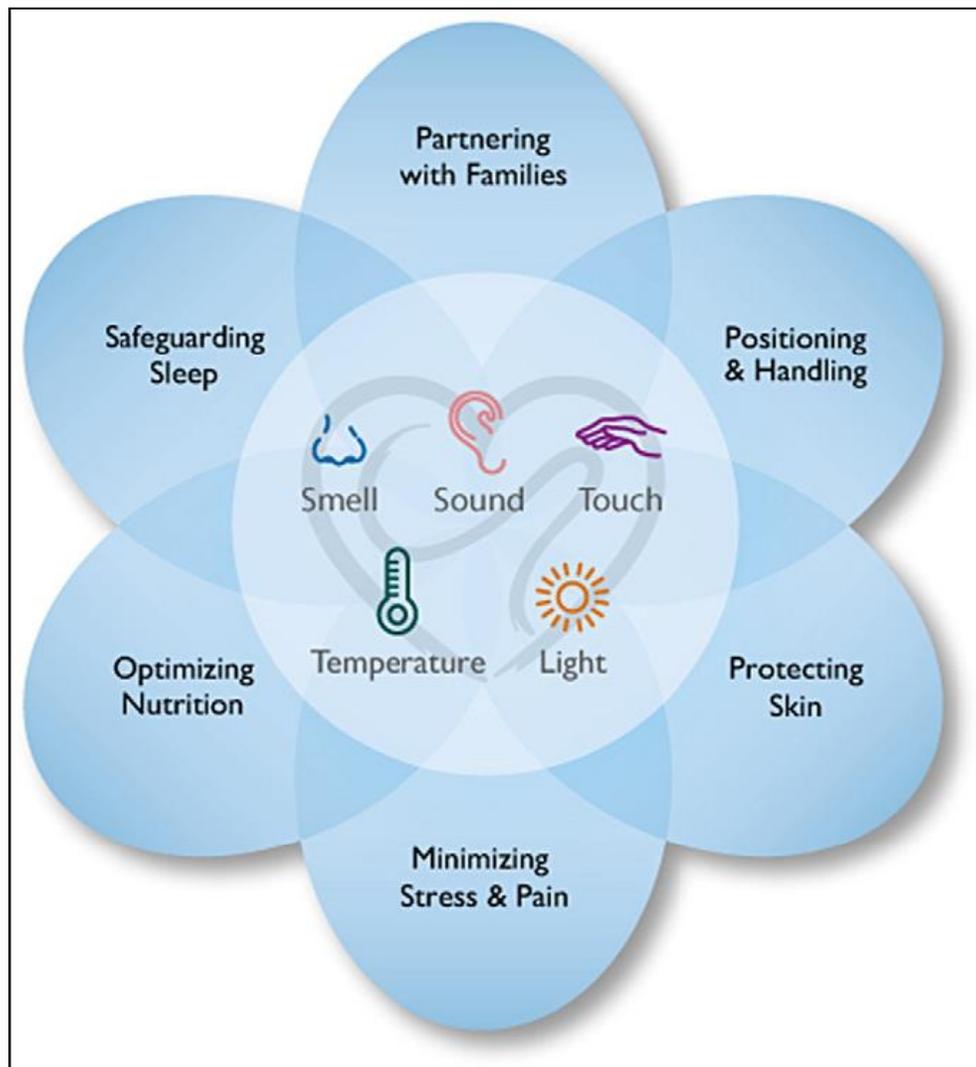


# Neonatal Neuro-protective Best Practice Guidelines

NICU Brain Sensitive Care Committee  
Swedish Medical Center



Adapted with permission from Altimier & Phillips. 2013. Neonatal Integrative Developmental Care Model: Seven Neuroprotective Core Measures for Family-Centered Developmental Care. NAINR (13) 9-22

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## Introduction: Neuro-protective Best Practice Guidelines

The third trimester of gestation is a period of intense growth and development for the fetal central nervous system. Preterm birth disrupts this delicate process and forces fetal development to continue within the potentially noxious extrauterine environment of the NICU. Parents and professional caregivers can work together to minimize the negative impact of the NICU experience, hopefully reducing subsequent impairment and disability.

The newborn brain is capable of making both temporary and permanent changes to the strength and number of its synaptic neuronal connections. These adaptations are based upon sensory input from different stimuli, environmental factors and experiences. This adaptive capacity is known as neuroplasticity and peaks early in life because of the rapid brain growth during that time frame. Neuroplasticity can be positive or negative. Because the brain is actively being “hard wired” throughout the infant’s NICU stay, both functional and dysfunctional synapses are being formed or deleted (“pruned”) based upon the infant’s unique experiences.

Neuro-protective interventions are strategies intended to support the developing brain, facilitating normal development and preventing disability. In the case of neuronal injury, neuro-protective interventions are intended to help the brain reduce neuronal cell death and permit healing by fostering functional synaptic connections and pathways.

Perhaps the most important neuro-protective intervention is provided not by professional caregivers, but by involved parents. Family is the single “constant” in an infant’s life, providing a unique emotional and nurturing connection that will endure over the course of time. It has been estimated that only about 5% of touch in the NICU is intended to comfort. Parents are in the best position to offer sustained nurturing touch and skin-to-skin care to offset some of the negative handling necessary for survival.

Neuro-protective care is organized by the seven core measures identified by Altimier & Phillips (2013)\*, and their model has been adapted for our use with the permission of the authors:

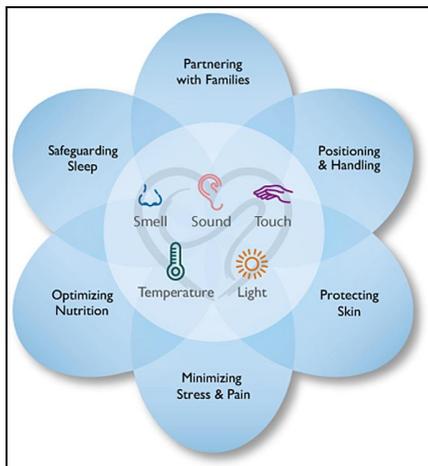
- |                               |                             |
|-------------------------------|-----------------------------|
| #1 Safeguarding Sleep         | #5 Nutrition                |
| #2 Positioning and Handling   | #6 Partnering with Families |
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Neuro-protective care, also known as “brain sensitive care”, can be very challenging. It is inconvenient at times and may not always permit caregiving to be provided in a routine or efficient manner. However, when combined with evidenced based medical and nursing care, neuro-protective care is the best way to promote optimal neurodevelopmental outcomes for our patients. For this reason, neuro-protective care is our standard of care.

