasibility* in a hospital setting, given the long-time usually required for patient examination, being too impracticable for regular assessments, as it is necessary in a postoperative setting. [27]. The expression of pain in children younger than six years old is essentially non-verbal and consists primarily in body movements and facial expressions.

When there is the need to assess pain in younger age groups, self-report scales cannot be applied, due to the patient's immature cognitive and language development, as mentioned before. Other pain measures must be put into action, being behavioral scales, the most validated tools in clinical practice, at least for now. These scales are based on the measure of facial expressions, body movements as well as crying, among other features [28]. Most times, a combination of all these features is calculated, in order to achieve a better assessment.

Some researches show behavioral methods, most specifically, *facial expressions*, are the most reliable tools in the pediatric pain assessment field, having the highest sensitivity and sensibility in infants. However, the specificity and sensitivity of these scales are disappointing, being influenced by other distress factors, such as fear, anxiety, hunger, or even physiological states, like fever. Nowadays, it is possible to say that behavioral pain assessment methods are more accurate when applied to newborns and young infants. Regarding toddlers (mostly between two and four years old), this task appears to be more difficult; as their facial expressions and body movements are not so specific for pain (they can express fear or anxiety as well). As was concluded in the study by Good enough [29-31], no facial expression scale could be proved to be superior to the others.

The most commonly used scales are the COMFORT and the FLACC scales [32], which will be described below and are summarized in Table 2, along with some others of the most used behavioral scales. The FLACC (Face, Legs, Activity, Cry, Consolability) scale is validated for children aged two months to seven years old, comprising five categories. It showed excellent correlation between observers and intraobservers [33]. Its usefulness furthers into cognitive impaired children, proving to be a reliable method in this population (mostly the revised FLACC [34]. It doesn't require a long observational time, lasting only up to five minutes [35].

The FLACC scale is one of the most widely used behavioral scales, although there is not enough evidence that allows recommendations for the application of this scale to all the contexts and age groups. It was designed in order to provide health care professionals with a simpler and quicker observational tool to evaluate pain in children. Therefore, it focuses on five behaviors, each scoring from 0 to 2, adding up to a maximum of 10 points.

The FLACC scale has proved to be a good measurement tool in a recent study, exhibiting excellent sensitivity (89.94% - 95%CI: 78.48-96.83%) and sensibility (87.82% - 95%CI: 78.6-95.23) [36]. The COMFORT Scale, on the other hand, is composed of six behavioral factors (alertness, level of agitation, body movement, muscle tone, facial tension, and respiratory response) and two physiological parameters (heart rate and blood pressure). It is validated for the assessment of pain in children between newborns and three years old, in postoperative setting [37].

Surprisingly, the two most objective measures of the scale (heart rate and blood pressure) are the ones that showed lowest interrater correlation, as opposed to four subjective measures (alertness, calmness, respiratory response and movement), which exhibited the highest agreement levels [38]. This scale is especially useful to assess pain in sedated or unconscious children, from birth to adolescence, being recommended in such contexts [22].

In postoperative settings, children are often ventilated, sedated, which makes behavior assessment difficult. Although promising at first, Cury demonstrated that this scale proved insufficient to properly guide analgesic administration in children following heart surgery, suggesting the need to develop a more accurate tool. There is also a new modified COMFORT scale, which has been developed, but still needs further studies to be validated [39, 40].

The Children's Hospital of Eastern Ontario Pain Scale (CHEOPS) is also validated for assessment of postoperative pain, in children from one to five years of age (some studies even recommend its application until 7 years old). Judging six pain behaviors (Cry, facial expression, verbal expression, torso position, touch and leg position), it proved to have good sensitivity and sensibility, which, together with its simple and quick application, makes it a good assessment tool in this age group [41, 42].

The Objective Pain Scale (OPS) can be used starting from the 18th month until the child is twelve years old. It was initially formulated based on six parameters, including blood pressure, crying, movement, agitation, posture and complaints (when the age is appropriate). However, the later developed modified OPS, omitted the blood pressure analysis and showed great reliability and validity [34].

