Assessment of Pain in the Neonate

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More than 15 million premature infants are born worldwide each year.1 These infants, along with term neonates who are born ill, compromised either by congenital abnormalities or by peripartum or intrauterine adverse events, spend their first weeks of life hospitalized in the neonatal intensive care unit (NICU) where they are subjected to multiple invasive procedures that are frequently painful. It has been reported that infants born at 25 to 42 weeks of gestation experienced an average of 14 painful procedures a day during the first 2 weeks of life.2–4 In addition, many neonates, both premature and term, undergo surgical procedures associated with postoperative pain.

Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage (International Association for the Study of Pain Subcommittee on Taxonomy [IASP], 1986).5 It is important to understand that the inability of these neonatal patients to communicate verbally or nonverbally does not mean that an infant is not experiencing pain. As the IASP states, “The inability to communicate verbally does not negate the possibility that an individual is experiencing pain and is in need

KEYWORDS
Neonate • Pain • Assessment • Pain scales

KEY POINTS

• Many neonatal pain assessment tools are available.
• Although “brain-oriented” technologies have been explored as more subjective indicators of neonatal pain, none are currently ready for clinical implementation.
• Each NICU should choose a limited number of tools for pain assessment in different populations (full term, preterm) and context and type of pain (procedural, postoperative).
• Nurses should be trained and evaluated for appropriate use of selected tools.
• Standards should be established for triggers for administration of rescue medication.

More than 15 million premature infants are born worldwide each year.1 These infants, along with term neonates who are born ill, compromised either by congenital abnormalities or by peripartum or intrauterine adverse events, spend their first weeks of life hospitalized in the neonatal intensive care unit (NICU) where they are subjected to multiple invasive procedures that are frequently painful. It has been reported that infants born at 25 to 42 weeks of gestation experienced an average of 14 painful procedures a day during the first 2 weeks of life.2–4 In addition, many neonates, both premature and term, undergo surgical procedures associated with postoperative pain.

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of appropriate pain-relieving treatment." Indeed, this circumstance requires caregivers to be knowledgeable about and to implement the most valid and reliable pain assessment tools to optimize pain management in this vulnerable population.

NEURODEVELOPMENTAL CONSIDERATIONS FOR PAIN ASSESSMENT

Although neonates were formerly suspected of having blunted, immature responses to pain, it is now clear that premature and full-term newborns have the neuroanatomic pathways from periphery to cortex required for nociception. In fact, by the 24th week of gestation, painful stimuli are associated with physiologic, hormonal, and metabolic markers of the stress response. Indeed, pain perception and the stress response may be greater in preterm infants because of immaturity of descending inhibitory pathways.

Because the still-developing nervous system of immature preterm neonates differs from that of term infants, preterm neonates are particularly vulnerable to the effects of pain and stress. The developmental neurobiology of pain confirms that afferent systems are fully functional at 24 weeks’ gestation; however, the self-regulatory autonomic and neuroendocrine systems modulating sensory experience may be immature in preterm babies. Development of descending inhibitory pathways may be delayed in both neurotransmitter-receptor relationships and in neural connections in the dorsal horn. Tactile threshold is lower, so these infants become sensitized to repeated skin breaking and even tactile stimuli, leading to greater sensitivity to pain during and after this vulnerable period. Careful observation of physiologic and behavioral indicators demonstrates that the sensory, distressing, and disruptive impact of pain is evident in this population; however, recognizing pain and distinguishing it from other conditions remain a challenge. This is especially true because although infants born at younger gestational ages clearly perceive pain, perhaps to a heightened degree, at the same time they do not have the capability to display the full spectrum of pain behavior seen in infants born closer to term, therefore requiring modification of assessment tools to take these differences into account.