*\*Altimier & Phillips. 2013. Neonatal Integrative Developmental Care Model: Seven Neuroprotective Core Measures for Family-Centered Developmental Care. Neonatal and Infant Reviews. (13) 9-22*

# Neuro-protective Best Practice Guidelines Part 1: Safeguarding Sleep

***Goal is assess infant sleep-wake state before caregiving, and to protect prolonged periods of uninterrupted sleep whenever possible***



## Background:

Providing for **adequate rest and sleep** may be the single most important contribution that NICU caregivers can make to a preterm infant's long-term outcome. At 32 weeks, the fetus within the protection of the womb will spend 90-95% of the time asleep. By term, sleep requirements decrease slightly in duration (85-90% of the time) but not in importance. Sleep plays a critical role in early neurosensory development, impacts memory and subsequent learning, and preserves brain plasticity. Sleep deprivation reduces both brain size and plasticity, and is associated with enduring consequences for learning, behavior, and function.

Like adults, babies have various stages and cycles of sleep. Sleep patterns begin to form in the last months of pregnancy, with predominantly active (rapid eye movement or "REM") sleep initially, followed by longer periods of quiet (non-REM) sleep. Preterm infants have shorter sleep cycles of 30-40 minutes with 80% of sleep being active/REM sleep. As a preterm infant matures (by approximately 36 weeks) sleep cycles average between 50-60 minutes with time divided more evenly between active and quiet sleep. Term infants begin and end their sleep cycle in active sleep and have longer periods of awake, alert time.

**Both REM and non-REM sleep are crucial during fetal and neonatal life for the development of neurosensory function within the central nervous system (CNS), which processes sensory information from the outside world.** Neurosensory development depends upon appropriate stimuli from both internal and external sources. Endogenous stimulation occurs only during REM sleep, something that a fetus at 32 weeks would be engaged in for the vast majority of the time. Once these sensory systems are formed using endogenous input from the baby's own CNS, they are ready for exogenous stimuli from the external world.

Fetal development of the sensory system occurs in a specific sequence: tactile (touch), vestibular (proprioception), olfactory (smell), gustatory (taste), auditory (hearing), and visual (sight). Disrupting this predetermined sequence of sensory development can interfere with later function. **Since the visual system matures towards the end of the normal gestation, preterm infants are not ready for light or any kind of visual experience prior to 36-40 weeks gestation.** Protecting sleep cycles, especially REM sleep, is absolutely essential for optimal neurosensory and visual development. Understanding the various newborn states of consciousness helps to guide both professional caregivers and parents.

## Newborn States and Caregiver Considerations

	State	Baby's Behavior	Caregiver Considerations
1	Deep/Quiet or Non-REM Sleep	<ul style="list-style-type: none"> <li>•No movement, only occasional jerks</li> <li>•Eyes closed, no eye movements</li> <li>•Startles with delay, suppresses quickly</li> <li>•Regular breathing</li> <li>•Lowest oxygen consumption</li> <li>•Low resting HR in some term infants</li> </ul>	<ul style="list-style-type: none"> <li>•Difficult or impossible to arouse</li> <li>•No interest in feeding at this time</li> <li>•Not receptive to social interaction</li> </ul>
2	Light/Active or REM Sleep	<ul style="list-style-type: none"> <li>•Random movements and startles</li> <li>•Eyes closed, rapid eye movements</li> <li>•Irregular respirations</li> <li>•Higher oxygen consumption</li> </ul>	<ul style="list-style-type: none"> <li>•Term infants start and finish sleep cycles in active sleep</li> <li>•Preterms react more to stimuli at this time than term infants</li> <li>•May fuss briefly, and be awakened before truly awake and ready to eat</li> <li>•Lower, more variable O2 saturations</li> </ul>
3	Drowsiness	<ul style="list-style-type: none"> <li>•Eyes open (dazed) or closed</li> <li>•Respirations more rapid and shallow</li> <li>•Intermittent startles</li> <li>•Slow response to sensory stimulation</li> <li>•Smooth state change after stimulation</li> </ul>	<ul style="list-style-type: none"> <li>•May awake further or may return to sleep (if left alone)</li> <li>•Talking quietly to infant may arouse infant to a quiet alert state</li> </ul>
4	Quiet Alert	<ul style="list-style-type: none"> <li>•Eyes open wide, face is bright</li> <li>•Focused attention</li> <li>•Body is quiet with minimal movement</li> </ul>	<ul style="list-style-type: none"> <li>•Best state for learning because infant focuses all attention on visual, auditory, tactile or sucking stimuli</li> <li>•Best for interaction with parents</li> </ul>
5	Active Alert	<ul style="list-style-type: none"> <li>•Eyes open and alert</li> <li>•Actively moving extremities</li> <li>•Reactive to external stimuli</li> <li>•Irregular respirations</li> <li>•May or may not be fussy</li> </ul>	<ul style="list-style-type: none"> <li>•Infant has increased sensitivity to internal (hungry, tired) and external (wet, handling, noise) stimuli</li> <li>•Unable to fully attend to caregiver or environment because of increased sensitivity and motor activity</li> </ul>
6	Crying	<ul style="list-style-type: none"> <li>•Cries, possibly intense</li> <li>•May be difficult to console</li> <li>•Respirations rapid, shallow, irregular</li> </ul>	<ul style="list-style-type: none"> <li>•Indicates that individual tolerance limits have been met or exceeded</li> <li>•Not receptive to learning</li> </ul>

Infants in the NICU often spend a lot of time trying to sleep in spite of bright lighting, noise, and unpredictable handling. Sleep allows infants to enter an unresponsive state of “protective apathy”, where they can maintain physiologic homeostasis, conserve energy, and grow. Infants hospitalized for extended periods may show classic signs of “hospitalitis” (asocial behavior, touch aversion and failure to thrive), as well as sleep and maternal deprivation. Since unrestricted maternal access in the womb is no longer an option for prematurely born infants, skin-to-skin care provides an unrivaled antidote. **Extended parent contact, reduced stress, and adequate sleep can be promoted by skin-to-skin care, as soon as possible, often, and as long as the infant remains stable.** When skin-to-skin is not an option, parents can provide gentle containment during sleep periods (“hand hugs”). Cuddlers can be used to hold swaddled infants whose parents are either uninvolved or unable to visit frequently.

## What can we do in the NICU?

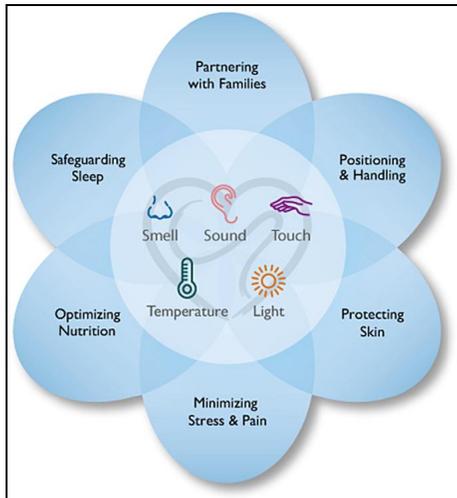
Caregiving based upon an infant's sleep-wake states rather than scheduled "care times" provides adequate rest and sleep for baby and is one of the most important contributions made towards positive long-term outcomes. To facilitate sleep and reduce unnecessary procedural handling, the "*Brain-Sensitive Caregiving*" *Vital Signs Order* has been developed.

