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Methods of pain assessment in neonates

Acute pain is one of the most common adverse experiences in children. It occurs as a result of injury, illness or necessary medical interventions. Furthermore, acute pain is associated with increasing anxiety, somatic symptoms and increasing parents' distress. Despite the magnitude of effects of acute pain on a child, it is often inadequately assessed and treated. Numerous myths among medical staff, insufficient knowledge amid caregivers, an inadequate application of knowledge contribute to the lack of effective management. The crucial aim of this article is presentation of achievements in pain assessment among children based on the latest publications.

The experience of pediatric acute pain is bound with interactions between: physiological, psychological, behavioral, developmental, and situational factors. Pain is an inherently subjective multifactorial experience and should be assessed and treated. Pediatricians are responsible for eliminating pain and suffering child when possible (1). Pain exists also in case of neonates. Neonates have the same number of pain nerve endings per square inch of body surface area as adults. Peripheral and central connections between sensory neurons and the spinal dorsal horn cells are complete early in fetal life. Higher centre pain perception via cortical connections with thalamus are completed by the 24th week of gestational age. Although the greater knowledge about pediatric acute pain only recently have we begun to value, accept and investigate for ways to alleviate pain in the neonate. While it is easy to anaesthetize the neonate for a major surgical procedure, it is much more difficult to assure adequate pain control during the postoperative period because it is difficult to measure the pain of neonate. The absence of objective tools to measure pain in this age group makes the assessment influenced by the personal bias of the evaluator. It has been shown that the setting, in which pain is evaluated and the knowledge of the assessor, influence on that assessment and subsequent management of pain (2). Even the most premature neonate has the neural pathways required for nociception and response to the pain and potential tissue damage. Peripheral nerve myelination is completed by birth (3). At birth, all the elements of the nociceptive system required to process noxious stimuli are present. Although C-fibers are mature in the pattern of firing at birth, their central synaptic connection in the dorsal horn is initially immature. However, nerve impulse can be produced by low-intensity A-fiber (rather the C-fiber) stimulation, as A-beta fibers initially extend up into laminae I and II and only withdraw once C-fibers connections have matured. This overlap is likely to contribute to large receptive fields of dorsal horn neurons observed in the early development. The descending inhibitor pathway, diffuse noxious inhibitory controls and local interneuron inhibitory mechanisms in the dorsal horn are not fully mature at birth and become mature during the first six months of life. Moreover, the N-methyl-d-aspartate receptors which are

essential for central sensation are present in higher concentrations and more generalized distribution in the dorsal horn in early development and activation results in greater influx of calcium ions. Therefore, rather than neonates being less sensitive to painful stimuli as was once thought, relative excess of excitatory mechanism and delayed maturation of inhibitory mechanisms produce more generalized and exaggerated reflex responses to low-intensity stimuli during early development (4). In the postnatal period a significant reorganization of synaptic connection occurs. The activity within sensory pathways is required for normal development, but abnormal or excessive activity related to pain and injury during the neonatal period may alter normal development and produce persistent changes (5). Recent studies have examined the persistent consequences of untreated pain both in animals (6, 7) and humans (8–10). The anatomical distribution of peripheral nerve terminals in the spinal cord can be permanently altered by nerve injury or chronic inflammation induced during the first post-natal week in rat pups, emphasizing the plasticity of the nervous system early in the development (6). Clinical studies also suggest that pain related to surgery and medical procedures in neonates may have long-term effect on pain-related behaviors and perception of pain. The studies about male neonates circumcised without analgesia show an increased behavioral pain response to immunization even several months later, however, the reaction was reduced if topical local anesthetic was used (8, 10). Hence, because of increased plasticity of the developing nervous system, pain and injury in early life may have adverse long-term consequences, which can be reduced by judicious use of analgesics, pain should be anticipated whenever possible and treated appropriately (11).

The assessment and measurement of acute pain of children is complex and every children's hospital faces the challenge of pediatric pain assessment. Pain estimation is a prerequisite for optimal pain management (12). Without adequate methods of assessing pain in children it is difficult to plan appropriate intervention and take steps to ensure their effectiveness (13). Pain assessment is considered to be the fifth vital sign (14). Measurement of pain among children is of major importance to substantiate a therapeutic decision and evaluate the effectiveness of particular intervention. Structured pain assessment can contribute to improvement in prescription and administration of analgesia in children (15). Moreover it is also needed to quantify pain intensity because interventions may vary on the basis of pain intensity.