IMPLICATIONS OF PAIN EXPERIENCED IN THE NEONATAL PERIOD

Although there is still little empiric data specifically related to long-term effects of early physical pain, studies have shown that newborns, especially preterm infants, are vulnerable to long-term effects that may lead to permanent changes in brain processing and impaired brain development, including altered pain sensitivity and maladaptive behavior later in life. A wide spectrum of developmental, learning, and behavioral problems are prevalent among preterm infants, especially in extremely low birth weight (ELBW, <1000 g) neonates. These outcomes are confounded by multiple factors, and are in part mediated by neonatal illness as well as socioeconomic environment. The view that the NICU environment may be a factor in altered development has been expressed for some time, with early repetitive pain interacting with other stressors in the NICU currently viewed as having the most pervasive potential effects. After discharge from the NICU, biobehavioral responsivity to invasive skin damage of former ELBW infants was compared with term-born healthy infants at 4 and 8 months corrected age. Pain reactivity of ELBW infants at 4 months corrected age did not appear grossly altered. At 8 months, ELBW infants initially showed greater facial response compared with term-born infants, but only immediately following finger lance. However, the response of the ELBW infants attenuated rapidly, showing more rapid behavioral and physiologic dampening (less facial and autonomic responses) during recovery. Furthermore, the ELBW infants displayed higher basal
resting heart rate, suggesting a possible long-term “resetting” of autonomic regulation. Conversely, parent rating of their child’s pain sensitivity to everyday bumps at 18 months corrected age showed that ELBW toddlers were significantly less reactive to everyday pain compared with heavier preterm (1000–2500 g) and term-born infants.18

Even infants born at term show persistent effects of pain experienced in the neonatal period. Full-term infants who underwent circumcision without analgesia in the newborn period showed increased pain responses to immunization at 4 to 6 months of age when compared with both female infants and infants who had circumcision with analgesia.19 These healthy infants do not have the confounders that may affect changes in pain perception and development seen in the premature population. In summary, some studies provide a basis for concern that pain response and behavior may be altered in former preterm infants but potentially confounding factors need to be considered carefully in evaluating human responses beyond infancy, because there are multiple sources of stress and impacts on neurologic development other than early pain that may contribute to alteration in neurodevelopment.

PAIN ASSESSMENT METHODOLOGY

The gold standard of pain assessment is self-report, using validated scales, such as a numeric scale, or visual analog scale for individuals who are cognitively intact and older than 8, and tools such as the Faces-Revised or Oucher scale for cognitively intact children ages 4 to 8.20 Because neonates are nonverbal, physiologic, biobehavioral, and behavioral indicators are used as a surrogate for self-report. Despite considerable research on the assessment of pain in infants undergoing neonatal intensive care, critical methodological issues remain. Pain assessment in infants becomes even more challenging when typical distress behaviors are confounded by mechanical ventilation, pharmacologic interventions, and physical restraint inherent to care in the NICU.

PHYSIOLOGIC INDICATORS OF PAIN

Physiologic indicators of pain that are measured by neonatal pain assessment tools are typically relatively noninvasive measures. These include changes in heart rate, respiratory rate, blood pressure, and oxygen saturation.21 Without the presence of an indwelling arterial line, blood pressure measurements via a cuff may be difficult to obtain without inducing discomfort. Use of vital signs alone for pain assessment has been demonstrated to be ineffective because of the inability of neonates to mount a sustained autonomic response to pain and the presence of other factors, such as mechanical ventilation and pharmacologic intervention that may impact vital signs.22 Physiologic measures may be the only method of assessing pain in infants who are pharmacologically paralyzed or who are severely neurologically impaired. However, it has been suggested that the validity and reliability of these measures are questionable, as they are influenced by other physiologic confounders, such as hypovolemia or fever (increased heart rate), or pulmonary parenchymal disease or atelectasis (desaturation, increased work of breathing with grunting).23

BEHAVIORAL INDICATORS OF PAIN

Behavioral parameters, such as facial activity, cry, body movements and resting positions, fussiness/consolability, and sleeplessness have been the most studied indicators.21 The ability to assess behavioral indicators may depend on gestational age,
mechanical ventilation, and pharmacologic interventions, including sedation and pharmacologic paralysis.10 The individual parameters in all pain scales used in preterm infants were originally derived from observations of term-born infants. Although preterm infants respond with facial, motor, and physiologic changes, with patterns similar to those seen in term infants, their responses are of smaller magnitude as gestational age decreases,9,21 and they may have dampened facial responses to repeated invasive procedures. In addition, they may “shut down” behaviorally to invasive stimuli, leading clinicians to the potentially erroneous conclusion that these infants are not experiencing pain.24 Furthermore, lack of observation of infants for longer periods of time may fail to capture delayed responses, resulting in underestimation of the need for caregiver intervention.