### Vital Signs and Clustering of Care if Stable 24 Hours After Admission:

- **Vital signs** should be done twice per shift minimum (approximately every 6 hours), preferably when infant is awake. A full assessment, vital signs, diaper change, repositioning, oximeter site change, CPAP/NAVA break, feeding, and any indicated interventions can be done at this time.
- VS and assessment frequency is modified according to caregiver's professional judgment. If a VS or assessment is not within defined limits (WDL), increased "events", or rising oxygen requirements, reassess more often as needed
- "**Hourly visual rounding**" without awakening a sleeping infant, or when an infant is awake and appears uncomfortable (crying, restless, increased HR, etc.). Check for wet diapers, evidence of pain, need for repositioning, conditions of IV sites, and parent needs.
- **Feedings are given at scheduled intervals (for example, every 3 hours)**
- RT and nursing collaborate on frequency and scheduling of CPAP/NAVA breaks
- Physicians, ARNP's and specialty providers assess infants per their schedules

**In summary**, best practice neuroprotective strategies to support sleep include:

- Protect sleep cycles, and especially REM sleep
- Use spontaneous awake periods for routine caregiving whenever possible
- Allow rest periods of at least 60 minutes to complete a normal sleep cycle
- Promote a quiet environment without loud noises to ensure uninterrupted sleep
- If necessary to wake up infant, approach using a soft voice followed by a gentle touch
- Protect eyes from bright lighting at all times and avoid use of overhead spot lights
- Maintain dim ambient lighting between "cares"
- Use narcotics and sedatives carefully, since both interfere with REM and non-REM sleep
- Facilitate prolonged skin-to-skin to promote normal sleep patterns



## Neuro-protective Best Practice Guidelines Part 2A: Positioning for Success

***Goal is to eliminate or reduce positional deformities by maintaining infants in a midline, flexed, contained, and comfortable position***

### Background:

When born prematurely or critically ill, gravity forces weak infants into an uncomfortable flat and extended resting posture, with the extremities abducted and externally rotated. The baby's head falls asymmetrically to one side, usually the right side, and causes uneven flattening of the skull. Over time, neuronal connections are reinforced that support these abnormal postures as a baseline. Developmental delays and permanent disabilities may ensue. In utero, the fetus kicks and moves freely against boundaries that provide constant soma-esthetic (touch), kinesthetic (movement), and proprioceptive (position) feedback.

### What can we do in the NICU?

- Aim for containment, rather than restraint
- Flexible enough to allow spontaneous movement, firm enough to limit excessive activity
- When possible, hands should be able to move towards face/mouth for self-comfort

### What neuro-protective strategies can we use?

**IVH Prevention Bundle:** for infants <30 weeks GA for the first 72 hours of life:

- Maintain neutral head position with head of bed up to the highest position
- No daily weights until day 4
- No holding or kangaroo care, but encourage parents to provide containment ("hand hugs") during this time as tolerated

**Positioning** to support optimal alignment and containment should be provided for all infants. Consider utilizing this "positioning checklist" before leaving the bedside:

- Shoulders softly rounded forward?
- Hands towards midline, able to touch face/mouth if possible for self-comforting?
- Hips aligned and pelvis tucked?
- Knees, ankles, feet aligned and softly flexed?
- Neck neutral or slightly flexed, no hyperextension?
- Head midline, or turned slightly right or left? Avoid turning more than 45° to either side

### Prone positioning:

- Select appropriate size. If infant is between sizes, use smaller size to prevent abduction of legs and shoulders, and to allow shoulders and hips to flex around the positioner
- Bottom of prone positioner should end around the umbilicus
- Avoid turning head to a full 90° angle by allowing it to rest slightly off edge of positioner

**Reposition** if infant appears restless, uncomfortable, and/or during “hands on care”. Teach parents how to position properly and solicit their input on baby’s comfort and preferences.

**Supportive containment with positioning aids** to approximate the defined boundaries the fetus experiences in utero. These aids are selected based upon individual infant needs:

- **Bedding “nest”** with horseshoe rolls and envelopes
- **“Freddy Frogs”**: Used to maintain desired position, especially the head. Remember these weigh about 1 pound each and are extremely heavy in relation to an infant’s weight. **Do Not** allow them to rest on infant.
- **Dandle Roos**: Stocked only on 6 South and used for less mature infants
  - XS for <1000 grams, S for 1000-1800 grams
- **Dandle Wraps**: Stocked on all three floors, and used for more mature infants
  - S for 1000-1800 grams, M for 1800-2500 grams, L for >2500 grams

The lower pouch of the Roo/Wrap promotes flexion of hips, legs and ankles while allowing infant to kick and move freely against the stretchy fabric. This is especially important since tight swaddling has been associated with acquired hip dysplasia.
- **Reminder: Servo control temp probe must never be covered by DandleRoo/Wrap fabric, and vascular access sites must be visible at all times**

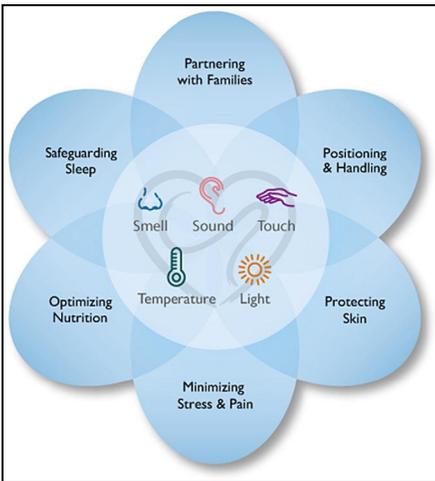
*Please put Dandle Roos & Wraps in bright green linen hamper when soiled!!!*

### WHY?

Therapeutic positioning promotes improved rest and growth, and normalizes neurobehavioral organization. Infants who are comfortably contained are more likely to be calmer, require less medication, and gain weight more rapidly.

# Neuro-protective Best Practice Guidelines Part 2B: Handling with Care

***Goal is to maintain autonomic stability throughout positioning changes and caregiving activities, as well as during periods of rest and sleep***



## Background:

Moving infants quickly may be efficient for caregivers, but is very stressful for infants and often leads to autonomic instability (i.e. apnea/bradycardia/desaturation “events”). Rapid and unsupported movement (such as the “premie flip”) triggers sensory distress and excessive motor activity, as infants attempt to stabilize themselves to a fixed surface during the vestibular disturbance. This is similar to a dizzy adult reaching for a wall to maintain balance, or grabbing the guardrails on a carnival ride. Infants may remain disorganized, nauseated, and dizzy for up to 30 minutes following a “premie flip”, and more “events” are likely to occur later in a delayed response to handling.

## What can we do in the NICU?

Minimize stress and support autonomic stability during rest and caregiving interventions by utilizing careful handling and containment techniques. Consider using a second person to assist with position changes for intubated infants. Whenever possible, avoid disturbing infants during sleep and try to use spontaneous awake periods for caregiving. If necessary to awaken infant, start with a soft voice followed by gentle touch.