In general, tools for assessing pain in children can be divided into physiological measures, observational (behavioral) measures, composite measures and self report. Several physiological parameters are used to assess pain in children. The most common are: increased heart rate, respiratory rate, blood pressure, intracranial pressure, cerebral blood flow, palmar sweating, decrease in oxygen saturation, transcutaneous carbon dioxide tension, and vagal tone (16,17,18). Changes of these parameters by analgesia can be a useful substitute of pain rate, but their sensitivity and specificity is influenced by associated clinical condition, such as sepsis, distress movement, hypoxemia, hypovolemia, fever, and overexcitement of a child that are unrelated to pain *per se* (11). Such physiological parameters as a heart rate variability, changes in salivary cortisol can be used indirectly to indicate the presence of pain (17, 19). However, blood pressure, heart rate, and respiratory rate have been shown to be unreliable indicators in newborns, infants and young children (20) with wide inter-individual in behavior-physiology correlations after major surgery in 0- to 3-year-old infants (21). While physiological parameters such as cortisol changes may be measured during clinical research studies, these measurements do not have high clinical utility. Physiological measures should be used in conjunction with other tools to determine pain.

Pain produces a series of behavioral responses in infant and children including crying, changes in facial activity, movement of torso and limbs, consolability and sleep state that can be used as surrogate measures of pain in children (22). Many scales incorporate both physiological and

behavioral measures to determine overall pain scores and may result in measurement which is more comprehensive. Some examples are COMFORT Scale (23) Children Hospital of Eastern Ontario Pain Scale (CHEOPS) (24), Face Legs Activity Cry Consolability tool (FLACC) (25). Self-report is the best measurement tool. Although it is usually likely to use in the group of children by the fourth years old, it depends on cognitive and emotional maturity of the child and cannot be applicable to preverbal children and children with cognitive disabilities. For neonates and infants as a special age group postoperative pain assessment tools were also created. The few of them are described hereafter.

Premature Infant Pain Profile (PIPP) (26, 27) – Table 1 – is used in pain assessment among preterm and term infants. PIPP consists of seven indicators which are divided into three groups: contextual (gestational age, behavioral state), physiologic (heart rate, oxygen saturation), behavioral (brow bulge, eye squeeze, nasolabial furrow). Moreover, it creates the score maximum to 21, which is the sum total of points indicating: lack of pain (0–6), mild-moderate pain (6–12) and severe pain (above 12) (28). This scale was created to measure procedural pain, later validated for postoperative pain. The measurement is based on videotaping the child for 45 sec. with recording of physiological parameters every 3 sec. during this period and the videotape is analyzed (29).

Table 1. The premature infant pain scale

Process	Indicator	0	1	2	3
Chart	Gestational age	36 weeks and more	32–35weeks, 6 days	28–31weeks, 6 days	Less than 28 weeks
Observe infant 15 s	Behavioral state	Active/awake	Quiet/awake	Active/sleep	Quiet/sleep
		Eyes open	Eyes open	Eyes closed	Eyes closed
		Facial movements	No facial movements	Facial movements	No facial movements
Observe baseline Heart rate Oxygen saturation Observe infant for 30 s	Heart rate maximum	0–4 b/min increase	5–14 b/min increase	15–24 b/min increase	25 b/min or ore increase
	Oxygen saturation minimum	0–2.4% decrease	2.5–4.9% decrease minimum	5–7.4% decrease moderate	7.5% or more decrease maximum 70% of time or more
	Brow bulge	None 0–9% of time	Minimum 10–39% of time	Moderate 40–69% of time	Maximum 70% of time or more
	Eye squeeze	None 0–9% of time	Minimum 10–39% of time	Moderate 40–69% of time	Maximum 70% of time or more
	Nasolabial furrow	None 0–9% of time	Minimum 10–39% of time	Moderate 40–69% of time	Maximum 70% of time or more

Table 2. The CRIES instrument

	0	1	2
Crying	No	High-pitched	Inconsolable
Requires oxygen for SpO2>95%	No	FiO2<30%	FiO2>30%
Increased vital sign from preoperative values	Heart rate and blood pressure equal to or less than	<20%	>20%
Expression	None	Grimace	Grimace and grunting
Sleeplessness	No	Awakens frequently	Constantly awake

0 = no pain, 10 = maximum pain

Another tool for the pain measurement is CRIES Instrument – Table 2 – (27, 30) which was designed for neonates up to 6 months. There are 5 indicators: crying, requires oxygen (for arterial oxygen saturation >95%), increased vital signs from preoperative values, expression, sleeplessness. This tool is proved to be valid up to 72 h after operation.