The FLACC scale only accomplished moderate to good validity with Objective Pain Scale (OPS) and Children's Hospital of Eastern Ontario Pain Scale (CHEOPS) [33]. The Behavioral Observational Pain Scale (BOPS) has been developed for children aged one to seven years old and it focuses on three specific behaviors: facial expression, verbalization and body position. A positive correlation between this scale and the CHEOPS was found, regarding construct validity, as well as a good interobserver reliability [43].

There is also the CRIES scale (crying, requires oxygen, increased vital signs, expression, and sleeplessness) and it can be used from newborns to infants aged 6 months. This scale is valid until 72 hours post-surgery and exhibits excellent interobserver reliability [44].

The EVENDOL (*Evaluation Enfant Douleur*) has been validated to use in postoperative pain assessment of children since birth to seven years old, and can be used when self-reporting scales are not an option [45]. This method is not influenced by fever, fear or hunger and it comprises four behavioral features as well as one environmental factor.

It is also worth mentioning the CHIPPS scale (Children and Infants Postoperative Pain Scale), which comprises four items in its assessment: crying, facial expression, trunk's posture, legs' posture and motor restlessness, which of each can be scored from 0 to 2 points. The higher the CHIPPS score, the higher the level of pain the child is experiencing. A great advantage of this scale is the short time it takes to assess the score, an observation time of only fifteen seconds. It has been validated for pain assessment in the post-operative period for newborns, toddlers and young children (until five years of age) [46].

Among all the behavioral scales used at the present time, the EVENDOL and the CHIPPS show the widest array of applications and are reliable for use on children younger than 1 year of age. The CRIES scale can be used for newborns and infants up until 6 months old. However, its validity didn't prove to be as strong as EVENDOL's and CHIPPS' [37].

When it comes to pain assessment in cognitive impaired children, the task is even more challenging. Not only do they share the usual confounding factors as the other children, but they also add some new difficulties, due to cognitive disabilities. For this reason, special scales were developed, as a result of a poor analgesic management in this target population following surgery, which resulted in undertreated patients.

Non-communicating Children's Pain Checklist Postoperative Version (NCCPC-PV), FLACC, revised FLACC and Individualized Numerical Rating Scales (INRS) can and should be used under these special circumstances [42]. Besides the physicians and caregivers' direct assessment using these pain scales, the future lies on video analysis of the children's facial expressions, thanks to machine learning algorithms, already put into practice, for instance, by Mansor [47] achieving 90.77% accuracy [12].

It is also important to recognize that behavioral pain scales are time consuming and require a good education on the subject, by the health care providers, a fact many times neglected in clinical practice [48]. A study by Slater [49] has concluded there can be cortical response to noxious stimuli without a change in facial expression or overall behavior. This lack of motor response to pain may happen due to the immaturity of the neuronal motor circuit, which translates into an absence of muscle contraction. Therefore, even in the absence of a motor response, expressed by body movements or variation in face expression, there can be no certainty that the child is not under pain. This discovery represents a big limitation to the accuracy of behavioral scales.

Another *limitation* is related to the fact that younger children exhibit lower stimuli threshold for spinal motor responses, such as reflexes (withdrawing from a noxious stimulus) [50] but, when it comes to facial expressions and body movements, they present less variations, when compared to older children [51]. These findings suggest that the *emotional reaction* to pain develops later in life, while the sensory-motor response is visible right at the beginning of life, which makes it difficult to apply the same scale in different ages.