“**Containment**”, also known as a “facilitated tuck” or “hand hugs”, refers to the parent’s or caregiver’s hands being used to maintain an infant in a flexed midline position. This technique provides support for the infant and the opportunity to control their own body. Infants who are not adequately “contained” demonstrate more physiologic instability, agitation, and stress cues. Containment is indicated for all handling, caregiving and procedures. When an additional caregiver is unavailable to assist, use Dandewraps/Roos or blanket swaddles.

Intracranial pressure (ICP) is lowest when the **head is midline** and the **HOB is elevated**. Caution should be taken when changing diapers to prevent sudden fluctuations in ICP when the feet are raised above the head. This is important during the first several days of life for IVH prevention, but should also be avoided throughout hospitalization to minimize GI reflux.

- Avoid raising feet above head whenever possible
- Slide new diaper under infant and lift slightly at hips to remove old diaper
- To clean diaper area, lift knees to the chest while supporting the back and buttocks
- Consider placing the infant on one side to clean buttocks and diaper area.

Miscellaneous strategies to prevent increased ICP include

- Suction (ETT, deep nasal/oral) only when clinically indicated
- Minimize pain and stress
- Flush and draw from umbilical lines very slowly (1 ml over 30-45 seconds)

**For weights or bathing** provide light swaddling. Swaddle bathing is similar to immersion bathing, but the infant is flexed and swaddled in a lightweight blanket prior to placement in the tub. The face is gently cleaned first with plain water. Each extremity is then individually unwrapped, cleansed and rinsed, and replaced in the swaddle. The stomach, back and genitals are cleaned and rinsed in a similar manner. The infant remains swaddled for shampoo and rinse, then removed from the swaddle, and the wet blanket left in the tub. The infant is placed in a warm blanket and dried as usual. Compared with routine bathing, infants who were swaddle bathed showed fewer stress cues, as well as decreased crying and agitation.

*Reminder:*

*When done with bath, wet blankets should be thoroughly wrung out before placing in laundry. Wet linen is very heavy for our Environmental Services staff to lift, and more expensive since we are charged by weight for laundry service*

## Neuro-protective Best Practice Guidelines Part 3: Protecting Skin

***Goal is to protect newborn skin integrity and to provide opportunities for nurturing input through this vital sensory organ.***



### **Background:**

The skin is the largest organ of the body, and makes up about 13% of weight in a preterm, versus 6-10% of adult's weight. Skin integrity is essential to survival and any break provides a portal of entry for infection. The skin is one of five sensory organs designed to help protect the body by relaying information about the environment via sensory neurons to the brain. Sensory receptors (nociceptors) embedded at the dermal layer detect and transmit messages about touch, pain, pressure, and temperature. Touch is the first of the senses to develop early in fetal life, with sensory neurons found around the mouth and face by week 7, and covering the entire body by week 20. The fetus (and preterm infant) has more sensory nerve endings than the adult, which are closer to the surface of the skin. The infant's hands, feet, and mouth are especially sensitive to touch due to the density of sensory nerve fibers that send constant messages to the cerebral cortex.

### **The skin is comprised of several distinct layers:**

- A. The *epidermis* (outer layer) acts as a protective barrier against the environment and assists with temperature management. Term infants have 10-20 protective epidermal layers, but the epidermis becomes less keratinized and thinner as GA decreases. Preterms < 30 weeks GA may only have 2-3 layers, while those < 25 weeks have negligible epidermal barriers. Thus, they are vulnerable to absorption of toxins, and prone to insensible heat and transepidermal water loss (TEWL).
- B. The *dermis* (middle layer) is made up of collagen fibers that provide strength and elasticity, and contains both blood vessels and nerves. Thin fibrils connect the dermis and epidermis. Because preterm infants have fewer fibrils connecting the skin layers, they are susceptible to "epidermal stripping" with tape removal. Epidermal stripping occurs when the bond between tape and skin is stronger than the bond between epidermal and dermal layers, and the epidermal layer is accidentally removed with the tape.
- C. The bottom layer of skin is *fatty connective tissue* that provides shock absorption and insulation. Fat stores accumulate during the third trimester, so most preterm infants have minimal "padding" to maintain heat or protect from the discomfort of hard surfaces.

## What can we do in the NICU?

- Role model use of gentle but firm touch, which is tolerated better than stroking
- Use care to minimize noxious touch to the hands, feet, and mouth.
- Skin to skin care (KC) provides an excellent means of offering safe, nurturing touch
- Apply and remove adhesives cautiously, as these are the primary source of skin breakdown in the NICU

### Protective skin strategies include:

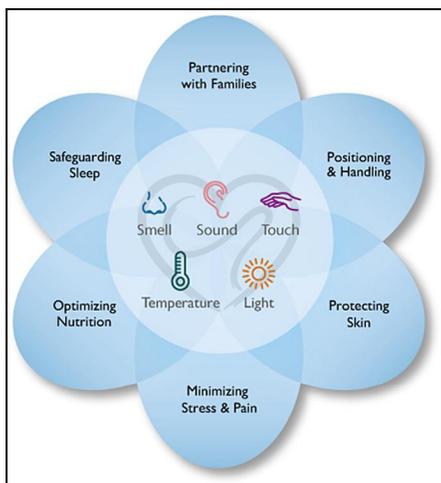
- Provide humidity for the first two weeks of life to reduce TEWL for ELBW infants (refer to *SMC Humidification of Incubators*)
- Utilize *SMC Skin Care: Premature infant < 26 Weeks* to prevent and treat skin breakdown
- Reduce unnecessary exposure to topical products, and rinse off with water if possible.
- Avoid skin breakdown from common sources such as adhesive removal, thermal injury, abrasion/friction, diaper dermatitis, CPAP devices, pressure ulcers, and/or infection
- Consider applying Tegaderm to clean, dry skin at risk for abrasion/friction
- Assess IV and PICC sites hourly for evidence of phlebitis and/or infiltration
- Change diapers Q 2-4 hours during spontaneous awake periods to avoid diaper rash
- Utilize *SMC Perineal Skin Care/Diaper Dermatitis Management Guideline for Neonates*
- Handle preterms gently and provide soft bedding to compensate for lack of “padding”, but remind parents that soft bedding and “nests” are safe only in hospital setting
- Refer to *Neonatal Skin Care: Evidence Based Clinical Practice Guideline, 3<sup>rd</sup> Edition*. (2013, Association of Women’s Health, Obstetric and Neonatal Nurses) for further details

### Avoid epidermal stripping during tape removal:

- Minimize the use of tape, adhesive products, and bonding agents such as Mastisol
- Consider Duoderm “platforms” and “key holes” if frequent re-taping is required, apply tape directly to platform rather than to skin. Since Duoderm removal can damage skin in a manner similar to tape removal, leave in place until it begins to work itself off
- Use blue silicone tape whenever possible, but not for securing critical lines
- Tegaderm can be stretched to reduce adherence
- Whenever possible, leave adhesives in place until adhesive bond starts to lessen
- Remove tape using saline pledgets or water-soaked cotton balls
- If re-taping is not needed, use Vaseline to loosen tape
- To remove tape, hold surrounding skin in place and slowly pull tape at a very low angle, parallel to the skin surface rather than straight up at a 90° angle
- Continuously moisten adhesive-skin interface with either water, saline, or Vaseline
- Use silicone-based, alcohol-free, adhesive removers when available, as they are the safest adhesive removers currently available for the neonatal population

## Neuro-protective Best Practice Guidelines Part 4A: Minimizing Stress

***Goal is to reduce stress whenever possible,  
and to promote both self-regulation and  
neurodevelopmental organization***



### Background:

Much of brain development and growth is preprogrammed during the first two trimesters. During the third trimester, brain development is largely shaped by the fetal experience within the protected setting of the womb, or for preterm infants, within the stressful environment of the NICU. As observed by Peter Gorski, MD, “This is a time when every experience a child either enjoys or suffers is fed into their growth, and most importantly, the growth of their emotional, cognitive, social, and communicative brain.”