COMFORT Scale – Table 3 – (31–33) is subsequent instrument for more accurate measure of pain. It is meant to be used among children in 0–3 years old. COMFORT Scale consists of 6 behavioral items (alertness, calmness, muscle tone, movement, facial tension, respiratory response for ventilated/crying for nonventilated) and 2 physiological items (heart rate, mean arterial pressure). Score ranges from 8 to 40. This scale was built to measure distress in intensive pediatric care, in children up to 24 months (23). It was extended to assess postoperative pain in 0–3 years old when crying was added in nonventilated (31). The scale was modified by Hatrick and Kovan. They eliminated physiological items as those which were weakly correlated with pain. According to this way of evaluation the child is observed for 2 min. at bedside. During this period, heart rate (HR) and mean arterial pressure (MAP) values are recorded from monitor every 20 sec. (six times in total). Shortly before the end of observation, the muscle tone of the child is assessed by lifting an arm or leg of the child. After 2 min. each item is scored (31).

Table 3. COMFORT Scale

Symptoms	Characteristics of symptoms				
Alertness	Deeply asleep	Lightly asleep	Drowsy	Fully alert and awake	Hyperalert
Calmness	Calm	Slightly anxious	Anxious	Very anxious	Panicky
Respiratory response	No coughing and no spontaneous respiration	Spontaneous respiration with little or no response to ventilation	Occasional cough resistance to ventilator	Actively breaths against ventilator or coughs regularly	Fights ventilator; coughing or choking
Crying	Quiet breathing, no crying	Sobbing or gasping	Moaning	Crying	Screaming
Physical movement	No movement	Occasional slight movement	Frequent, slight movement	Vigorous movement limited to extremities	Vigorous movement involving torso and head
Muscle tone	Muscles totally relaxed; no muscle tone	Reduced muscle tone	Normal muscle tone	Increased muscle tone and flexion of fingers or toes	Extreme muscle rigidity and flexion of fingers and toes
Facial tension	Facial muscles totally relaxed	Facial muscle tone normal; no facial muscle tension is evident	Tension evident in some facial muscles	Tension evident throughout facial muscles	Facial muscle contorted and grimacing
Blood pressure (MAP) baseline	Blood pressure below baseline	Blood pressure consistently at baseline	Infrequent elevations of 15% or more above baseline (1–3 during 2-min observation)	Frequent elevations of 15% or more above baseline (>3 during 2-min observation)	Sustained elevation of 15% or more
Heart rate baseline	Heart rate below baseline	Heart rate consistently at baseline	Infrequent elevations of 15% or more above baseline (1–3 during 2-min observation)	Frequent elevations of 15% or more above baseline (>3 during 2-min observation)	Sustained elevation of 15% or more

Children and Infant Pain Scale (ChIPS) (Table 4) (20) is intended to be used in case of newborn, infant and young children. It consists of 5 behavioral items: crying, facial expression, posture of the trunk, posture of legs and motor restlessness. In this scale score ranges from 0 to 10 while 0–3 means lack of pain, 4 and more points indicates the need for analgesics (34). ChIPS was built for measure of postoperative pain as a result of studies on 26 items in 584 newborns, infants, and young children (20).

Table 4. Children and infant pain scale

Items	Structure	Points
Crying	None	0
	Moaning	1
	Screaming	2
Facial expression	Relaxed/smiling	0
	Wry mouth	1
	Grimace (mouth and eyes)	2
Posture of trunk	Neutral	0
	Variable	1
	Rear up	2
Posture of legs	Neutral, released	0
	Kicking about	1
	Tightened legs	2
Motor restlessness	None	0
	Moderate	1
	Restless	2

Cardiac Analgesia Assessment (CAA) – Table 5 – is intended to be used among children aged 0-16 years old and consists of 4 indicators: pupillary size, heart rate, blood pressure (mean), respiratory and motor response. Score of this scale ranges from 0 to 8. Score higher than 4 is interpreted as the appropriate level of pain when analgesic is required. CAA is not useful for intubated postoperative cardiac children on ventilator because facial expression, crying and body movements cannot be estimated as a result of using muscle relaxants and sedatives in immediate postoperative period. After recording baseline movement at rest, stimulus (suctioning or turning) given to the patient, and then highest measurement that occurs up to 1 minute of stimulus is recorded (35).

