

**PHYSICAL THERAPY OBSERVATION AND ASSESSMENT IN  
THE NEONATAL INTENSIVE CARE UNIT**

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**ABSTRACT.** This article presents the elements of the Observation and Assessment section of the Infant Care Path for Physical Therapy in the Neonatal Intensive Care Unit (NICU). The types of physical therapy assessments presented in this path are evidence-based and the suggested timing of these assessments is primarily based on practice knowledge from expert therapists, with supporting evidence cited. Assessment in the NICU begins with a thorough review of the health care record. Assessment proceeds by using the least invasive methods of gathering the behavioral, developmental, physiologic, and musculoskeletal information needed to implement a physical therapy plan of care. As the neonate matures and can better tolerate handling, assessment methods include lengthier standardized tests with the psychometric properties needed for informing diagnosis and intervention planning. Standardized tests and measures for screening, diagnosis, and developmental assessment are appraised and special considerations for assessment of neonates in the NICU are discussed.

Campbell introduced the concept of the clinical care path for managing NICU care and presented the Infant Care Path for Physical Therapy in the NICU developed by Byrne (Campbell, 2013, Figure 1). Care paths have been introduced in many areas of health care but none has been specific to physical therapy practice in the NICU. A care path presents diagnostic and intervention recommendations for care of a specific class of patients. The care path is used to document the care provided in a succinct fashion and its use helps to guard against omissions of important elements of care. The Infant Care Path for Physical Therapy in the NICU suggests appropriate ages for conducting the various aspects of care and is divided into sections on Physical Therapy Observation and Assessment, Intervention (including Family Support and Education), and Team Collaboration. Observation and Assessment, the topic of this article, includes sections for Observation only, Limited Hands-on Assessment, Full Hands-on Assessment, and Sensory Assessment.

This article guides the reader through the elements of the Observation and Assessment section of the Infant Care Path for Physical Therapy in the NICU (Fig. 2.1, Campbell, 2012). This section corresponds to the elements Examination and Evaluation in the Guide to Physical Therapist Practice (American Physical Therapy Association, 2001). Assessment by the physical therapist in the NICU environment begins with gathering information on the infant's pre- and perinatal history and current medical status from careful review of the health care record. Assessment then proceeds with use of the least invasive methods of gathering the behavioral, developmental, physiologic, and musculoskeletal information needed for diagnosing impairments and activity limitations in order to initiate a physical therapy plan of care. As the infant matures and becomes capable of tolerating and responding to testing involving handling, assessment methods include lengthier standardized tests for making more definitive diagnostic

decisions and intervention planning. In this article, each of these elements of observation and assessment is discussed according to the NICU Care Path guidelines. When a variety of tests are available, we include information on those most commonly used in clinical practice that have the best evidence of validity and clinical utility. Limitations of the tests are also described.

### **Review of the Health Care Record**

Assessment begins with a review of the health care record. A careful review of the medical, nursing, and social history provides a picture of the neonate within the context of the family. The purpose of the record review is to gather pertinent pre- and postnatal information needed for planning the physical therapist assessment and subsequent plan of care for intervention. Pertinent information typically includes referral information, past medical history, current health and feeding status, social history, and consultation history.

The Physical Therapy Referral: The necessary information to obtain from the referral for physical therapy services includes the name of the requesting physician or nurse practitioner, the priority of the order, the reason for the referral, the assessment and treatment service requested, and the service onset, frequency and duration, if noted. Knowing who the referring health care professional is allows the physical therapist to communicate directly with this person as needed. The priority status of the request guides the physical therapist in addressing and managing multiple simultaneous referrals in the acute care setting. Knowledge of the reason for the referral and what is requested allows the therapist to determine the appropriateness of that request and make alternative recommendations as needed. This is especially important when working within a team. Often, the physical therapist and occupational therapist collaborate to provide care in the NICU and there may be times when one service is more appropriate than the other.

To illustrate how two service lines might differentiate their services based on educational background and training, the roles of the occupational therapist and physical therapist in the NICU at Lucile Packard Children's Hospital (LPCH) at Stanford Medical Center will be discussed. At LPCH, physical therapists prioritize seeing infants with, or those suspected of having, neurologic impairment, range of motion limitations, endurance limitations, and infants with medically complex conditions. Neurologic impairment in this case may involve the brain or spinal cord. Physical therapists use their skills in assessment of postural tone and motor patterns, to conduct clinical neurologic examinations. In addition, physical therapists conduct specific myotome and dermatome testing for infants with myelodysplasia. At LPCH, the occupational therapist is the primary professional responsible for assessment related to feeding and hand care. In other NICUs feeding activities may be done by the physical therapist or the speech and language pathologist.

Prenatal and Birth History: Obtaining the past medical history includes intrauterine health, labor and delivery circumstances, and the postnatal course. Complications in intrauterine health may include gestational diabetes, maternal anemia, maternal pre-eclampsia, intrauterine drug exposure, twin-to-twin transfusion in the case of multiple gestation, oligo- or polyhydramnios, maternal illness, fetal breech positioning, and preterm labor (Gomella, Cunningham & Eyal, 2009). These complications impact the neonatal hospital course and, therefore, are important for the physical therapist to appreciate. At discharge the physical therapist will recommend appropriate community service referrals to the health care team and family. Accordingly, a thorough record review is needed in order not to miss pertinent information and qualifying criteria needed for discharge recommendations.

Infant physiological status at delivery is measured by the Apgar score (Table 1), developed by Dr. Virginia Apgar (Apgar, 1953). The scoring is typically conducted at 1 minute and 5 minutes, but may be conducted at 10, 15, and 30 minutes if the infant continues to experience physiologic compromise. After 5 minutes, or once the infant has achieved a score of seven or greater, the scoring typically ceases (Gomella et al., 2009). Infant responses at birth in these five areas dictate the type of medical interventions needed (e.g., resuscitation, ventilator support, pharmacologic support).

Infants born weighing less than 1500 grams are said to have a very low birthweight (VLBW) (Doyle & Saigal, 2009) which is correlated with high risk for later developmental delay (Chen, Wang & Fang, 2005; Doyle & Saigal, 2009). Consequently, physical therapists may be consulted to examine and provide intervention to neonates with a birthweight less than 1500 grams. In some hospitals these infants and others with specified high risk conditions are seen under standing orders with no need for an individual referral.

Similar to birthweight, an infant's gestational age (GA) at birth may impact later development (Doyle & Saigal, 2009). Determining the infant's maturity is important for making all clinical decisions. Calculating the age of an infant born preterm is done by describing age at birth as GA in weeks, age after preterm birth up to term age as postmenstrual age in weeks (PMA), and his or her corrected age (CA) thereafter (see AAP policy statement at: <http://aappolicy.aappublications.org/cgi/content/full/pediatrics;114/5/1362>). The infant's age at birth may serve as a criterion for high risk infant follow up when it is less than 32 weeks GA, or very preterm. Because very preterm infants are at greater risk for developmental delay, they, too, are typically seen by the physical therapist in the NICU. However, it is important to note that all infants born preterm are at risk for developmental delay. Recent studies indicate that infants born

moderate to late-preterm are also at risk for delays, particularly in behavior and cognitive functioning (de Jong, Verhoeven, & van Baar, 2012).

Postnatal Health and Management: An understanding of the infant's health status includes knowledge of the current medical interventions, including pharmacologic management, and conditions, pertinent lab values, the short- and long-term medical goals, and head imaging results (discussed in a subsequent section). Common pharmacologic interventions in neonates include methylxanthine therapy (caffeine) to treat apnea and bradycardia of prematurity, dopamine hydrochloride to stabilize blood pressure, analgesics for sedation and pain control, albuterol for bronchospasm in reversible airway obstruction, phenobarbital for seizures or cholestasis, vitamin therapy, and corticosteroids (Gomella, et al., 2009). Infants with apnea and bradycardia of prematurity requiring caffeine treatment are considered to have a higher risk of neurobehavioral complications as measured on the Neonatal Medical Index (Korner, et al., 1993), and infants with prolonged or increased incidence of apnea and bradycardia of prematurity are at greater risk for compromised neurodevelopmental outcome (Pillekamp, Hermann, Keller, von Gontard, Kribs, & Roth, 2007). Similarly, the presence of neonatal seizures increases risk for neurobehavioral complications (Nunes, Martins, Barea, Wainberg & Costa, 2008).