The early life of most mammals is spent in close maternal contact, and animal studies have demonstrated that separation causes significant amounts of stress. Neonatal stress is greatly exacerbated by maternal separation, exposure to repetitive and uncomfortable caregiving interventions, painful procedures, and unfiltered noise and lighting. Short-term, stress may increase energy expenditure and cortisol levels, and cause **cardiorespiratory instability**. Long-term, there is evidence that repeated stress during this vulnerable period of brain development may result in **permanent structural and functional changes**. Minimizing stress may support the preterm’s capacity for neuroplasticity and decrease the likelihood of encoding abnormal stress responses. **Strategies known to reduce infant stress and improve outcomes include skin to skin care (KC), “cue based caregiving” and safeguarding sleep.**

Much infant stress can be reduced by thoughtful use of **parental nurturing touch**, either with skin to skin care or containment (“hand hugs”). Parents should provide nurturing touch whenever possible, especially following caregiving or procedures until the infant has returned to baseline and/or fallen asleep. Procedural touch activates the sympathetic nervous system (“fight or flight response”), which increases stress and disrupts sleep. Nurturing touch activates the parasympathetic nervous system (“rest and digest response”). In animal studies, increased parental touching during infancy was associated with improvements in brain structure, reduced levels of stress hormones, and better ability to cope and survive in stressful surroundings.

“**Cue based caregiving**” is based upon the concepts of *neurobehavioral organization*, which refers to a smooth balance between an infant’s physiologic and behavioral systems. Individualized caregiving is dictated by different cues that tell caregivers to either continue with handling, or to pause temporarily to provide for recovery. Stress cues are physiologic signals that the infant is overwhelmed, and needs gentle containment and a break to avoid energy loss and decompensation. Stability cues indicate that it is safe to interact or proceed with caregiving. Self-help cues should be supported, since they indicate that an infant is trying to “organize” himself within the NICU environment. Help parents identify and respond to cues.

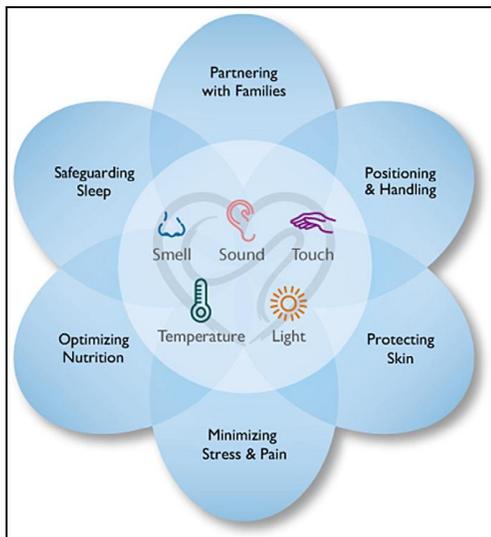
NICU Brain Sensitive Care Committee/Terrie Lockridge/ 11-2015/Swedish Medical Center – used with permission

<b>Stress (Disorganization) Cues</b>	<b>Stability (Organization) Cues</b>
<u>Physiologic/Autonomic System</u> <ul style="list-style-type: none"> <li>◦Apnea, bradycardia</li> <li>◦Respiratory pauses, tachypnea</li> <li>◦Color changes (pallor or cyanosis)</li> <li>◦Tremors, startles, twitches</li> <li>◦Gagging, spitting up, straining</li> <li>◦Sneezing, yawning, hiccupping</li> </ul> <u>Behavioral/Motoric System</u> <ul style="list-style-type: none"> <li>◦Flaccidity (trunk, extremities, face)</li> <li>◦Hypertonicity, arching</li> <li>◦Finger splays, fisting</li> <li>◦Facial grimace</li> <li>◦Frantic, diffuse activity</li> </ul> <u>Behavioral/State System</u> <ul style="list-style-type: none"> <li>◦Rapid movement between states</li> <li>◦Fussing, irritability</li> <li>◦Glassy-eyed, staring, gaze aversion</li> <li>◦Panicked, worried alertness</li> </ul>	<u>Physiologic/Autonomic System</u> <ul style="list-style-type: none"> <li>◦Maintains consistent color</li> <li>◦Stable respirations</li> <li>◦Reduction of tremors</li> <li>◦Stable digestion</li> </ul> <u>Behavioral/Motoric System</u> <ul style="list-style-type: none"> <li>◦Smooth, well-modulated tone</li> <li>◦Synchronous, smooth movements</li> <li>◦Grasping and hand to mouth activity</li> <li>◦Sucking</li> </ul> <u>Behavioral/State System</u> <ul style="list-style-type: none"> <li>◦Clear, robust sleep states</li> <li>◦Rhythmic, robust crying</li> <li>◦Active self-quieting/consoling</li> <li>◦Focused shiny-eyed alertness</li> <li>◦Intent, animated facial expression</li> </ul>
<b>Self-help Cues</b>	
<ul style="list-style-type: none"> <li>◦Hand to mouth activity</li> <li>◦Hands clasped</li> <li>◦Grasping</li> </ul>	<ul style="list-style-type: none"> <li>◦Seeking boundaries</li> <li>◦Habituating to repetitive stimulation by entering into light sleep</li> </ul>

**Protect sleep by clustering of care whenever possible, but be aware that the infant may not tolerate all of the caregiving measures that have been bundled into a single session.** Clustering of care is intended to provide longer rest periods but may actually result in more physiologic alterations (changes in blood pressure, cardiorespiratory stability, altered cortisol levels, and heightened pain responses) than single care-taking events. Clustered care appears to be especially stressful for preterms < 28 weeks GA, so individualized cue-based caregiving is essential to avoid overwhelming an infant.

### What can we do in the NICU?

- Assess for stress cues, indicating need for containment and a pause to allow recovery
- Assess for stability cues, indicating that it is safe to continue caregiving or interaction
- Provide nurturing touch whenever possible, especially after caregiving or procedures
- Safeguard sleep



## Neuro-protective Best Practice Guidelines Part 4B: Minimizing Pain

***Goal is to minimize the intensity, duration and physiologic cost of the pain experience, and to maximize the infant's ability to cope with and recover from painful experiences***

### Background:

For many years, it was believed that newborns were incapable of either experiencing or remembering pain due to central nervous system immaturity. These myths were dispelled by research over thirty years ago, but appropriate analgesia remains underutilized in many NICU's. A prospective study in 2003 (Simons, et al) showed minimal procedural analgesia for neonates despite the perception of pain by providers. It is now understood that the ability to perceive pain at the cortical level is present early on, and that the **pain experience is actually prolonged and more intense in newborns**, especially for those born prematurely.