Table 5. Cardiac analgesia scale

	Scoring		
Variables	0	1	2
Pupillary size[a]	≤2 (pinpoint)	3–4 mm (midsize)	>4 mm (dilated)
Heart rate[b]	Within baseline[c]	5–15% increase	>15% increase
Blood pressure (mean)	Within baseline	5–15% increase	>15% increase
Respiratory and motor response[d]	No response	Cough and minimal movement settles after removal of stimulus	Cough and/or excessive movement > 1 min after removal of stimuli

Response to suctioning and turning: [a]pupils: score to nearest size. [b]Patients with pacemaker on fixed rate or junctional ectopic tachycardia are scored 1. [c]Within baseline of <5% increase of blood pressure or heart rate [d]Paralyzed patients are scored 1

Another scale is the Neonatal Facial Coding System (NFCS) (36, 37). It has been used to study pain behavior of full term, preterm and older infants and was developed and validated using videotaping which let to analyze intensive slow motion stop frame videocoding, and playback. With these methods good reliability has been consistently demonstrated. Neonatal Facial Coding System consists of 8 items: brow bulge, eye squeeze, deepened nasolabial furrow, opened lips, stretched mouth, lip purse, taut tongue, chin quiver (38).

Different scales are used for estimation of pain depending on is procedural or postoperative character. To assess acute procedural pain, the most popular and well validated are as follows: Premature Infant Pain Profile (PIPP) (28, 29, 39), CRIES (2), Neonatal Facial Coding System (NFCS) (36, 37). For postoperative pain the most useful are: PIPP (26, 27), CRIES (27, 30), COMFORT (31–33).

Analyses mentioned above prove that children's pain should be assessed. It is an essential contribution to ensuring that pain is both prevented and relieved (12, 40). No individual measure can be broadly recommended for pain assessment across all children or all context (41, 42). Childrens' self report of pain, is the preferred approach (41). The results of pain assessment must be documented, acted upon, reassessed, and reevaluated to determine effectiveness of interventions (40, 43, 44). Improved documentation can result in improved pain management (45, 46). Studies demonstrate that pain is underassessed and poorly documented what results in poor management of pain (47). Regular pain evaluation can lead to the safety and efficacy of management of acute pain (48). Parents and other carers should also receive appropriate information about their child's pain (49, 50). Their beliefs about their child's pain need to be taken into consideration as these which may impact their child's care. Parents/carers also need appropriate information, teaching, and confidence in the use of pain assessment tools if they are to be effective in assessing (and managing) their child's pain (51, 52).

The best summary of this article are recommendations of recognition and assessment of pain of neonates and infants made by the Agency for Health Care Policy and Research (AHCPR) in 1992. This research recognizes that it is possible to measure the level of pain in premature infants. Behavioral measures can reliably and validly indicate that infants are experienced by the pain. Main indicators of the pain are: crying, facial expressions, motor responses, body posture, activity, undue quietness, restlessness and specific appearance. There is no pain assessment tool which should be used in isolation. The overall status and gestational age of infants, parental views and the environment must be taken into account (53).

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SUMMARY

Acute pain is one of the most common adverse experiences relating to children. It occurs as a result of injury, illness or necessary medical interventions. Pain also exists in case of neonates and it is difficult to measure. It is particularly difficult to assure effective pain control in the postoperative period. Without adequate methods of evaluating children's pain, it is impossible to plan appropriate intervention and to take steps to ensure effectiveness of any medical action. The crucial aim of this article is presentation of achievements in pain assessment among children based on the latest publications. There were created postoperative and procedural pain assessment tools for neonates and infants such as Premature Infant Pain Profile (PIPP), CRIES Instrument, COMFORT Scale, Children and Infant Pain Scale (ChIPS), Cardiac Analgesia Assessment (CAA), Neonatal Facial Coding System (NFCS). These tools, combined with other ways of assessing neonates' pain, can improve management of pain among the youngest patients.

Metody oceny bólu u noworodków

Ostry ból jest jednym z najczęstszych nieprzyjemnych doznań doświadczanych przez dzieci. Może się pojawić w wyniku urazu, choroby lub jako efekt niezbędnych procedur medycznych. Noworodki także doświadczają bólu, co więcej jego ocena przysparza wiele trudności. Szczególnie dużym problemem jest zapewnienie skutecznej kontroli bólu w okresie pooperacyjnym. Brak wystarczających metod ewaluacji bólu u dzieci uniemożliwia planowanie stosownej interwencji oraz podejmowanie kroków zapewniających efektywność działań medycznych. Celem artykułu jest prezentacja osiągnięć dotyczących oceny bólu wśród dzieci na bazie najnowszych publikacji. Dla noworodków oraz niemowląt stworzono pooperacyjne i proceduralne narzędzia oceny bólu. Są nimi: *Premature Infant Pain Profile (PIPP), CRIES Instrument, COMFORT Scale, Children and Infant Pain Scale (ChIPS), Cardiac Analgesia Assessment (CAA), Neonatal Facial Coding System (NFCS).* Te narzędzia, w połączeniu z innymi metodami oceny bólu, mogą udoskonalić zarządzanie bólem wśród najmłodszych pacjentów.