Currently, no individual physiologic or behavioral indicators reliably and specifically mark the presence of pain in preterm neonates. Moreover, dissociations between physiologic and behavioral responses to painful stimuli are common.22 For these reasons, reliance on a unidimensional pain index is insufficient.

- Despite awareness of the importance of pain prevention, neonates continue to be exposed to multiple painful procedures daily as part of their routine care
- Currently, no physiologic or behavioral indicators specifically mark the presence of pain in preterm neonates
- Preterm neonates are vulnerable to long-term effects that may lead to permanent changes in brain processing, including altered pain sensitivity and maladaptive behavior later in life

PAIN ASSESSMENT

Accurate assessment of pain is vital to ensure optimal effectiveness and safety of pain management therapy in neonates who experience pain during the course of their NICU stay. As discussed previously, neonatal pain assessment is complicated by the fact that neonates are preverbal and must rely completely on caregivers for pain assessment.25

PARENTAL INVOLVEMENT IN PAIN ASSESSMENT

In older preverbal or nonverbal children, parents play an essential role in the pain-assessment process, as they know their children better than intermittent care providers in the hospital setting. However, the NICU presents some unique challenges in the integration of parent input for pain assessment. For a variety of reasons, parents may or may not be present in the NICU.26 To provide the appropriate level of care after birth, a neonate may need to be transferred to a NICU at another hospital while the mother remains at the delivering hospital. Sometimes the circumstances surrounding the birth may have resulted in the mother being critically ill and unable to visit the NICU. During a prolonged NICU stay, parents may need to return to work or visit less frequently because of the need to care for other children. All of these factors may lead to a reduced parental presence in the NICU.26

Even when parents are able to be present, there may be several factors that prevent parents from feeling comfortable providing input on their baby’s pain. New parents often feel insecure about their babies, and if something unexpected has occurred, such as a premature birth, a term infant with a congenital malformation, or a traumatic birth, parents may feel even further unqualified to assist in providing pain assessment.27 Parents may feel ambivalent: they simply do not wish to see their baby in pain but not too sedated. The NICU environment includes many painful procedures,
as well as infants who respond differently to pain based on gestational age, illness, or medical treatment. All of these things can be very disconcerting and frightening to parents and make it more difficult for them to be active participants in pain assessment. If primary nursing is available for very sick neonates from the onset of care, the primary nurse can assist both in providing an accurate description of the baseline for a given infant and also in educating parents on what to look for and the continuum between adequate analgesia and oversedation.28

NEONATAL PAIN ASSESSMENT TOOLS

Because neonates are preverbal, and parents may not be able to provide assistance in pain assessment, nurses and other care providers must be well trained in neonatal pain assessment to ensure adequate pain management.29 A large variety of validated neonatal pain-assessment tools have been developed. These tools vary in their combination of physiologic and behavioral measures, as well as whether they take gestational age into account. Additionally, tools have been designed and validated for different types of pain, including procedural, postoperative, acute, and chronic pain.30 Although more than 40 different neonatal pain assessment tools have been developed,31 only a few are regularly incorporated into use in most NICUs. Because no comprehensive data exist on those used most commonly, one must infer this from tools used in published studies of neonatal pain. Table 1 summarizes the features of these commonly used scales according to parameters measured, neonatal population, and painful conditions for which they have been validated, and scale metric.29 Commonly used neonatal pain tools are listed in Table 1.