Infants with increased oxygen requirements or prolonged ventilator support may require the use of corticosteroids and may be at risk for developmental delay. Corticosteroids are used to prevent bronchopulmonary dysplasia (BPD) and chronic lung disease (CLD) (Grier & Halliday, 2005). Although corticosteroids, particularly dexamethasone, reduce intubation time, CLD and risk for patent ductus arteriosus (PDA), their use has been linked to cerebral palsy (CP) and later abnormal neurologic findings (Halliday, Ehrenkranz & Doyle, 2010). Because poor long-term developmental outcome has been associated with the early postnatal use of corticosteroids (Grier

& Halliday, 2005), corticosteroid use is typically reserved for very sick neonates requiring high level respiratory support or prolonged ventilator support. Neonatal medical conditions and/or pharmacological interventions are an important consideration for the physical therapy examination. For example, hyperbilirubinemia and exposure to tocolytic agents such as magnesium sulfate can cause infants to be lethargic and confound the results of the physical therapy examination. A good resource summarizing medical conditions of infants in the NICU is the chapter on the Special Care Nursery in *Physical Therapy for Children*, 4th Ed. (Kahn-D'Angelo, Blanchard, & McManus, 2012).

Knowledge of respiratory support is essential when making decisions on the physical therapist intervention plan. Types of respiratory support include a ventilator, nasal continuous positive airway pressure (CPAP), and nasal cannula oxygenation (Gomella, et al., 2009). In more serious situations, cardiopulmonary support is needed in the form of extracorporeal membrane oxygenation (ECMO) (Gomella, et al., 2009). For neonates whose respiratory status is stable, no extra respiratory assistance is needed and these infants are said to be “on unassisted room air” only. According to the National Institute of Child Health and Human Development, an infant requiring oxygen supplementation prior to or at 36 weeks PMA is considered to have BPD, a disease of the lung tissue (Jobe & Bancalari, 2001). CLD is typically diagnosed for infants requiring oxygen after 36 weeks PMA.

Retinopathy of prematurity (ROP) is a medical complication common in infants born preterm. ROP is a potentially blinding eye disorder that is most commonly seen in infants born at less than 31 weeks GA or weighing less than 1250 grams (National Eye Institute <http://www.nei.nih.gov/health/rop/index.asp>). Infants with ROP have abnormal blood vessel growth into and around the retina. These vessels are fragile and may leak blood into the retina,

causing scarring and retinal detachment (Phelps, 1995). It is important for the physical therapist to know if an infant has ROP because the severity of ROP is associated with poorer developmental outcome later (Msall, et al., 2000). In addition, these infants require serial eye exams which can be stressful and painful. Observational assessment during ROP exam provides useful information for recommendations for pain management during procedures.

Another common medical condition in the infant born preterm is necrotizing enterocolitis (NEC; Schulzke, Deshpande & Patole, 2007). The infants at greatest risk for NEC are those born very preterm. Similar to the condition of ROP, infants who develop NEC are at risk for poorer developmental outcome and, as the severity of the NEC increases, the likelihood of having neurodevelopmental delay also increases. Surgery under general anesthesia is correlated with decreased volume of deep nuclear gray matter and risk for adverse cognitive outcome (Filan, Hunt, Anderson, Doyle, & Inder, 2012).

Laboratory Values: When conducting a review of the health care record, it is important to note lab values that pertain to decisions regarding the infant's ability to safely tolerate movement and handling. Particular lab values for physical therapists to note are alkaline phosphatase (ALP), platelet count, pH after birth, and phenobarbital level. Infants who are at risk for bone fractures may have an elevated ALP level (e.g., > 800 IU/L) (Cloherty, Stark, & Eichenwald, 2007). This information is important to the therapist who may be handling this infant or providing specific range of motion intervention. It is often the responsibility of the physical therapist to provide instruction to the family and to nursing staff regarding modified handling techniques for infants at risk for bone fracture.

A normal platelet count for the infant born preterm is 150-350 ( $10^3/\text{mm}^3$ ) (Bowman & Fraser, 2010). When the platelet count is low the neonate is said to have thrombocytopenia. The

significance of thrombocytopenia depends on the overall health of the neonate and does not always indicate a risk for bleeding (Stokowski, 2007). Thus it is up to the physical therapist to communicate with the medical team about the significance of platelet values and risk for bleeding with handling and positioning interventions.

Umbilical arterial pH is a measure of neonatal acidosis. The range of normal pH varies slightly among sources, but a range of 7.27-7.32 for infants less than 30 weeks PMA and 7.30-7.35 for infants 30-36 weeks PMA is generally be considered normal (Gomella, et al., 2009). Umbilical pH level can give information regarding neonatal risk for medical and developmental morbidities. In a follow-up study conducted by Belai and colleagues (1998), neonates with umbilical arterial pH values of less than or equal to 7.00 had a greater incidence of seizures, hypoxic-ischemic encephalopathy, and vital organ dysfunction. It is important for the physical therapist to know an infant's phenobarbital level when this medicine is prescribed. A serum phenobarbital level of 40 mg/dL or more may have a sedative effect, which could confound interpretation of observations and standardized assessments (Gomella, et al., 2009).

Medical Goals and Management Planning: Knowledge of short-term (e.g., weekly) and long-term (e.g., monthly) medical goals is necessary because it gives the physical therapist an understanding of where the infants are in their hospital course. The physical therapist will progress interventions (see Byrne & Garber, 2013; Garber, 2013) as the infant is medically and developmentally ready. It is particularly important for the physical therapist to anticipate discharge in order to make appropriate recommendations and to provide needed anticipatory guidance to the family (for more information on family support and education see Goldstein, 2013). Examples of health and developmental milestones that typically indicate a readiness for discharge are when the baby is feeding and gaining weight while cared for in an open crib and is

maintaining body temperature stability (American Academy of Pediatrics, 1998). When these milestones are achieved the baby typically will be discharged within 48 hours.

Social History: A primary role of the physical therapist in the NICU is family-centered collaboration and guidance (Sweeney, Heriza, Blanchard & Dusing, 2010). It is critical, therefore, that the physical therapist is knowledgeable of the family unit, home environment, and family supports and resources. Understanding the family unit will allow the physical therapist to better engage with the parents. A physical therapist in the NICU may consider using a hope-empowerment model to facilitate parent-therapist collaboration (Sweeney & Swanson, 2001). Using this model, therapists and parents form a *partnership* for coping and *empowerment* (Lowman, Stone & Cole, 2006). Instructing and guiding parents on how to safely handle and position their young infants and listening to parent concerns and preferences empowers parents to participate in the care of their infant and may help with infant health and well being (Gale & Franck, 1998). The importance of parental participation in the care of their infant is supported by research and parent-professional collaboration in decision making is a goal of family-centered care (Dunst & Trivette, 1996; Dudek-Shriber, 2004; Teti, Hess & O'Connell, 2005).

Consult History: To gain a broad understanding of the neonate's hospital course, it is important to know the consultation history. Other health professionals may be following or have provided consultation when a physical therapist receives a referral to begin services. For example, it may be important for the physical therapist to know what neurologic testing has been completed or what the cardiology consult revealed. Results from a cardiac evaluation may provide insight into a neonate's tolerance for handling and endurance levels. This information would guide the physical therapist's interventions and the family instruction provided. Similarly, brain imaging results may provide information regarding infant risk for current or possible future

developmental problems that the therapist can use for providing the family with anticipatory guidance and instruction or for making discharge recommendations.

Brain Imaging Studies: Infants with brain injuries are commonly referred for physical therapy. Advances in imaging technology continue to improve identification of abnormalities of brain structure and function that occur in the pre- and perinatal periods (Huang, 2010; Rutherford, Mercuri & Cowan, 2007). Although ultrasound imaging of the brain is often used to identify intraventricular hemorrhage (IVH) and early signs of ischemic injury leading to periventricular leukomalacia (PVL), magnetic resonance imaging (MRI) identifies lesions that cannot be seen with ultrasound. In addition to large cystic lesions identifiable on repeated head ultrasound examination which have a high association with the outcome of cerebral palsy (CP), MRIs can reveal smaller focal cystic lesions.

MRI can also identify diffuse, non-cystic, periventricular white matter injury (WMI) that is now believed to be responsible for some of the neurologic outcomes of a less severe nature than CP, including cognitive and neurosensory impairment (Hart, Whitby & Griffiths, 2008; Constable, et al., 2008). For example, one imaging study found that 80% of infants born at < 36 weeks GA and imaged with MRI at term demonstrated WMI associated with neurologic abnormalities (Hashimoto, Hasegawa, Kida & Takeuchi, 2001). Advanced methods of fiber tracking using diffusion tensor imaging (DTI) from MRI scans are able to reveal the pathways involved, leading to the future possibility of more accurate prediction of the type of CP or other motor dysfunction that might result (Ment, Hirtz, Hüppi, 2009; Murakami, et al., 2008; Yoshida, et al., 2010). Imaging for this purpose is best done near term age because the posterior limb of the internal capsule which contains descending motor fibers should demonstrate an advanced

stage of myelination (Rutherford, et al., 2007). Imaging at later ages reveals the maturation of white matter paths and adaptation to injury (Figure 1).