A review of fetal neurophysiology helps to understand the pain experience in preterm infants. *Afferent* nerve pathways carry pain impulses from peripheral nociceptors ("nerve endings") to the brain, and are fully intact by 24-26 weeks GA. *Efferent* nerve pathways send protective impulses back to motor neurons, and trigger reflexive withdrawal from pain. These pathways also regulate neuromodulators (such as serotonin) that control pain signals by reducing or blocking the continued transmission of painful stimuli. Unfortunately, efferent pathways are largely undeveloped until 36-40 weeks GA, and continue to mature postnatally. Because these pathways mature more slowly, **infants may not withdraw in response to pain and are often unable to inhibit persistent pain signals**. The lack of neuromodulators results in more sustained and severe pain, especially in preterm infants. In general, newborns are "wired" to transmit pain signals, but the wiring is still being "installed" to moderate their pain experience.

Pain is known to elicit many acute physiologic changes, including elevated heart rate, respiratory rate, blood pressure and intracranial pressure. A growing body of evidence also indicates that the cumulative impact of repetitive pain on the developing brain may be greater than previously understood. **Pain exposure may result in permanent structural changes to the spinal cord and brain, with adverse long-term developmental outcomes**. While early pain might not be consciously "remembered" later in life, it is thought to be encoded into "procedural memory", a type of "unconscious memory" created by repetition of an experience or activity.

Pain assessment includes behavioral and physiologic indicators, which may be immediate, delayed, or absent. Preterm or ill newborns often show less robust behavioral responses. Pain triggers a "fight or flight" response with activation of the sympathetic nervous system, and release of glucocorticoids such as cortisol, epinephrine and norepinephrine. Since the sympathetic nervous system can't cope with persistent and unrelieved pain, "protective apathy" may occur with a return to baseline physiologic parameters despite continued pain.

Most common symptoms of pain	Additional responses to pain
<ul style="list-style-type: none"> <li>◦Tachycardia</li> <li>◦Tachypnea</li> <li>◦Elevated blood pressure</li> <li>◦Crying</li> <li>◦Body movements</li> <li>◦Facial expression <ul style="list-style-type: none"> <li>◦Brow bulge</li> <li>◦Brows drawn together</li> <li>◦Eyes squeezed shut</li> <li>◦Raised cheeks</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>◦ Desaturations and/or cyanosis</li> <li>◦ Pallor</li> <li>◦ Flushing</li> <li>◦ Muscle tremors</li> <li>◦ Hypertonic</li> <li>◦ Hypotonic</li> <li>◦ Sleep/wake cycles changes <ul style="list-style-type: none"> <li>◦ More wakeful or lethargic</li> </ul> </li> <li>◦ Fussy, irritable, listlessness</li> <li>◦ Feeding difficulties</li> </ul>

**Clinical studies show that initiating analgesia prior to painful procedures is helpful to decrease both neonatal pain and stress.**

**The timing of routine caregiving and painful procedures is important.**

- After pain exposure, sensitivity is accentuated by increased excitability of nociceptive neurons in the spinal cord. This hypersensitivity (known as “wind-up phenomenon”) may persist after the procedure, causing routine handling and caregiving to be perceived as painful due to heightened activity in nociceptive pathways. **Allow infant to fully recover from painful stimulus before resuming caregiving.**
- Handling in preparation for painful procedures can also heighten pain responses by increasing activity in nociceptive pathways. Decreased physiologic pain responses were noted when containment and/or swaddling were used to maintain flexion and allow hand to mouth for self comforting during procedures.

Animal studies have shown that the effects of repetitive pain are lessened by the nurturing presence of the mother animal. **Helping to provide containment during uncomfortable procedures is an ideal opportunity for parent participation.** The parent’s presence is reassuring to the infant, and the parent is able to actively contribute to their infant’s comfort.

### **What can we do in the NICU?**

Both non-pharmacologic (“comfort measures”) and pharmacologic therapies should be used to control and prevent pain. An additive or synergistic effect is seen when these strategies are combined.

- Comfort measures are indicated for all minor or moderately stressful procedures
- Add pharmacologic agents to comfort measures whenever moderate or severe pain is anticipated

The following **comfort measures** are known to minimize pain and stress, while maximizing an infant’s regulatory and coping abilities:

- Provide **containment** with hands (facilitated tuck or “hand hugs”), Dandlers/wraps or standard swaddling. Maintain flexion and allow hand to mouth for self-comforting. Containment may reduce pain by providing gentle stimulation across proprioceptive and tactile sensory systems
- **Skin-to-skin** contact significantly diminishes pain responses during and after heel sticks for preterm and term infants
- **Nonnutritive sucking** (NNS) during painful procedures is thought to activate nonopioid pathways, but the pain-relieving effects of NNS stop as soon as the sucking stops

- A systematic review found that **breastfeeding** and **breast milk** reduced pain responses. If available, use breastfeeding to minimize procedural pain
- **Sucrose** is effective in reducing pain responses, especially when combined with sucking (i.e. dipped pacifier) and other comfort measures. It should be applied to the tip of the tongue (where sweet receptors lie) two minutes before a painful procedure. The two minute interval is thought to coincide with the endogenous opioid release triggered by the sweet taste. Refer to *SMC Sucrose Analgesia* for our parameters for use of sucrose

Use **nonopioid analgesics**, such as **acetaminophen**, for short-term management of mild to moderate pain. Acetaminophen works by inhibiting prostaglandin formation, and provides mild analgesia as well as some antipyretic and anti-inflammatory benefits. When used in conjunction with opiates, there is an additive effect that may allow lower doses of both medications to be used. Since acetaminophen is metabolized by the liver, care must be taken to avoid overdosing.

In addition to comfort measures, add pharmacologic agents such as **opioids** for moderate or severe procedural, post-operative, or disease related pain. Analgesics such as **fentanyl** and **morphine** work by binding with receptors to block the transmission of pain messages. Opioids are indicated for pain control, but extended use for ventilation or sedation is not recommended due to lack of long-term outcome data.