- 2 scales have metric adjustment for prematurity (Premature Infant Pain Profile/Neonatal Pain, Agitation, and Sedation Scale [PIPP/N-PASS])
- Other scales have been used in premature infants, although developed in full-term infants
- Only 1 scale takes sedation into account (N-PASS)

As previously discussed, gestational age can significantly impact the ability of a neonate to mount or display a response to pain, whether through physiologic or behavioral indicators. Historically, neonates have been stratified into groups according to gestational age, birth weight, or postconceptual age (gestational age plus postnatal age). Most neonatal pain scales that make adjustments for prematurity do so using gestational age. Premature infants of all gestational ages (fewer than 37 weeks) demonstrate a decreased ability to mount a physiologic response to painful stimuli.22,25 Multiple factors may influence a premature infant’s vital signs, and an increase in heart rate and/or respiratory rate may not be an indicator of pain alone. In addition, very premature infants may be completely unable to demonstrate a change in vital signs because of pain, and the ability to sustain this for any prolonged period of time is markedly diminished.23 Similarly, the lack of energy reserve present in premature infants of any gestational age may result in an absent or muted behavioral response to painful stimuli.30 Only 2 of the aforementioned commonly used pain scales (PIPP and N-PASS) have a metric adjustment to account for prematurity; however, other scales have demonstrated validity and reliability in the premature population.29

In addition to gestational age, scales are tested for validity and reliability based on the type of pain that they are designed to assess. These types of pain include procedural, postoperative, acute, and chronic (or prolonged) pain. Additionally, some scales take sedation into account.29 The presence of agitation or sedation in a neonate can
<table>
<thead>
<tr>
<th>Pain Assessment Tool</th>
<th>Gestational Age/Post-conceptional Age</th>
<th>Physiologic Components</th>
<th>Behavioral Components</th>
<th>Type of Pain</th>
<th>Adjusts for Prematurity</th>
<th>Scale Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIPP (Premature Infant Pain Profile)</td>
<td>28–40 wk</td>
<td>Heart rate, oxygen saturation</td>
<td>Alertness, brow bulge, eye squeeze, nasolabial furrow</td>
<td>Procedural and Postoperative</td>
<td>Yes</td>
<td>0 to 21</td>
</tr>
<tr>
<td>CRIES (Cries, Requires Oxygen, Increased Vital Signs, Expression, Sleeplessness)</td>
<td>32–56 wk</td>
<td>Blood pressure, heart rate, oxygen saturation</td>
<td>Cry, expression, sleeplessness</td>
<td>Postoperative</td>
<td>No</td>
<td>0 to 10</td>
</tr>
<tr>
<td>NIPS (Neonatal Infant Pain Scale)</td>
<td>28–38 wk</td>
<td>Breathing pattern</td>
<td>Facial expression, cry, arms, legs, alertness</td>
<td>Procedural</td>
<td>No</td>
<td>0 to 7</td>
</tr>
<tr>
<td>COMFORT (and COMFORTneo)</td>
<td>0–3 y (COMFORTneo: 24–42 wk)</td>
<td>Respiratory response, blood pressure, heart rate</td>
<td>Alertness, agitation, physical movements, muscle tone, facial tension</td>
<td>Postoperative (COMFORTneo: prolonged)</td>
<td>No</td>
<td>8 to 40</td>
</tr>
<tr>
<td>NFCS (Neonatal Facial Coding System)</td>
<td>25 wk to Term</td>
<td>None</td>
<td>Brow bulge, eye squeeze, nasolabial furrow, open lips, stretch mouth (vertical and horizontal), lip purse, taut tongue, chin quiver</td>
<td>Procedural</td>
<td>No</td>
<td>0 to 10</td>
</tr>
<tr>
<td>N-PASS (Neonatal Pain, Agitation, and Sedation Scale)</td>
<td>0–100 d</td>
<td>Heart rate, respiratory rate, blood pressure, oxygen saturation</td>
<td>Crying/irritability, behavior state, facial expression, extremities/tone</td>
<td>Acute and prolonged pain Also assesses sedation</td>
<td>Yes</td>
<td>Pain: 0 to 10 Sedation –10 to 0</td>
</tr>
<tr>
<td>EDIN (Échelle de la Douleur Inconfort Noveau-Né – Neonatal Pain and Discomfort Scale)</td>
<td>25–36 wk</td>
<td>None</td>
<td>Facial activity, body movements, quality of sleep, quality of contact with nurses, consolability</td>
<td>Prolonged</td>
<td>No</td>
<td>0 to 15</td>
</tr>
<tr>
<td>BPSN (Bernese Pain Scale for Neonates)</td>
<td>27–41 wk</td>
<td>Respiratory pattern, heart rate, oxygen saturation</td>
<td>Alertness, duration of cry, time to calm, skin color, brow bulge with eye squeeze, posture</td>
<td>Procedural</td>
<td>No</td>
<td>0 to 27</td>
</tr>
</tbody>
</table>
be misinterpreted as pain by those scales that do not take sedation into account. The vast majority of scales were designed for acute pain, either procedural and/or postoperative. The presence of prolonged pain in neonates is much more difficult to assess, as neonates may adapt to the presence of prolonged pain from the standpoint of both physiologic and behavioral measures. Only 2 scales have demonstrated validity and reliability for prolonged pain (N-PASS and EDIN [Échelle Douleur Inconfort Nouveau-Né (Neonatal Pain and Discomfort Scale)]), but the COMFORTneo scale, adapted for use in neonates based on the COMFORT scale, has shown promise in measuring prolonged pain in one study.