[Insert Figure 1 (Two .tif files 1A & 1B)]

Notation in the health care record of negative imaging findings from head ultrasound, MRI, or DTI makes an infant a candidate for physical therapy because of exceptionally high risk of abnormal neurologic outcome; relevant findings include PVL, IVH (especially Grades III/IV), cerebral infarction (i.e., stroke), ventricular dilation, hydrocephalus, microcephaly, diffuse periventricular WMI (including diffuse excessive high signal intensity appearance on MRI), and hypoxic-ischemic encephalopathy.

### **NICU Care Path: Observation & Assessment: Observation**

The first section of the Infant Care Path for Physical Therapy in the NICU (Campbell, 2013) focuses on observation of the infant. An important reason for observation is to identify potentially stressful effects of caregiving and obtain knowledge of infant sensorimotor behavior in the NICU environment. Observation of the infant's responses to routine caregiving can begin shortly after birth with the role of the physical therapist being one of assessing the infant's behavior, vital signs, musculoskeletal system, positioning, mobility, and other developmental areas of strength and needs (Figure 2). Assessment includes recordings of the infant's behavioral and physiological responses during routine care including vital signs for heart and respiratory rates and oxygen saturation. In a nursery in which the Newborn Individualized Developmental Care and Assessment Program (NIDCAP) (Als, 1995; Als, et al., 2004) is used, observations of 91 behaviors (autonomic, motor, and behavioral state organization) are done before a routine caregiving session, during the session, and continued during the recovery period. In other nurseries, observational assessment is a more informal process. A discharge plan that includes

family-focused education is always a goal of the assessment process. The next section describes assessment within the theoretical framework of the NIDCAP approach to illustrate the process.

[Insert Figure 2]

NIDCAP: In the NIDCAP approach (Als, 1995; Als, et al., 2004; Als, Lester, Tronick, & Brazelton, 1982), nursery team members receive training in assessing the infants' responses to typical caregiving in the NICU environment. Results are used to develop a care plan to foster individual development. Reassessment over time allows evaluation of progress including increased endurance and tolerance of handling without undue stress. As described by Campbell (1999), physical therapists with NIDCAP certification can play a role in:

- 1) Assessing infant reactions to caregiving or developmental assessment,
- 2) Environmental modifications,
- 3) Recommendations for commercially-available or hand-made materials useful in providing infants with a supportive environment,
- 4) Educating parents in understanding their infant's signals for welcoming or discouraging interaction and in responding in a developmentally appropriate way to promote cognitive and motor development, and
- 5) Initiating physical therapy assessment and plans of care for infants with especially high risk for neurologic dysfunction or delayed motor development that are sensitive to developmental and physiologic readiness to participate in movement therapy.

Because all members of the NICU team can assume the first four roles, those roles are not unique to the physical therapist. The lead role is typically played by the infant's primary nurse, but it is important that all team members are consistent in using the prescribed management approach. Thus the NICU Care Path also lists a NIDCAP assessment under the section entitled

Team Collaboration. The fifth role is the unique province of the physical therapist and should be carried out based on reliable and valid assessments and use of interventions with evidence of effectiveness.

Campbell (1999) described a case exemplifying use of a NIDCAP behavioral assessment of 91 behaviors monitored every 2 minutes on an infant who was assessed by a physical therapist trained in its use. As is typical of a NIDCAP assessment, the report 1) described the initial environmental conditions, both of the overall nursery area and of the infant's personal space, 2) the results of a baseline behavioral observation, 3) observations during caregiving, 4) post-caregiving observations, 5) a summary of goals, and 6) recommendations for the care plan. The NIDCAP assessment helps to identify changing developmental needs. For example, at an early point in time the infant's developmental care plan might include achieving physiologic stability; later as health improves, the plan might include social interaction with caregivers. All members of the care team can use the results of a NIDCAP behavioral assessment to plan individualized care for infants. Repeated assessments are necessary in order to capture the changing level of maturity and readiness for engagement of infants as they develop and recover from complicated medical conditions. Accordingly, no specific age for assessment is listed in the care path.

For professionals with advanced training in NIDCAP, the Assessment of Preterm Infants' Behavior (APIB) is a more detailed instrument for measuring global maturation of the preterm infant (Als, Lester, Tronick & Brazelton, 1982). Efficacy of the NIDCAP for improving developmental outcomes and shortening hospital stay has been reported (e.g., Als, et al., 1986, 1994; Symington & Pinelli, 2006), but a meta-analysis published in 2002 indicated that evidence was insufficient to recommend a multicenter clinical trial (Jacobs, Sokol & Ohlsson, 2002). A subsequent study by Als' group demonstrated brain structure and function at 2 weeks CA as well

as neurobehavioral outcome at 2 weeks CA on the APIB and at 9 months CA on the Bayley II to be superior in infants cared for in the NIDCAP approach compared with a control group who received standard care (Als, et al., 2004; Bayley, 1993).

A systematic review by Wallin and Eriksson (2009) concluded that scientific evidence in support of NIDCAP was limited and based on studies of only medium quality in terms of design and execution. Findings included increased anxiety but more feelings of closeness to their infants on the part of mothers whose infants were in NIDCAP groups. In the same year, two clinical trials reported conflicting results. Maguire and colleagues (2009) found no effects on respiratory support, days of intensive care, growth, or neuromotor development at term age while Peters and colleagues (2009) found reduced length of stay and incidence of chronic lung disease, and less mental delay at 18 months CA, although there were no significant differences between groups on motor and mental quotients. A commentary by Ohlsson (2009) suggested a meta-analysis that included the 288 infants in the studies by Maguire and colleagues (2009) and Peters and colleagues (2009) but expressed the need for clinical trials with improved designs to better rule out threats to internal validity.

In addition to the inconclusive research evidence on effectiveness in improving developmental outcomes, limitations of the NIDCAP include the extensive and costly training involved in instituting the approach (\$6,000 to become a certified observer according to Westrup, 2007). Training for individuals typically takes 12 months and NICUs planning to institute the NIDCAP approach are encouraged to develop a 5-year strategic plan for completing the process based on the premise that all members of the NICU care team must be proficient to optimize effectiveness. Training information is available at <http://www.nidcap.org> .

Pain: It has been well established that infants experience pain and that responses to painful and other stressful stimuli can be measured physiologically (e.g., by the presence of increased heart rate and decreased oxygen saturation) and via facial expressions and body movements in preterm infants (Duhn & Medves, 2004; Holsti, Grunau, Oberlander, Whitfield & Weinberg, 2005). A plethora of measures exist (e.g., 35 tools are identified in the 2004 review by Duhn and Medves), but selection of one specifically designed for preterm infants is important because these infants may have less clear signals (behaviorally or because of equipment restrictions on observation), less ability to cry, and altered responses as a result of sensitization to repeated experiences of exposure to painful stimuli (Morison, et al., 2003). Although nurses may repeatedly assess pain to evaluate the effectiveness of pain control interventions, physical therapists are particularly interested in assessing whether routine care or environmental conditions are associated with pain that might affect the infant's interaction with caregivers and response to developmental intervention. For example, because clustered care has been shown to evoke pain-like responses in infants, particularly body movements, assessment of pain is useful in determining whether spacing out of caregiving procedures might be more beneficial than the more routinely used clustered care procedures (Holsti, et al., 2005). Research has also shown that higher numbers of skin-breaking procedures are related to poorer cognition and motor function (Grunau, et al., 2009).

Although heart rate increases and facial responses, in particular nasolabial furrowing, eyebrow bulging and eye squeezing, have generally been shown to be the most valid behavioral indicators of pain-like responses in infants born preterm (Holsti, et al., 2005), Morison and colleagues (2003) have reported that extension of the arms and legs and finger splay are common responses to painful stimuli in preterm infants while startles and twitches are not necessarily

associated with pain. Of note is that infants with more prior pain exposure showed more motor stress cues and less facial activity following lancing for blood draw than infants with less prior pain exposure.

Porter, Grunau, and Anand (1999) showed that effects of early pain exposure continue long after the NICU experience and low pain reactivity at 32 weeks PMA is associated with poorer motor function at 8 months CA (Grunau, Whitfield, Fay, Holsti, Oberlander & Rogers, 2006). Eyre (2007) believes that altered patterns of sensory input associated with painful experiences can disrupt the synaptic organization of the sensory system at the spinal cord level where development of connections has been shown in animal models to be activity-dependent. This idea is supported by research showing long-lasting anatomic and physiologic changes in the dorsal horn of the spinal cord (e.g., increased responses to a heat stimulus and larger receptive fields for responses to sensory stimulation) in adult rats following an injection that produced peripheral inflammation in the neonatal period (Peng, Ling, Ruda & Kenshalo, 2003). Research on animals has demonstrated that there are sensitive periods in development that result in varying (i.e., hypoalgesia or hyperalgesia) long-lasting changes in the nervous system and, as a result, in behavioral responses to new noxious inputs (Ren, et al., 2004).