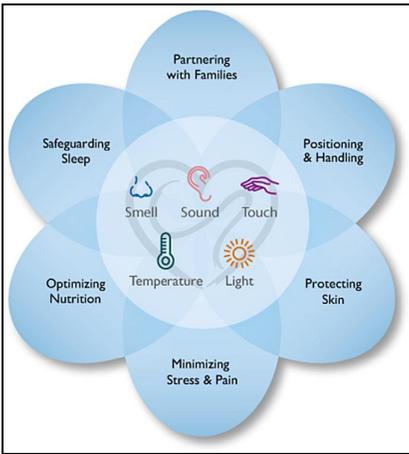
Manage procedural pain by using standardized best-practice guidelines:

Pain Intensity	Procedure	Management Strategy															
		Nonnutritive sucking (NNS) +/- sucrose	Contactment and positioning	Skin-to-skin contact	Breast milk use	Gentle technique	Topical anesthetic	Consider acetaminophen prophylactically for preterm infants	Consider venipuncture for full-term and older	Consider local anesthetic eye drops	Consider opioids	Consider subcutaneous lidocaine or topical anesthetic	Use combination of atropine, morphine/fentanyl, and nondepolarizing muscle relaxant	Use opioids	Consider subcutaneous infiltration of lidocaine	Dorsal penile nerve block or other regional block	
Mild	Tape removal	X	X	X	X	X	X										
	Suctioning	X	X	X	X	X	X										
	Diaper change	X	X	X	X	X	X										
	Nasogastric/orogastric tube insertion	X	X	X	X	X	X										
Moderate	Umbilical catheterization		X	X		X	X										
	Intramuscular injection		X	X	X	X	X	X									
	Venipuncture		X	X		X	X	X									
	Arterial puncture		X	X		X	X	X									
	Heel stick		X	X	X	X	X			X							
Moderate to severe	Eye exam		X	X		X	X				X						
	Percutaneous venous/arterial catheterization		X	X		X	X	X				X					
	Central venous line placement		X	X		X	X	X				X					
Severe	Lumbar puncture		X	X		X	X					X					
	Endotracheal intubation												X				
	Chest tube insertion		X	X										X	X		
	Circumcision		X	X				X									X

Adapted from Newborn Pain Assessment and Management: Guideline for Practice National Association of Neonatal Nurses, 2012

# Neuro-protective Best Practice Guidelines Part 5: Optimizing Nutrition

***Goal is to provide the best nutritional support available, and to support a positive infant-driven breast or bottle feeding experience***



## Background:

Preterm birth interrupts the third trimester, when protein and fat stores accumulate. Early parental nutrition is essential to minimize catabolism for these infants, and to support them until enteral feedings can be established. Ideally, glucose should be infusing within 30-60 minutes after birth to meet the brain's energy demands. Protein is vital for growth and prevention of poor neurodevelopmental outcomes. Intralipids prevent essential fatty acid deficiency and contribute to myelination.

There is compelling evidence to support **breastfeeding as the optimal form of infant feeding**. Since breast milk is the most well tolerated substrate for preterm infants, it allows full enteral feedings to be reached more quickly, and reduces the need for prolonged use of parenteral nutrition. The risk of necrotizing enterocolitis (NEC), retinopathy of prematurity (ROP), and sepsis are reduced when breast milk is used rather than formula. Higher IQ's, larger brain volumes, and improved neurodevelopmental outcomes have been reported in preterm infants fed breast milk. Because of the clear advantages, it is essential to support mothers in establishing and maintaining an adequate milk supply. Utilize lactation consults as needed.

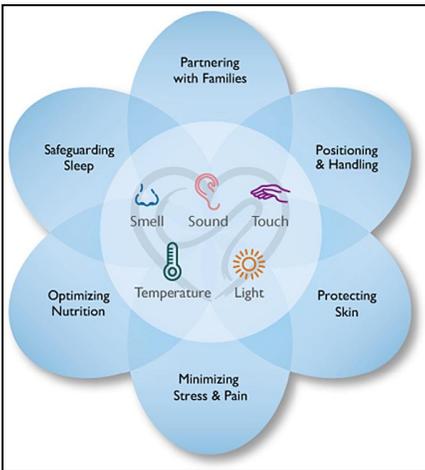
Oral feeding is a complex undertaking for preterm infants, especially since only about 53% of cortical volume is present at 34 weeks GA when such feedings are often introduced. Care must be taken to **provide a safe, functional, nurturing, and developmentally appropriate feeding experience**. The use of an infant driven feeding approach and appropriate feeding techniques are vital to provide for a successful experience and to avoid oral aversion. Pediatric therapy consults should be utilized as necessary to support oral feeding.

## What can we do in the NICU?

- Refer to *SMC Infant-driven Feeding Pathway* for detailed information
- Minimize negative perioral experiences such as suctioning, vigorous oral care, and saline for oral care
- Use colostrum for gentle oral care (see *SMC, Colostrum: Oral Administration*)
- Promote nonnutritive sucking (NNS) at mother's pumped breast during gavage feeds
- Provide the taste and smell of breast milk during gavage feedings (binky dips)
- Focus on quality of feeding rather than quantity of feeding
- Glucose should be infusing within 30-60 minutes after birth

# Neuro-protective Best Practice Guidelines Part 6: Parent Partnerships

***Goal is to support parents in their role  
as the most importance caregivers for their infant,  
and to promote secure attachment***



## Background:

Pregnancy, birth, and parenthood have traditionally been viewed as life crises for parents. The upheaval, change, and vulnerability triggered by these developmental crises are greatly intensified when associated with premature birth or admission to an NICU. Professional caregivers are called upon to offer support as parents work through their shock, anger, and grief over the loss of a normal pregnancy and childbirth experience.

Because a sick or preterm infant is focused upon the physiologic demands needed for survival, engagement with parents or caretakers often occurs at the expense of physiologic stability. Let parents know that as the infant's clinical status stabilizes, there will be more energy to direct towards social interaction.

Neurobehavioral organization is the product of CNS function and maturation, and improves over the first year of life. Assure parents that infant's disorganization with handling is due to an immature CNS, and "not their fault".

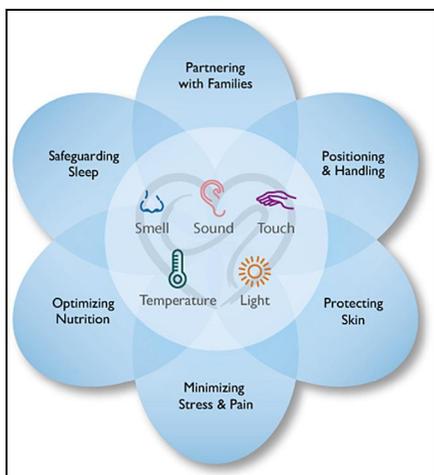
## What can we do in the NICU?

- Discuss infant's clinical condition and needs in a culturally appropriate, clear manner
- Use active, empathetic listening with parents as they express their concerns and fears
- Acknowledge and support where parents are in terms of the stages of grief and loss
- Assist parents in accessing resources such as the March of Dimes Family Support Program, The Lytle Center, or further counseling
- Create a welcoming environment where parents know that they are valued
- Allow parents to join in infant's care to the extent they choose, whenever they desire
- Encourage containment ("hand hugs") both during and after caregiving
- If able to do so without awakening, allow parents to provide containment during sleep
- Parents may hold "between" cares as tolerated, but stress the critical need for infant to sleep as much as possible
- Encourage parents to read to infant when awake to support language development
- Promote skin-to-skin as soon as possible, as often as possible, for as long as possible
- Empower parents to recognize and respond to infant cues appropriately
- Explain that when dealing with infants, "the infant leads and the adult follows"
- Help parents become competent in infant care, building confidence towards discharge
- Support parents as they evolve into their roles as expert and advocate for their child.