Tool	Age Group	Advantages	Disadvantages	Observations
Behavioral Scales	Recommended <6years	Allow for a more reliable pain assessment in younger children	Influenced by several distress factos. Impractible for regular assessment. Demands highly trained professionals.	Lack of an universally adapted method
FLAAC	2 months to 7 years	Quick assessment time. Can be used with disabled children	Lack of evidence to be applied to all contexts and age group	Analyses 5 behavior components
COMPORT	Newborn to 6 years	Validated for postoperative settings. Suited for sedated or unconscious patients.	Accuracy not proved for conscious patients.	Comprises 6 behavioral and 2 physiological parameters.
CHEOPS	1 to 5 years	Validated for postoperative pain assessment. Simple and quick application	Narrow age group applicable	Composed of 6 behavior factos.
OPS	18 months to 12 years	Wide age range	Assessed parameters are not very specific	Combines physiological and behavioral factos.
BOPS	1 to 7 years	Showed a good correlation with CHEOPS. Easy and quick assessment.	Potentially more inaccurate than the FLAAC scale.	Focuses only on 3 behavior patterns (derived from FLAAC scale).

CRIES	Newborn to 6 months	Excellent interobserver reliability.	Valid only up to 72h post-surgery. Very small group applicability.	Validity not as strong comaring to EVENDOL and CHIPS.
EVENDOL	Newborn to 5 years	Validated for postoperative settings. Not very influenced by distress factos.	Lack of satisfactory validation for children aged 2 to 6 months.	Evaluates 4 behavioral components and 1 environmental factor
CHIPPS	Newborn to 5 years	Short observation needed.	Only validated for postoperative setting.	4 behavioral items.

Table 2: Summary of Behavioral Pain Assessment Scales and their main advantages and disadvantages. FLACC: Face, Legs, Activity, Cry, Consolability Scale, OPS: Objective Pain Scale, BOPS: Behavioral Observational Pain Scale, CRIES: Crying, Requires oxygen, Increased vital signs, Expression, Sleeplessness, EVENDOL: Evaluation Enfant Douleur, CHIPPS: Children and Infants Postoperative Pain Scale.

Physiological measures

Among the physiological parameters usually analyzed for pain measurement are heart rate, respiratory rate, transcutaneous oxygen levels and blood pressure. Because all of these factors can also change due to other causes of distress, and not necessarily noxious stimuli, there is not a single physiological measure able to determine accurately pain intensity in children and several studies support the idea that physiological measures should be used in *combination* with other parameters, as they are not reliable enough for individual use [52, 53].

Moreover, some studies also mention intracranial pressure, cerebral blood flow, palmar sweating, decrease in oxygen saturation and vagal tone, for instance, as physiological pain indicators. However, as mentioned before, they are *not specific* to painful stimuli and their sensibility is also lacking. They are greatly affected by several clinical conditions, as sepsis, hypoxemia or even fever. Therefore, they are not reliable enough to translate pain intensity [54].

Mainly based on physiological factors, the *Cardiac Analgesia Assessment Scale* (CAAS) comprises four indicators: pupillary size, heart rate, blood pressure and respiratory and motor response. This scale is consistent in reflecting pain over time and it reported to be a more consistent measure than VAS [55]. It is especially useful when evaluating an invasively ventilated patient subjected to high doses of sedatives and muscle relaxants, when motor responses are not exuberant. On the other hand, bio factors, translating autonomic nervous system responses, such as ECG, photoplethysmography (PPG), electrodermal activity (EDA), galvanic skin response (GSR), surgical pleth index (SPI), pupillary dilating reflex (PDR) and skin temperature, for instance, have been studied for measuring pain in children during painful procedures, general anesthesia or postoperative period. Nevertheless, the results were disappointing, and it has been understood that using exclusively physiological factors to determine pain does not translate satisfactory accuracy. Therefore, they should be included in scales together with behavioral factors, producing a better outcome [56].

SPI, for instance, has been studied on its post-operative application. Although it shows a direct relation to pain during general anesthesia, these results don't seem as promising when the patient is awake. PDR proved to be a more sensitive index of noxious stimulation than the commonly used variables of HR and arterial BP in anaesthetized children and it is also independent of age, which facilitates its use in clinical practice [57, 58].