The Premature Infant Pain Profile (PIPP): The PIPP is reported to have the strongest psychometric properties and clinical utility for use with premature infants (Duhn & Medves, 2004) and, therefore, is recommended for this NICU Care Path. The PIPP is a multi-dimensional assessment for infants from 28 to 40 weeks PMA that includes 7 indicators rated on 4-point scales: GA, behavioral state, heart rate, oxygen saturation, brow bulge, eye squeeze, and nasolabial furrow. In a study by Ahn and Jun (2007) comparing the PIPP with the 5-indicator CRIES (an acronym for Cry, Requires O<sub>2</sub> for oxygen saturation above 95, Increased vital signs

and blood pressure, Expression, and Sleeplessness) and the 5-indicator FLACC (an acronym for Face, Legs, Activity, Cry, and Consolability), each tool discriminated among responses to invasive stimuli such as endotracheal suctioning or lancing, routine care, and environmental sounds, but the PIPP was most effective in detecting pain-like responses to sounds in infants born preterm (Ahn & Jun, 2007). The PIPP was responsive to evaluating changes in pain among preterm neonates who received skin-to-skin care (SSC, also called kangaroo care; Johnston, et al., 2003).

The time post-stimulus during which measures on the PIPP are taken is 30 seconds, longer than for other scales. On the one hand, this may be an advantage in capturing the often delayed responses seen in preterm infants; on the other, it may mask the acute response better captured by scales with shorter measurement periods (Ahn & Jun, 2007; Morison, et al., 2003). A limitation is that the multi-dimensional PIPP may not differentiate responses indicating stress rather than pain (Holsti, et al., 2005). Therapists using the PIPP should examine individual item responses to determine whether reductions in behavior might indicate sedation rather than effective pain control. Training involved is minimal, taking approximately one minute to review and 2-3 minutes of practice (Duhn & Medves, 2004).

The Behavioral Indicators of Infant Pain (BIIP): Holsti and colleagues (2005, 2011) contend that differentiating infant responses of stress from pain is critical to selecting the most appropriate interventions (e.g., analgesics with the potential for long-term side effects of opioid use versus SSC to reduce pain, or clustered routine care versus spaced-out care to reduce stress). As a result they developed the BIIP assessment as a unidimensional scale to specifically measure behavioral indicators of pain that combine items on sleep/wake states, 5 facial actions, and 2 hand actions. Behaviors are scored from 0-2 points. Selection of items was based on the

synactive theory of development underlying NIDCAP; each item has been individually validated for responsivity to acute pain in preterm infants (Holsti & Grunau, 2007; Morison, et al., 2003). Because the BIIP is a unidimensional assessment of behavior in response to pain, therapists using this assessment should also record physiologic indices in order to assess all indicators of pain. Although less studied than the PIPPS, research showed sensitivity to change across phases of blood collection (Holsti & Grunau, 2007). The BIPPS is available at [www.developmentalcare.net](http://www.developmentalcare.net) along with an introductory training video.

Musculoskeletal System Screen: The musculoskeletal screen consists primarily of observation with or without a brief hands-on component. It is performed in lieu of a more thorough assessment to address positioning needs of very preterm or fragile infants. The components of the musculoskeletal screen include observation at rest and observation of the infant moving spontaneously or in response to touch during care. Observation of the infant's resting position will reveal the infant's position of comfort. This position may be influenced by the intrauterine environment, infant behavioral state, respiratory comfort, lines and leads, and positioning aides.

The following are three examples of factors contributing to positional preferences in neonates. If the intrauterine environment was confined due to decreased amniotic fluid or a pregnancy with multiple births, the neonate may position her extremities in the way that accommodated space restrictions in utero. If a peripheral or central neuropathy occurred prior to birth, the neonate's muscles will be underdeveloped and antigravity movements decreased. A neonate experiencing respiratory distress often postures in prone or supine with neck extended and shoulders retracted and externally rotated. Addressing these positioning preferences may be important in preventing the development of inefficient motor patterns or contractures. For

instance, the infant who strongly prefers to position himself with his neck extended and shoulders retracted and externally rotated in supine may develop a head rotation preference and weakened shoulder flexor and protractor muscles. Prolonged use of this position has been associated with problems in early development (Sweeney & Gutierrez, 2002)

To screen the musculoskeletal system, the physical therapist observes the infant's spontaneous movements and responses to touch during care. Movements should be observed for their fluidity, midline orientation, and organization. Antigravity movements are noted in all four limbs, neck and trunk. Range of movement should be symmetric on the right and left sides of the body. The vigor of movements may be evaluated while observing routine care such as a diaper change.

General Movements (GM) Assessment: The GM assessment is a method designed to determine the integrity of the infant nervous system through observation of the quality of spontaneous movement patterns from videotape (Einspieler, Prechtl, Bos, Ferrari & Cioni, 2004; Snider, Majnemer, Mazer, Campbell & Bos, 2008). The GM assessment involves no handling of the infant and is, therefore, compatible with use in the youngest, most fragile infants. Because its primary use is to rule out or predict a diagnosis of CP, the GM is most useful for following infants with a history of brain injury. The aim is to characterize the evolution of spontaneous movements over the first months of life in order to predict neurologic outcome based on the theory that endogenously generated spontaneous movements are a better indicator of the integrity of the central nervous system than the elicited behaviors on traditional neurologic examinations (Einspieler, Prechtl, Bos, Ferrari & Cioni, 2004). The NICU Care Path suggests use of this assessment beginning at 30-31 weeks PMA but it can be done at any age through about 4 months CA; repeated assessment over time is necessary for predicting a neurologic diagnosis.

GMs are movements of the whole body, with variable sequences of arm, leg, neck, and trunk movements that are spontaneously generated by the infant, not elicited by external stimuli (Einspieler, et al., 2004). In the preterm period, GMs vary greatly in speed and amplitude; however, movements described as cramped synchrony are abnormal at any age. At term, refinement of the GMs begins in two distinct stages. Normal writhing movements of the extremities, having smaller, more elliptical amplitudes, evolve and are present until 6-9 weeks corrected age (CA). At this point, a pattern of fidgety movements, i.e., tiny, circular, elegant movements involving the neck, trunk and limbs, emerges. The greatest prevalence of this pattern occurs at approximately 12 weeks CA, but fidgety movements remain present until voluntary, goal-directed, purposeful movements begin to predominate at 16-20 weeks post term in the typically developing infant. Their absence is related to the diagnosis of CP.

The GM assessment was reported as having a sensitivity of 95% and specificity of 96% to identify infants 9–20 weeks CA with and without neurologic deficits (i.e., CP) (Noble & Boyd, 2012; Prechtl, et al., 1997). Cramped synchrony movements that persist have a sensitivity of 100% for prediction of spastic CP at 3 years of age (Ferrari et al., 2002). Cramped synchrony is a pattern of rigid GMs that lack in fluency, and involve simultaneous contraction and relaxation of all limb and trunk muscles (Cioni, Einspieler, & Paolicelli, 2007). The GM has not been demonstrated to be responsive to change with intervention so its use is limited to diagnosis based on repeated longitudinal assessment from 10- to 30-minute videotaped recordings. A videotape and a CD are available to illustrate GM; information on these media and on basic and advanced training courses can be found at [www.general-movements-trust.info](http://www.general-movements-trust.info) . The reader is referred to a recent systematic review of assessments for infants less than 4 months CA for a summary and

critique of research on the reliability and validity of the GM assessment and other tests described later (Noble & Boyd, 2012).

### **NICU Care Path: Observation & Assessment: Limited Hands-on Assessment**

This section will address the components of a limited hands-on assessment from the Infant Care Path for Physical Therapy in the NICU (Campbell, 2013). A limited hands-on assessment may be the most appropriate for the very young or medically fragile neonate. This hands-on assessment is limited both in terms of the amount of handling of the infant and in terms of the length of time of the assessment. A limited hands-on assessment may include the following components: diaper change, infant re-positioning, gentle facilitation of exploratory movements, informal assessment of general movements, facilitation of upper and lower extremity recoil responses, scarf sign and grasp reflex measurement, and assessment of non-nutritive sucking (NNS) (Figure 3). Not all components need to be examined at one time, nor do they need to occur in any particular order. The decision to include a component and in a certain order depends on the goal of the visit and what the neonate is able to tolerate without undue discomfort. As with all infant interactions in the NICU, the infant's behavior guides the assessment. If the goal is to assess the infant's developmental status (e.g. postural tone, motor coordination, state regulation, and physiologic stability) and tolerance to routine care, then assessing the infant's posture and spontaneous movements during a diaper change and the subsequent response to re-positioning may be appropriate. If the goal is to assess the developmental status (e.g. motor coordination, extremity tone, state regulation, and physiologic stability) of the infant through response to focused stimuli, then facilitation of exploratory movements and testing of scarf sign and recoil responses might be most useful. These limited assessments can provide valuable baseline information about the infant's current developmental status in a minimally invasive

manner. As with all assessments, scheduling should be done to accommodate the infant's sleep-wake cycles.