When choosing specific scales to use for neonatal pain, it is always important to select scales that have been proven validated and reliable, and, if possible, have studies replicating this. There are many challenges to selecting appropriate scales for a given NICU setting. This includes the fact that NICU populations are diverse, often made up of premature and term infants; some sedated, paralyzed, and mechanically ventilated infants; and some surgical infants. If a given scale relies on an audible cry for assessment, then this scale may not be usable for a sizable portion of the given population. As noted previously and in Table 1, scales may have demonstrated validity and reliability only for a certain gestational age and a certain type of pain, which makes selecting a single scale for the entire NICU population very difficult. Practical considerations also must be factored into scale choice.

As can be seen in Table 1, another major difference among tools is the scale metric (the numerical range of possible scores). Although the most commonly used scales in older infants, children, and adults use a 0 to 10 scale, neonatal scales vary widely, with maximum scores ranging from 7 to 40 and minimum scores from 0 to 8. This variability makes the use of tools with disparate scales problematic in a single NICU and may impair education, as well as attempts to compare outcomes for research purposes.

Choosing the best scale, or scales, for a given NICU population will require close examination of the typical patient population(s) for the unit. Scales should be ultimately considered more useful if they are demonstrated to be valid and reliable, if they account for a broad range of gestational ages, and if they have a long track record of use. Even if a scale is determined to be valid and reliable, the feasibility and practical utility must be examined by those who will be using it. If 2 scales are chosen for use on a unit, care providers must be carefully trained and their performance evaluated on an ongoing basis to ensure that they remain consistent among themselves for individual patients. Units may choose to adapt a scale designed for procedural pain to assess pain in all circumstances, but clinicians must constantly assess what they may be missing by not using a scale designed to monitor postoperative pain or in cases of prolonged pain.

NOVEL PHYSIOLOGIC PAIN ASSESSMENT TOOLS AND BIOMARKERS

Despite the plethora of neonatal pain assessment tools, there is no generally agreed on “gold standard” and there are problems of inconsistency among assessors. Because of the imperfect nature of the various multidimensional neonatal pain assessment tools described previously, more objective, technology-based autonomic, brain, and biohormonal measures have been explored as a possibly more objective indicator of pain level. These tools include autonomic measures, such as heart rate variability, skin conductance, and brain measures, such as electroencephalogram (EEG) or near-infrared spectroscopy (NIRS). In addition, hormonal markers of stress, such as cortisol and plasma parameters of oxidative stress, have been evaluated. Holsti and colleagues have referred to this approach as “brain-oriented.”
Slater and colleagues\textsuperscript{39} used NIRS to assess hemodynamic activity over the somatosensory cortex during procedural pain (heel lance) and found correlation between cortical hemodynamic and behavioral responses. NIRS works through the differential absorption of infrared light by hemoglobin and cytochrome aa\textsubscript{3}, with changes in hemoglobin absorption reflecting changes in cerebral blood flow. There were some painful episodes in which hemodynamic changes were observed in the absence of behavioral changes, suggesting the possibility that pain assessment based on more conventional pain assessment tools may underestimate the pain response in neonates. If this is confirmed with further investigation and the technology made easier to use in the clinical setting, NIRS may provide a more objective measurement of pain. Implementation of NIRS is problematic because movement and other environmental factors (drug treatment, hemodynamic changes, and respiratory changes) can interfere with accuracy, making its clinical utility questionable.