Infrared thermal imaging may be helpful in analyzing thermic variations in pain processing. Mostly regarding neuropathic pain, it can measure not only superficial (skin) temperatures, but also in-depth variations. This method has proven to obtain good results, combining normal thermographs with altered temperature patterns in patients under painful stimuli [59]. However, this study was not conducted on children and the results are not sufficient to estimate good performance for its use in this setting.

Regarding the *Analgesia Nociception Index* (ANI), contradictory studies exist. On one hand, Ledowski et al concluded it didn't perform as well as physiological parameters (blood pressure and heart rate) when measuring pain during a surgical procedure [60]. On the other hand, Boselli and Jeanne found a significant negative correlation between these two scales, when specifically assessing postoperative pain. Meanwhile, Sabourdin concluded that the ANI might provide a more sensitive assessment of nociception in anesthetized children than hemodynamic parameters or skin conductance [61, 62].

The ANI bases itself on calculating heart rate variability, through a continuous ECG analysis, which correlates with parasympathetic activity. It has shown good inverse correlation with NRS [63] and its interpretation is both easy and quick. Indeed, it is translated by a number (from 0 to 100, where 0 means absence of analgesia and 100 absence of pain), both as an average value for a period of time or as a instant measure [64].

A study by Funcke has shown promising results regarding the ANI, SPI and PDR, finding them highly sensitive and specific for pain assessment. Although this study was conducted in adults during general anesthesia, it implies a good correlation between these factors and noxious stimuli, findings that may be applied to children, also in postoperative settings [65]. Although the ANI already promoted good expectations, it also presented some limitations when dealing with infants and very young children, due to their differences in heart rate variability. For this reason, the Newborn Infant Parasympathetic Evaluation Index (NIPE) was developed [66]. However, limited research has been lead, and this new tool lacks yet validation to be implemented in clinical practice. Nevertheless, Faye et al found correlation between the NIPE and the *Échelle Douleur Inconfort Nouveauné* (EDIN), a scale for postoperative neonatal pain [67], which provides promising results that should lead to further studies.

Conclusion

As the most validated pain assessment tools cannot be applied to all age groups, alternatives to the self-report scales are necessary in order to improve health care in postoperative pediatric settings. Even though self-report scales are considered the gold standard for children over six years of age, in some cases their application is not possible, due to cognitive impairment or in sedated patients for instance, which compromises pain assessment even in older children.

Although behavioral scales are widely used, there is evidence about the absence of behavioral pain manifestation even when cortical pain pathways are activated, which translates into a lack of sensibility of behavioral measures. For this reason, a child scoring a low value on behavioral scales may not, indeed, be pain free. Furthermore, these scales lack universal validity, and require highly trained observers, being subjective and with high intra and interobserver variability, which represents a problem in terms of reliability.

In postoperative setting, where children may be under sedation and invasive ventilation, specific problems may arise (such as reduced muscular responses to pain), for which behavioral methods are not so accurate and should be used with care. Physiological scales prove not to be reliable when used as a single assessment method. It is postulated, by the American Society of Pain Management, that a combination of behavioral and physiological features is beneficial.

There is not a unique observation method recommended for pain assessment across all ages and contexts. The lack of a global cut-off point from a pain scale for pain treatment puts the patients at risk for overmedication or undertreated pain, with severe consequences, as mentioned before, and it constitutes a great problem left unsolved in pediatric intensive care units all over the world.

Therefore, further research in this area is needed, due to the frequent inability to accurately assess pain in clinical practice in postoperative pediatric intensive care units and to be able to provide optimal analgesia to children in such settings. Several studies are already underway, such as neuroimaging and machine learning algorithms to evaluate facial expressions, among others. It is also important to wait for more studies to validate recently developed methods, such as the ANI and NIPE, so that they can be properly implemented in clinical practice. Meanwhile, health care providers should be familiar with the different available tools and be informed about the recommendations for each age group and clinical setting.

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