[Insert Figure 3]

Diaper Change: A diaper change provides the opportunity to move and handle the neonate in the context of routine care. The therapist simultaneously assesses the infant's range of motion, spontaneous movements, postural tone, and tolerance for handling while minimizing the infant's energy expenditure. This brief assessment provides the therapist insight as to whether the neonate has musculoskeletal or neuromuscular problems that need to be assessed in more detail.

Re-positioning: Re-positioning the infant may also be performed in the context of routine care during a limited hands-on assessment, thereby minimizing sleep disruption and energy expenditure demands on the neonate. The goal of re-positioning may be to improve respiration. For example, the prone position is associated with decreased central apnea and periodic breathing in infants born preterm (Heimler, Langlois, Hodel, Nelin, & Sasidharan, 1992) and, therefore, is considered to promote stability in neonatal respiration (Levy, et al., 2006). Other goals of re-positioning may include facilitating contained exploratory movements and maintaining joint integrity (Sweeney & Gutierrez, 2002), increasing comfort and facilitating infant state organization through motor-based self-regulatory behaviors (Grenier, Bigsby, Vergara & Lester, 2003), fostering infant development through more coordinated spontaneous midline movements (Nakano, et al., 2004), and maintaining skin integrity, assisting with head shaping (Najarian, 1999) or preventing an acquired torticollis (Neufeld & Birkett, 2000).

Gentle Facilitated Movement: Providing gentle facilitated movements allows the therapist to determine the infant's tolerance for graded handling while observing the general motor patterns that follow. When assessing both facilitated and subsequent spontaneous movements, it is

important to note the vigor, range, and organization of these movements. The range of movement refers to the ability of the infant to move their limbs against gravity while the organization of the movements refers to the amount of midline limb movements (hands to face/mouth, kicking) and the degree of control over non-midline movements.

Reflex Testing: Several reflex responses may be evoked to assess muscle tone (Allen & Capute, 1990; Amiel-Tison, 1968). These reflexes include upper and lower extremity recoils, scarf sign, plantar and palmar grasp reflexes, and non-nutritive sucking. The upper extremity recoil is performed by flexing the lower arm at the elbow, holding for 5 seconds, then quickly extending the lower arm and releasing it. The subsequent recoil is then graded as brisk and complete to absent (Dubowitz, Dubowitz & Goldberg, 1970; Dubowitz, Dubowitz & Mercuri, 1999). Similarly, the lower extremity recoil is tested by flexing the leg at the hip and holding for 5 seconds, then quickly extending the leg and releasing it. Of note, due to the manner in which tone develops in the infant born preterm, the lower extremity recoil matures prior to the upper extremity recoil (Allen & Capute, 1990; Amiel-Tison, 1968). The subsequent recoil is then graded as brisk and complete to absent (Dubowitz, et al., 1970, 1999).

The scarf sign is used as an indicator of neonatal tone (e.g., Ballard Test) in the upper extremity. The scarf sign, which may be measured as the scarf ratio, has been used as a predictor of later motor performance (Lekskulchai & Cole, 2000a). The “scarf ratio is the distance of the elbow (olecranon process) of the arm being tested as it moves across the trunk compared with the infant's own biacromial width” (Lekskulchai & Cole, 2000b). Others note the scarf sign to be where the elbow is in relation to the infant's midline (nose) as the arm is gently nudged across the chest toward the posterior aspect of the opposite shoulder. Using this method, movement of

the elbow across the chest past midline indicates an immature response while resistance to passive movement before midline indicates a more mature response (Dubowitz, et al., 1970).

The plantar grasp reflex is tested by placing one finger on the plantar surface of the foot just proximal to the ball of the toes. Early absence of this reflex has been correlated to the development of CP (Zafeiriou, 2000; Futagi, Suzuki & Goto, 1999). Similar to testing the plantar grasp, the palmar grasp is elicited by moving one finger distally in the palm of the infant's hand. A typical response would involve the infant contracting her fingers around the therapist's finger (Schott & Rossor, 2003). Unilateral presence, absence, or persistence of the reflex may indicate peripheral (brachial plexus injury) or frontal lobe involvement (Schott & Rossor, 2003).

Non-nutritive Sucking: Non-nutritive sucking (NNS) may also be assessed as part of limited hands-on assessment. The procedure involves placement of an appropriately-sized pacifier or a caregiver's gloved finger within the infant's mouth to elicit at least some degree of sucking effort, with minimal fluid other than oral secretions to control. Evaluation of the infant's oral-motor activity provides information about readiness for feeding (Neiva, Leone, & Leone, 2008). In addition, NNS may assist with mediating neonatal pain (Elserafy, Alsaedi, Louwrens, Bin Sadiq, & Mersal, 2009) and comfort. Other aspects of oral-motor organization and intervention are discussed by Garber (2013).

### **NICU Care Path: Observation & Assessment: Full Hands-on Assessment**

This section will address the components of a full hands-on assessment from the Infant Care Path for Physical Therapy in the NICU (Campbell, 2013). Assessments described include standardized tests of motor performance, neurologic integrity, neurobehavioral function, and oral motor and feeding behavior. Although infants with borderline physiologic stability should be excluded from evaluative handling (Sweeney, et al., 2010), by 34 weeks PMA many infants have

sufficient physiological stability to be tested safely and reliably with standardized tests and measures to: 1) compare the infant's performance with age expectations which may be useful in indicating the need for intervention, 2) educate parents regarding their infant's motor development, 3) plan intervention, and 4) prepare for referral and follow-up after hospital discharge (Figure 4). Potentially useful tools included in the NICU Care Path are tests for 1) screening for delayed motor performance, 2) diagnosis of delayed motor performance, 3) neurologic assessment, 4) neurobehavioral organization, 5) oral-motor and feeding skills, and 6) sensory systems. Each area will be discussed in light of the clinical utility and evidence base of the available tests. Tests chosen as recommended for use in the NICU Care Path are not only those with the strongest psychometric characteristics, but also those with demonstrated value as parent education tools. It is our strong belief that tests and measures are useful not only in gathering data for decision making, but also as an aspect of family-centered care including support and education (see Goldstein, 2013, for more information on family support and education).

[Insert Figure 4]

Given the variety of tests available for assessing sensorimotor development, the NICU Care Path does not prescribe the use of any particular tool nor specify an exact age for assessment, but thoughtful selection is encouraged based on the characteristics of the infant and the therapist's information needs. The NICU Care Path suggests an appropriate range of ages for use of various assessments, but the infant's condition must not only prescribe the type of assessment that is appropriate, but also dictate when testing involving handling is warranted. For example, administration of the Brazelton Neonatal Behavioral Assessment Scale (BNBAS), a test that takes about 30-35 minutes, has been shown to decrease plasma growth hormone at 36 weeks

PMA and elevate cortisol to levels indicative of stress (Kuhn, et al., 1991). Sweeney (1986, 1994) reported that neurologic assessment of preterm infants resulted in increased heart rate and blood pressure with skin mottling.

On the other hand, when parents observe the testing of their infant, an educational aspect of the assessment process is anticipatory guidance, i.e., teaching parents how to recognize and respond to their infant's signals and capabilities in order to individualize care such that stress is minimized and developmental progress maximized. For example, the Test of Infant Motor Performance (TIMP) has been shown to reflect the demands for movement caregivers place on infants in daily life interactions (Murney & Campbell, 1998) providing parents the opportunity to learn how their infant responds to demands of handling and movement. Research by Goldstein and Campbell (2008) showed that African-American mothers with low incomes learned about premature infant motor development from observation of a TIMP on their baby, and Dusing, Murray, and Stern (2008) showed that viewing a videotaped TIMP assessment was a method preferred by parents for their education in the NICU. Standing orders on all infants is not appropriate; the rationale for use of a test or measure should be clear and logical to the members of the NICU care team including parents. If the purpose of assessment is not to make a clinical decision regarding the infant's current or future care or to provide information for parent education or making referrals, use of a standardized assessment is unlikely to be appropriate or necessary.

### **Standardized Testing: Motor Performance**

The Test of Infant Motor Performance Screening Items (TIMPSI): The TIMPSI is a 10- to 20-minute screen of functional gross motor performance that can be administered to infants 34 weeks PMA through 17 weeks post-term CA to determine risk for delayed postural and selective

control of movement and need to complete the full Test of Infant Motor Performance (Campbell, 2005). The TIMPSI allows for efficiency in standardized testing and for assessment of infants unable to tolerate the complete TIMP (Campbell, 2005). Age standards for performance on the TIMPSI with comparison to expected performance on the full TIMP were collected in 2002-2004 on 990 infants in 13 centers across the U.S. (Campbell, Swanlund, Smith, Liao, & Zawacki, 2008). TIMPSI scores correctly predicted delayed versus non-delayed performance on the TIMP in 81% of infants which is judged as adequate to recommend use of the shorter TIMPSI for screening purposes. A limitation of the TIMPSI is that scores tend to underestimate TIMP performance at 34-35 weeks PMA, meaning more infants than necessary will be recommended to receive the full TIMP (Campbell, et al., 2008). Use of the TIMPSI requires knowledge of how to administer and score the TIMP.