EEG monitoring measures cortical neuronal activity, but isolating cortical evoked responses to pain may require complex “time-lock” technology, as demonstrated by Slater and colleagues,\textsuperscript{40} which limits its practical implementation at this time. In addition, it may be difficult to distinguish increased cortical somatosensory activity from that related to motor activity, especially in the smallest infants.

Skin conductance, sometimes referred to as galvanic skin resistance (GSR) is related to palm and sole sweating, which reflects increased sympathetic nervous system activity. Changes in frequency and area under the curve have been demonstrated with procedural pain and have been shown to differentiate between pain (heel stick) and stress (alcohol wipe on skin).\textsuperscript{41} Gjerstad and colleagues\textsuperscript{42} found that increase in the number of skin conductance fluctuations correlated with increase in COMFORT score with tracheal suction in intubated children, but sensitivity was impaired by other sources of stress (postoperative pain in the first 24 hours after surgery) and subject to movement artifact. In the setting of postoperative pain in older children, however, skin conductance was found to have low sensitivity and specificity. In the awake patient, measurement was confounded by non-noxious factors that affect sympathetic activity, casting doubt on its utility for postoperative pain in neonates.\textsuperscript{43} Although heart rate and heart rate variability have been proposed as more objective measures of pain, investigators, such as Oberlander and Saul,\textsuperscript{37} have found that medical condition confounders interfere with the utility of heart rate alone as a pain measure and suggest further work.

Cortisol level is a biomarker of pain and stress states, which has been used in clinical trial study designs, but it is impractical for real-time pain assessment for treatment decision making, as there is a considerable delay in obtaining the results. Although a further impediment was the need to draw blood for cortisol determination, recent studies have successfully used salivary cortisol levels. Although some studies have found increased serum or salivary cortisol with increased pain and stress, one study has found a downregulation of serum cortisol response to stress in premature infants with higher exposure to procedural pain in the neonatal period.\textsuperscript{44,45} Measures of oxidative stress, such as uric acid and malondialdehyde, have been found to increase after a tissue-damaging procedure.\textsuperscript{46} This is not a practical real-time measure of pain but might be useful to assess efficacy of pain treatment strategies in a research setting.

These biologic and brain-based measures have been used experimentally and are theoretically attractive and potentially may be more objective measures of pain in neonates and infants than composite pain assessment tools subjectively interpreted by bedside caregivers. However, the lack of standardization and familiarity with these technologies make their use in the clinical setting impractical at this time; therefore, we remain dependent on the pain assessment tools described previously.
PRACTICAL PROBLEMS IN IMPLEMENTATION OF NEONATAL PAIN ASSESSMENT AND ASSESSMENT-BASED TREATMENT

There is no generally agreed on clinical standard for pain score threshold at which analgesic intervention should be administered. Even in the same infant there is poor correlation between pain score and the presence or absence of analgesic intervention. On the other hand, clinical trials of analgesics frequently establish specific numeric thresholds for different pain interventions, as in the recently study of intravenous acetaminophen by Ceelie and colleagues. This study design follows on the work of Allegaert and colleagues, who demonstrated that implementation of systematic evaluation of pain (both surgical and nonsurgical), including specific interventions based on pain scores, led to an increase in both amount and duration of prescribed analgesics. Despite the availability of multiple neonatal pain scores at the time of these studies, these investigators used a pain scale developed at their institution, the Leuven neonatal pain scale. One proposed method of improving the linkage of pain assessment to analgesic intervention involves the incorporation of a pain and discomfort tool (COMFORT) into the computerized order entry (Computerized Provider Order Entry [CPOE]) system, which was then linked to ordering sufentanil for pain or midazolam for sedation for mechanically ventilated premature infants.

Postoperative studies only rarely link pain scores to specific analgesic treatment, as discussed previously. Franck and colleagues compared 4 pain scales (Children’s and Infants’ Postoperative Pain Scale [CHIPPS]; Cries, Requires Oxygen, Increased Vital Signs, Expression, Sleeplessness [CRIES]; COMFORT; and PIPP) in addition to urinary and plasma cortisol in 81 neonates after cardiac surgery. This was done separately from the clinical care of the patient. In this setting, they found that the COMFORT scale performed best with both physiologic and behavioral parameters playing a role, correlating best with both plasma cortisol levels and opioid dose, although the caregivers did not consistently use pain assessment in determining the necessity for analgesic intervention. These investigators point out that “there is no consistent definition or objective measure of the “need for analgesia,” which may cause bias toward the use of behavioral over physiologic measures or vice versa in intubated, paralyzed patients. This is a fundamental problem in the clinical setting, where there is ambiguity in the interface between distress and pain, and ambivalence on the part of the caregiver with regard to the positive and adverse effects of opioid treatment and the tension between avoiding the adverse effects of untreated pain and the negative consequences of overmedication. It is difficult even for trained nurses to accurately differentiate pain from other sources of distress, especially in intubated patients. Although nonpharmacologic measures (sucrose-pacifier, swaddling, kangaroo care) have been shown to be efficacious in the procedural pain setting, their utility in the setting of postoperative pain is less clear.

PAIN CHAMPIONS

Many audits of compliance with institutional/unit standards of pain assessment have revealed poor compliance and lack of fidelity to the way the tool was to be applied. Whatever tools are chosen for a given neonatal unit, it is important that the tool be used in the specific manner described. The meticulous training of “pain champions” or pain assessment “superusers” may be helpful in ongoing training and assessment of accuracy in implementation of pain assessment tools. For example, the PIPP requires 2 periods of observation of the infant for 15 seconds before the procedure and for 30 seconds after the painful stimulus. De Oliveira and
colleagues\textsuperscript{55} showed that there was variability among raters using the PIPP score for procedural pain. Raters had difficulty applying the tool, especially with respect to the time required for observation and confusion about the definitions of the behavioral categories. This study identified these factors as a source of confusion and lack of reproducibility of scoring among untrained raters, differentiating the “real world” clinical from the research setting. Franck and Bruce\textsuperscript{56} identified multiple issues of interpersonal dynamics and caregiver decision making that interfere with effective use of clinical pain assessment and its relationship to pain treatment. Brahnam and colleagues\textsuperscript{57} proposed using facial recognition technology for assessment of neonatal facial pain expressions because it has been observed that “health professionals are frequently biased and may over- or under-emphasize elements” of the assessment tool in question. Although use of such facial recognition technology may not be practical in the clinical setting, such photographs could be used in training caregivers.

CONCLUSION

Accurate pain assessment in preterm and term neonates in the NICU is of vital importance because of the high prevalence of painful experiences in this population, in the form of both daily procedural pain and postoperative pain. Over 40 tools have been developed to assess pain in neonates, which rely on physiologic parameters, behavioral parameters, or both. Each NICU should choose a limited number of tools for pain assessment in different populations (full term, preterm) and context and type of pain (procedural, postoperative). Nurses should be well-trained in the use of selected neonatal pain assessment tools, and ongoing evaluation and re-education should be implemented to ensure accurate use of these tools. Currently, there is no combination of physiologic and/or behavioral indicators that mark the presence of pain in preterm neonates as reliably and specifically as those validated in full term infants. This can make pain assessment in preterm neonates particularly challenging. Only two pain assessment tools have a metric adjustment to account for prematurity. Preterm neonates are also vulnerable to long-term sequelae of painful experiences, which may lead to permanent changes in brain processing including altered pain sensitivity and maladaptive behavior later in life. In both term and preterm neonates, parents can be valuable participants in the evaluation of their infant’s pain, but they may need reinforcement and education from nursing providers. In the future, “brain-oriented” technologies may become available to help objectively assess neonatal pain. Future directions include the development of the these technologies and the need for further studies on the optimization of the use of current and future neonatal pain assessment tools and on other methods with which to objectively measure and form the basis for safe and effective treatment of neonatal pain.

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