Test of Infant Motor Performance (TIMP): The TIMP is a quantitative assessment of functional motor activity that is normed for infants 34 weeks PMA through 17 weeks CA (Campbell, Levy, Zawacki, & Liao, 2006). The 42-item test requires about 25-35 minutes to administer; 13 items are scored 0/1 from observation of the infant and 29 items are scored based on responses to handling using 4- to 7-point rating scales (Figures 5-7). Age standards are available in two-week age bands, i.e., 34-35 weeks PMA through 16-17 weeks CA, for the purpose of diagnosing delayed gross motor development. Use of the TIMP in clinical trials on neuro-developmental therapy in the NICU (Girolami & Campbell, 1994) and home physical therapy programs following hospital discharge (Lekschulchai & Cole, 2001) demonstrated its usefulness in both identifying infants for early physical therapy and as an outcome measure. A cutoff of -0.5 SD from the mean on the TIMP at 3 months CA has a sensitivity of 72%, specificity of 91%, positive predictive validity of 75%, and negative predictive validity of 91%

for prediction of motor development at 4-5 years of age (Kolobe, Bulanda, & Susman, 2004). The predictive validity of the TIMP is not adequate in infants less than 3 months CA, therefore, scores should only be used to determine current motor performance relative to the norms at ages under 3 months CA (Campbell, 2005).

[Insert Figures 5-7]

A limitation of the research on the TIMP is lack of evidence on how much change constitutes an effect larger than that expected based on maturation alone. It is known, however, that typically developing infants show significant change every two weeks (Campbell, 2005). Another limitation is the time required for testing which can be mitigated for many infants by use of the TIMPSI. Information on training workshops and rater reliability assessment for the TIMP is available from Infant Motor Performance Scales, LLC, at [www.thetimp.com](http://www.thetimp.com).

### **Standardized Testing: Neurologic Assessment**

Neurologic Assessment of the Preterm and Full Term Newborn Infant (NANI): One of the most frequently used assessments for neonates with identified neurological conditions such as perinatal brain injury or asphyxia is the Neurologic Assessment of the Preterm and Full Term Newborn Infant (Dubowitz, et al., 1999), also known as the Hammersmith Neonatal Neurological Examination. The NANI includes 34 items on habituation to repeated stimuli, reflexes, postural tone, and neurobehavioral organization and takes 10-15 minutes to complete. The NANI has been demonstrated to have validity for predicting at term-equivalent age high-risk infants who do not have neurological impairment but is less accurate in differentiating high-risk infants who will recover from a neurological brain injury from those who will have a lifelong disability (Dubowitz et al., 1984). Positive predictive validity of 64% was obtained based on use of abnormal results on the NANI at 40 weeks PMA to forecast one-year developmental outcome;

negative predictive validity of a normal or borderline performance at term was 93% with a sensitivity of 83% and specificity of 84%.

Formal age standards are not available for the NANI, however, Molteno, Grosz, Wallace, and Jones (1995) developed a method to sum deviant scores and reported improved predictive validity: sensitivity of 91%, specificity of 79%, positive predictive validity of 76%, and negative predictive validity of 92% to predict developmental outcome at one year. A limitation of the NANI is that it has not been shown to be responsive to change with intervention. No training requirements are prescribed by the authors of the scale.

### **Standardized Testing: Neurobehavioral Assessment**

Neurobehavioral assessments include items on multiple areas of development such as behavioral state and responsivity, orientation to visual and auditory stimulation, and postural tone and reflexes.

Neurobehavioral Assessment of the Preterm Infant (NAPI): The NAPI (Korner, Brown, Thom, & Constantinou, 2000) is one of the most carefully designed and evaluated tests for newborns from a psychometric perspective (Korner, Kraemer, Reade, Forrest, & Dimiceli, 1987; Majnemer & Snider, 2005; Snider, et al., 2005). The NAPI includes 28 items divided among 8 clusters: active tone and motor vigor, alertness and orientation, excitation proneness, inhibition proneness, scarf sign, popliteal angle, vestibular response, and vigor of crying. Testing can be completed in about 30 minutes. The value of the NAPI comes from its sensitivity to weekly change in the infant born preterm, but it has not been studied for sensitivity to intervention or prediction of long-term outcome. No training requirements are prescribed by the authors of the NAPI. The 2nd Edition of the NAPI is available from Child Development Media at <http://www.childdevelopmentmedia.com>.

Newborn Behavioral Observations (NBO) System: The NBO (Nugent, Keefer, Minear, Johnson, & Blanchard, 2007) is an individualized, infant-focused, family-centered observational assessment designed to engage parent interaction with their 0- to 3-month-old infant while the clinician helps them to understand their baby's temperament and competencies in different behavioral states (sleep, wakefulness, and crying). The goal of the NBO is to strengthen the relationship between the parents and child and to promote the development of a supportive family-professional relationship. An offshoot of the BNBAS (Brazelton & Nugent, 1995), the NBO is an 18-item system for recording the infant's capacity to habituate to repeated stimuli, regulate motor activity and behavioral state changes, respond to the stress of handling, orient to visual and auditory stimuli, and engage in social interaction (Figure 8). Observations can be accomplished in 5-10 minutes but the session can take up to an hour, depending on the depth of the discussion that ensues between the parent and professional. We list the NBO under assessment but it could just as easily appear under intervention because its goal is relationship-building between parent and infant and between parent and professional.

[Insert Figure 8]

Research is limited, but Sanders and Buckner (2006) reported that the NBO was a feasible and cost-effective intervention for use by nurses that was effective in enhancing mother-infant interaction. The design of the NBO assumes that the typical newborn infant is competent to regulate physiologic and motor activity and to demonstrate social interaction capabilities; however, the manual for the NBO indicates that it is appropriate for use with infants born preterm from about 36 weeks PMA on to help parents identify signs of stress when interacting with their baby (Nugent et al., 2007). The clinician is able to observe the parents' responses to and engagement with their infant and potentially identify relational difficulties that should be

addressed. When problems with behavioral organization are identified during the observation, a full BNBAS assessment is recommended. Although the BNBAS is used primarily to assess behavioral interactions, infants with at least three abnormal or asymmetrical reflexes on the BNBAS motor items have been shown to benefit from neuro-developmental therapy (NDT) in the NICU (Girolami & Campbell, 1994). Training and certification in use of the NBO and BNBAS are required; information is available at [www.brazelton-institute.com](http://www.brazelton-institute.com).

Noble and Boyd (2012) drew the following conclusions based on a systematic review of research on standardized tests for neonates and infants under 4 months CA (the NBO and the TIMPSI were not reviewed):

1. The GM assessment and the TIMP have the strongest psychometric properties.
2. The GM assessment, TIMP, and NAPI have the best utility for use in clinical settings; the TIMP is recommended as a good overall assessment.
3. The GM assessment provides the best prediction of future outcome.
4. The TIMP has the best validity for outcome assessment.

The clinical decision of which test to use requires 1) identification of the primary purpose of assessment, and 2) the relative validity of various assessments appropriate for the purpose of the measurement. To facilitate the clinician's decision-making process, Figure 9 summarizes the testing choices appropriate for various purposes in the NICU and first year after hospital discharge.

[Insert Figure 9]

### **Oral-motor Control and Feeding Assessment**

No area of care is more important in helping infants to a good start in life than feeding (Figure 4). Nutrition is critical to developmental progress and health, and the ability to

successfully feed their infant is viewed by all families as a hallmark of good parenting. Furthermore, the infant's ability to feed orally is an important criterion for hospital discharge. The primary goals of assessment and intervention are to facilitate the transition from tube to oral feeding and subsequently to oral-motor skills sufficient to support the needs for nutrition and hydration (Sheppard & Fletcher, 2007). As is true of other areas in the NICU Care Path, assessments of oral-motor behavior and feeding can be performed by a variety of professionals, including nurses, physical therapists, occupational therapists, and speech and language pathologists. As noted previously, nursery practice varies in this regard, depending on the presence of appropriately trained and available personnel. Our focus is on tests used by physical therapists with appropriate training and experience in this specialized area of NICU care.

Suck, swallow, and respiration must be coordinated for successful eating to take place and research has shown that the coordination and rhythm of each of these components may mature at different rates (Vice & Gewolb, 2008). Maturation of the suck-swallow-respiration cycle is highly individual with the last part of the synergy to mature being breathing; pharyngeal swallowing is mature at very early ages while synchronized nasal and thoracic respiratory efforts during bottle feeding increase significantly after 36 weeks PMA. Ability to begin oral feeding is, of course, affected by the infant's health status and oral-motor capacity. In a study of 147 healthy preterm infants, the age at initiation of bottle feeding varied from 29 to 40 weeks PMA and in infants born weighing < 1501 grams varied from 29-46 weeks PMA (Howe, Sheu, Hinojosa, Lin, & Holzman, 2007a).

In general, 34 weeks PMA is used as an estimation of when an infant born preterm is likely ready to begin oral consumption of feeds. Inhibition of respiration during swallowing is usually not developed prior to this age (Vice & Gewolb, 2008). In the NICU Care Path, we suggest

assessment of oral-motor function and feeding readiness between 32-34 weeks PMA with repeated assessment as indicated by progress in skills or outcomes of intervention.

Because of their high respiratory rates, coordination of respiration with swallowing is particularly difficult for infants with BPD who may be unable to reduce their respiratory rate to that needed for swallowing while still maintaining adequate oxygen saturation. These infants often require careful assessment of the various aspects of feeding behavior to minimize the risk of aspiration which is often clinically silent (da Costa & van der Schans, 2008). Infants suspected of or at risk for aspiration should have videofluoroscopic swallowing studies conducted by specialists (DeMatteo, Matovich, & Hjartarson, 2005). Research has also shown that infants born after 35 weeks GA whose oral-motor coordination is not sufficient within a week of beginning oral feeding have a high risk of poor developmental outcome at 18 months CA (Mizuno & Ueda, 2005). Above all, it is important to recognize that arbitrary age and weight criteria should not be the only indicators for oral feeding, making careful objective assessment of feeding readiness behaviors critical to successful feeding interventions (Howe, et al., 2007a).

Although the guidelines for feeding assessment in the care path are typical for infants who will be bottle fed, it is important to note that nurses have documented that rooting, areolar grasp, and repeated short sucking bursts at the breast can be seen as early as 29 weeks PMA in premature infants without serious illness (Nyqvist, 2008). Long sucking bursts and repeated swallowing were observed from 31 weeks and full breastfeeding to meet nutritional needs was achieved by a median age of 35 weeks PMA (between 32 and 38 weeks). It took infants 9-38 days to progress to full breastfeeding (median of 33 days). Thus early assessment of parent preference for breast versus bottle feeding is essential to the assessment and intervention

planning process in NICUs with a philosophy supporting breastfeeding. A lactation expert should be involved early when the mother seeks to breastfeed her infant.

Preterm Infant Breastfeeding Behaviour Scale (PIBBS): When breastfeeding is planned, the PIBBS can be used by either parents or professionals to assess the infant's oral-motor behavior during breastfeeding (Hedberg Nyqvist, Rubertsson, Ewald, & Sjoden, 1996; Nyquist, 2008). The test assesses rooting, areolar grasp, i.e., how much of the breast is in the infant's mouth, latching on and fixing to the breast, quality and frequency of sucking, longest sucking bursts, and swallowing behavior (5 items have 2-5 response levels; one item is quantitative). Because breastfeeding requires careful measurement of intake, knowledge of the reliability of various means for assessing milk intake is important (Scanlon, Alexander, Serdula, Davis, & Bowman, 2002). Simple observation is least reliable; the highest validity is obtained with use of doubly labeled water and test weighing pre- and post-feeding.

Several tests are available for assessment of oral-motor behaviors needed for bottle feeding, with varying degrees of evidence reported on reliability, validity for diagnosis and prediction, and responsiveness to change. Although a 2008 review of neonatal feeding assessments (Howe, Lin, Fu, Su, & Hsieh, 2008) found that none were completely satisfactory in terms of psychometric properties, including representativeness of samples studied in research, to be discussed here are the Neonatal Oral-Motor Assessment Scale (NOMAS) and the Nursing Child Assessment Feeding Scale (NCAFS). The NOMAS assesses the biomechanical and functional aspects of successful feeding on the part of the infant up to approximately 2 months of age (Palmer, Crowley & Blanco, 1993) while the NCAFS assesses the interaction between infant and caregiver and may be useful for long-term assessment through 36 months of age (Hodges, Houck, & Kindermann, 2007).

Neonatal Oral-Motor Assessment Scale (NOMAS): The NOMAS (Howe, Sheu, Hsieh & Hsieh, 2007b; Palmer, et al., 1993) is a 28-item checklist of feeding characteristics observed during non-nutritive sucking and the first two minutes of nutritive sucking in infants from birth up to 8 weeks CA. The NOMAS can be used during breastfeeding but is more difficult to score because infants must adjust their swallowing to variations in flow (da Costa & van der Schans, 2008). Results are classified as normal (scores 0-9), disorganized (arrhythmic jaw movements; difficulty coordinating sucking, swallowing and breathing; inability to slow rate for nutritive intake), or dysfunctional (abnormal jaw excursions or flaccid tongue). Case-Smith, Cooper, and Scala (1989) found that preterm infants with differences in feeding efficiency were reliably discriminated by the NOMAS. Characteristics associated with inefficient feeding scores on the NOMAS were lack of rhythm, disorganization in jaw and tongue movements, and pauses of more than 6 seconds (related to respiratory patterns). Howe and colleagues (2007b) reported convergent validity between NOMAS scores and transitional feeding rate (ratio of feeding intake to feeding duration) at 32 and 33 weeks PMA (correlations  $\geq 0.6$ ), but magnitude of the correlation scores was less strong at ages 34-35 weeks PMA and was unacceptably low at 36 weeks and older. The authors suggest that this is because numerous items lack response variability at later ages, i.e., all infants perform similarly, reducing the opportunity for discriminating among infants with different abilities. Factors not assessed by the NOMAS, such as endurance and state regulation, might play a role in individual differences at later developmental stages.

Predictive validity for outcome at 2 years of age was examined by Palmer and Heyman (1999), but findings were inconclusive. Similarly, test-retest reliability (da Costa and colleagues, 2008) was not deemed sufficient for use of the NOMAS for diagnostic purposes. The 1993

revision of the NOMAS is available online as a supplement to the article by da Costa and van der Schans (2008), and information on training courses and online rater reliability certification is available at <http://successfulfeeding.com/nomas.php> .

Nursing Child Assessment Feeding Scale (NCAFS): The NCAFS (Sumner & Spietz, 1994) is a 76-item checklist of observed behaviors on the part of the parent (50 items) and the child (26 items) during a feeding and was designed by Kathryn Barnard as part of a set of tools to assess parent-child interaction for use with infants through 12 months of age. This test is unique in assessing interactions between the parent and infant. Areas assessed include: positioning, pacing of feeding in response to infant behaviors, and social interaction between the infant and parent, and behavioral state and social responsivity of the infant. Dichotomous scores for each item are summed to reflect 6 areas of functioning: 1) sensitivity to cues, 2) response to distress, 3) social-emotional growth fostering and 4) cognitive growth fostering on the part of the parent, and 5) clarity of cues and 6) responsiveness to the parent on the part of the child. This test is, therefore, unique in being a measure of co-occupation of parent and child. The NCAFS does not assess the efficiency of feeding per se but does assess parent-child interaction during feeding and, therefore, is useful with mothers when concerns exist regarding basic parenting skills (Figure 9). Among mothers and infants with brain injury, those dyads who received intervention from a public health nurse demonstrated better interaction scores on the NCAFS at 6 months CA compared with a control group who did not receive the intervention (Badr, Garg, & Kamath, 2006). A limitation of the test is the need to observe an actual feeding session with a parent. Information on training and purchase of scales is available at <http://www.ncast.org/>.

### **NICU Care Path: Observation & Assessment: Sensory Assessment**

This section will address the components of a limited sensory assessment from the Infant Care Path for Physical Therapy in the NICU (Campbell, 2013). Assessment of the infant's physiological responses to sensory stimulation is important in order to respond sensitively to the infant's readiness to engage in social interaction and prepare for discharge to the home environment (Glass, 2005). In using assessment results to plan intervention, Glass suggests two guiding principles: 1) stimulation should begin with the most mature senses, and 2) the optimal form of stimulation should resemble the sources naturally available to the fetus and infant, i.e., those that come from the mother. The earliest maturing systems are the tactile, vestibular, and gustatory-olfactory; later maturing are the auditory and visual systems. Testing can occur at any time during the infant's NICU stay, depending on the indications for assessment (Figure 4).

A NIDCAP assessment is an ideal way of assessing the infant's responsiveness and ability to tolerate tactile and vestibular inputs. The report of the infant's responses during baseline, routine care, and recovery provides information for supporting the infant's development of sensory systems. Identification of findings such as tactile defensiveness or stress in response to routine care are important as well as observation of behaviors that represent the infant actively seeking sensory engagement with the environment (Vergara and Bigsby, 2004) because many aspects of sensorimotor development are experience-dependent (Greenough, Black & Wallace, 1987). Infants vary in their sensory thresholds, reactivity, ability to respond, and ability to ignore irrelevant inputs; for infants in the NICU, degree of maturity and illness-related factors are also determinants of responsiveness. Vergara and Bigsby (2004) suggest that assessment of sensory systems should include information on modality, intensity needed to reach response threshold, length of stimulus exposure needed to elicit a response, and location where stimulus is received. Based on assessment results, interventions are often aimed at: 1) protection of the infant from

excessive handling, such as clustered care, 2) provision of graded sensory inputs to promote sensory development when infants demonstrate that they seek stimulation, or 3) desensitization to sensory stimuli, such as graded oral stimulation. As Glass emphasizes, minimal handling protocols have a place in NICU practice but are not the end point (2005). The infant's tolerance for handling and movement should be progressed in preparation for discharge and strategies identified for infants with abnormal reactivity to sensory stimuli.

An important consideration in infants born preterm is that the uterus no longer confines body position and movement is affected by gravity. Vestibular, proprioceptive, and tactile inputs, therefore, are experienced differently. Based on assessment of the infant's reactions to changing positions in space from a NIDCAP assessment or a TIMP, interventions like positioning supports, rocking or oscillating surfaces, waterbeds, hammocks, and hydrotherapy might be considered to provide sensory experiences that promote development (Glass, 2005; Korner, Guilleminault, Van den Hoed, & Baldwin, 1978; Sweeney, 1983).

The primary olfactory tracts are myelinated before birth and infants can reliably respond to odors by 28-32 weeks PMA (Glass, 2005). Full term infants can express their preferences for odors associated with their mother. Taste receptors are also present early in gestation and preterm infants 30-36 weeks PMA show characteristic facial expressions in response to bitter and sour flavors and will suck more in response to glucose solutions than to water. Although we are unaware of any standardized protocols for assessment of the olfactory and gustatory senses in the neonate it is important to consider the milieu of tastes and smells that characterize the extrauterine environment. Chemicals, drugs, plastic tubes and nipples, and non-maternally-derived milk are all examples of sensory inputs. Moreover, the infant no longer experiences

sensory stimulation from the amniotic fluid environment which has more than 120 compounds as early as 18 weeks GA (Glass, 2005).

Visual and Auditory Assessment: Because of the vulnerability of preterm infants to auditory and visual impairments, these areas are specifically mentioned in the NICU Care Path (Figure 4). Assessment by hearing and ophthalmological professionals is routinely done in the NICU before discharge. Diagnostic testing includes the auditory brainstem response (ABR) or otoacoustic emissions (OAE) assessment for hearing (Hall, 2000) and ophthalmologic visualization of the retina to evaluate the presence of ROP or other disorders (Graven, 2004).

The role of the physical therapist in assessment of these areas lies in defining the infant's functional abilities within the context of the infant's level of maturation and the nursery environment's challenges to the provision of natural inputs for which an infant's nervous system is prepared to respond.

A number of the measurement tools already described contain items for the assessment of visual and auditory orientation to stimulation from which the infant's capabilities in these areas can be derived; added to the interpretation of the findings of this testing is the context in which the infant receives routine stimulation in their bed space and room, and the general environmental supports for protection from inappropriate sensory stimulation and for engaging in social interaction appropriate for their age and level of maturity.

Human speech is considered the most important auditory input for preterm infants in the NICU (Graven, 2000; Glass, 2005). NICU guidelines suggest that natural inputs are preferred over recorded messages, and most preferred of all is regular family presence engaging in live interaction with their infant at the bedside to provide the inputs typical of those the child will receive at home after discharge (Graven, 2000). Research by Caskey and colleagues (2011)

showed that even infants as young as 32 weeks PMA vocalize on average 7 times per hour, and parent talking during NICU visits increases infant responding to parent vocalization. Tests like the NBO, BNBAS and TIMP provide opportunities for parents to participate in presenting speech stimuli to encourage their infants' orientation to sound, and parents are frequently surprised to see that their infant will turn to find the source of their voice. Thus testing behavioral response to speech presents an important opportunity to engage the family with their infant and to help them to understand the infant's capabilities to respond to stimulation by localizing and orienting to natural sounds and vocalizing in response to parent conversation (turn taking). Orientation to soft sounds can typically be elicited by 28-34 weeks PMA, but it is important to realize that auditory thresholds decrease considerably from 25 weeks GA to term (Glass, 2005).

Unlike the auditory sense which responds to stimulation in utero, development of the visual system during the last trimester of gestation does not require stimulation from light. Based on research with animal models, Graven (2004) suggests that early visual stimulation of the preterm infant may actually be harmful by interfering with development of the auditory system. Assessment should include analysis of whether the infant's caregiving routine provides adequate time in rapid eye movement (REM) sleep, a form of endogenous stimulation that is needed for development of the visual nervous system. Another area for assessment is whether the infant is provided protection from direct light to the eye and even to the chest because shielding of the chest from exposure to phototherapy light has been shown to reduce the occurrence of PDA (Glass, 2005). The faces of the parents are the most important form of visual stimulation during the late preterm period when infants prefer high contrast and black and white images. The TIMP, the NBO, and several other tests have items that assess the infant's ability to focus on and

track visual stimuli. Use of family photographs with high contrast images can be used to demonstrate to parents the early preferences of infants and the most appropriate distance for presenting visual stimuli.

Integration of the results from assessment of all sensory systems is recommended in determining the appropriateness of interventions such as physical therapy, SSC, and the massage and sensory stimulation program designed by White-Traut and colleagues (White-Traut, et al., 2002), each of which provides multi-modal stimulation which could be overly stressful to some infants. Limitations of assessment of sensory systems are the lack of standardized tools with normative standards for performance of infants born preterm.

### **Summary**

Multiple decisions must be made in the NICU regarding the why and when of assessment. The physical therapist must collaborate with all members of the health care team and the parents to plan assessment as the basis for developing an intervention plan, and assessment needs change with the infant's physiologic stability, maturity, and health conditions. All data obtained from formal and informal assessment need to be synthesized in the decision making process rather than relying on any single result from testing, and assessment results should be considered to be a part of the family education plan.

### **Declaration of interest**

Suzann K. Campbell is managing member of Infant Motor Performance Scales, LLC (IMPS), the publisher of the Test of Infant Motor Performance, the Test of Infant Motor Performance Screening Items, and the NICU Care Path.

## Illustration Legends

Fig. 3.1. Diffusion tensor images of brains of 12-month-old infants with perinatal IVH and BPD but different developmental outcomes. Infant in A was born at 23 weeks GA and had a TIMP score at the borderline for delay at 4 months PMA but normal motor outcome at 12 months (walks with one hand held). Infant in B was born at 24 weeks GA, TIMP score showed severe delay at 4 months PMA and has CP at 12 months (GMFCS level V, cannot roll or sit alone). Arrows in A show symmetrical and well-developed posterior limbs of the internal capsule. Brain in B shows asymmetrical development with observable posterior limb of the internal capsule on the left (right side of image) but indistinguishable descending motor paths on the right side of the brain.

Fig. 3.2. Elements of the Observation & Assessment section of the NICU Care Path for Observation-based Assessment.

Fig. 3.3. Elements of the Observation & Assessment section of the NICU Care Path for Limited Hands-on Assessment.

Fig. 3.4. Elements of the Observation & Assessment section of the NICU Care Path for Full Hands-on Standardized Testing, Oral-motor Control/Feeding Assessment, and Sensory Assessment.

Fig. 3.5. TIMP assessment by physical therapist of infant Eryn born at 25 weeks GA, now CA 1 month. Response to Item 22, head held in midline with visual stimulation, is a 4 as Eryn was able

to maintain the head in midline for more than 15 seconds without hands being held. Photo courtesy of Yvette Blanchard.

Fig. 3.6. TIMP assessment by physical therapist of infant Eryn born at 25 weeks GA, now CA 1 month. Response to Item 27, hip and knee flexion, is a 2 as Eryn was able to hold her legs up in the air and kick after the therapist released her legs from a flexed position, but could not sustain antigravity kicking for the required minimum of 5 seconds to achieve a score of 3. Photo courtesy of Yvette Blanchard.

Fig. 3.7. TIMP assessment by physical therapist of infant Eryn born at 25 weeks GA, now CA 1 month. Response to Item 31, rolling toward the left elicited from the arms, is a 3 as Eryn was able to actively use trunk and legs to turn toward the left (A) after the right arm was directed across the body toward the left shoulder and reached sidelying (B) without continuing into the prone position. Photo courtesy of Yvette Blanchard.

Fig. 3.8. Relationship-building NBO assessment by physical therapist with mother and infant Eryn born at 25 weeks GA, now CA 1 month. Therapist instructs mother to call infant by her name and they discuss the infant's behavioral response. Photo courtesy of Yvette Blanchard.

Fig. 3.9. Decision tree for selection of standardized assessments in NICU and post-hospital care.

Table 3.1. Apgar score definitions

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