## Why is this important?

Successful partnerships between families and professionals have been shown **to reduce length of stay, increase parent and staff satisfaction, and improve neurodevelopmental outcomes**. Encouraging initial attachment between infant and parents, and actively involving them in the care of their infant supports the most important relationship of that child's life, setting the tone for all subsequent emotional connections. Because of this special bond, involved parents are known to play the most important role in their child's eventual neurodevelopmental outcomes.

Because long term developmental outcomes are so significantly influenced by family involvement, professional caregivers must **actively engage families early on** in their infant's care. Educating families about neuro-protective strategies empowers them to become "experts" at interpreting and responding to their infant's cues and needs. This sets the stage for **parents to foster their infant's growth and development after discharge from the NICU**. Prematurely born children are at higher risk for a wide range of motor impairments, cognitive deficits, poor academic achievement, behavioral issues, and emotional disorders. Since many neurodevelopmental issues will not present themselves until school entry and beyond, NICU graduates will benefit from parents who recognize and advocate for their child's needs throughout childhood, adolescence and early adulthood.



## Neuro-protective Best Practice Guidelines Part 7: Healing Environment

***Goal is to provide an environment that promotes healing by minimizing the impact of NICU environment on the infant's developing central nervous system***

### Background:

As early as the 19<sup>th</sup> century, Florence Nightingale recognized the value of a nurturing, healing environment in her patient's recovery. This remains true two centuries later, and is especially applicable for preterm infants, whose protective intrauterine environment has been replaced by the NICU. The contrast between these two settings is stark.

The intrauterine environment allows unrestricted access to mother, and provides unique sensory input that is crucial for normal brain development. The fetus is protected from harsh outside stimulation, and both light and noise are filtered by transmission through fluid and solid media. The predictable nature of intrauterine life supports sleep and the development of normal sleep cycles. Nine months spent within this nurturing intrauterine environment prepares term infants for the variety of sensory experiences that the extrauterine world has to offer. The situation is very different for preterm infants, who are not yet ready for the sensory input that ensues after early delivery. **Preterm infants are abruptly separated from their mothers, and exposed to persistent lighting, noise, and noxious odors.** Temperature and oxygen levels fluctuate. Handling is random and often dizzying. Most touch is procedural in nature, uncomfortable at best, and painful at worst.

Since the preterm is engaged in critical maturation of the central nervous system during the NICU hospitalization, it is our goal to create a healing environment that best mimics fetal life and reduces the impact of an unpredictable extrauterine environment. In utero, the sensory system develops in a precise order that should not be altered. The developing brain is very sensitive to the nature of sensory stimuli that it receives, and **sensory interference occurs when immature sensory systems are stimulated out of sequence by unexpected sensory stimuli** (for example, exposure to light before the auditory system has completed its pre-programmed development). Preterms are especially vulnerable to Sensory Processing Disorders, which can result in difficulties in the way the brain receives messages from the senses and translates them into appropriate motor and behavioral responses.

A healing environment goes beyond the basic components of space, safety, and privacy for infant and family. A healing environment also includes the sensory surroundings and experiences of temperature and touch, position and movement (proprioception), smell and taste, hearing and noise, vision and light. **It is important to modulate these sensory exposures as much as possible to avoid enduring alterations in brain development and function.**

## What can we do in the NICU?

**7A. Temperature:** Supporting appropriate thermoregulation is a priority during the transition from the warm fluid-filled womb to the dry cool extrauterine environment of the NICU. Our goal is to provide a *neutral thermal environment* in which the infant is able to maintain a normal core temperature with minimum oxygen consumption and calorie expenditure.

- Infants who are admitted to pre-warmed warmers for initial stabilization should be transferred to incubators with quiet motors as soon as possible
- Humidity should be used for ELBW infants, see *SMC Humidification of Incubators*
- Medically stable infants may be weaned from incubators to **open cribs around 1500-1600 grams**. See *SMC Weaning Preterm Infants from Incubator* and *SMC Temperature Management of Preterm or Compromised Infant*

While incubators provide a practical mechanism to support thermoregulation for extended periods, the ideal environment for the preterm infant is **skin-to-skin contact** with a parent. Thermosynchrony refers to the mother's ability to increase the temperature of her chest as much as 2° C to warm a cool infant, and decrease by 1° C to cool an overheated infant. See *SMC Kangaroo Care (KC) (Skin-to-Skin Holding)* for further details.

**7B. Touch:** Touch is the first of the senses to develop early in fetal life. It is critical for growth and development, communication and learning. An infant's first emotional bonds are built through touch, which lays the foundation for future emotional and intellectual development. The opportunity to touch and nurture their infant is essential for new parents, just as **parental touch and nurturing is critical for the infant's emotional well-being**. Because preterms are exposed to a significant amount of painful "procedural touch" as part of medical therapy, it is vital to offset these negative experiences with positive tactile encounters such as nurturing touch. Parents can provide nurturing touch, reassuring the preterm infant that all touch is not noxious in nature. In the NICU, skin-to-skin contact meets the infant's need for nurturing touch and parental contact under the most natural conditions available outside the womb.

- Because preterm infants are not able to modulate sensory input well, light touch or gentle stroking can seem over-stimulating and irritating
- Demonstrate **gentle but firm "static containment" ("quiet hands" or "hand hugs")**
- Encourage frequent and extended periods of skin to skin care (KC)
- When parents are uninvolved or unable to visit frequently, encourage consistent use of cuddlers or available staff to provide swaddle holding

**7C. Vestibular/Proprioception:** The vestibular and proprioceptive systems develop after the sense of touch. The vestibular system includes parts of the inner ear and brain that control balance and eye movements. Proprioception refers the sense of the orientation of one's limbs in space. In more practical terms, proprioception allows us to control our limbs without directly looking at them. The womb provides the optimal setting for these sensory systems to develop. The secure boundaries of the uterine wall promote generalized flexion and gentle containment, supporting the development of proprioception. **Maternal movement and fetal activity within warm amniotic fluid offer vestibular and tactile stimulation. In the NICU, skin-to-skin contact is the most logical means of providing essential proprioceptive sensory input to the developing brain.** Caregivers can further support the development of the vestibular/proprioceptive systems by careful positioning and handling practices.

- Provide containment during caregiving, change infant's position slowly and without sudden movements
- Utilize supportive positioning devices such as the DandleRoos/Wraps
- Facilitate skin to skin opportunities

**7D. Taste and Smell:** The gustatory (taste) system is intact by 24 weeks GA and even young preterm infants are capable of responding to bitter, sweet, or salty flavors. Maternal diet and flavors are identified in amniotic fluid, and flavonoids in amniotic fluid are identical to those in maternal breast milk. Mother's milk appears to be recognized by the preterm on a biological level. **Providing the scent and taste of mother's milk has been shown to promote infant cueing, sucking, and arousal in anticipation of eventual oral feedings. "Pacifier dips" with mother's milk increase nonnutritive sucking, intake, and growth.**

The olfactory system is functional by 28 week GA, with olfactory input communicated directly from the nose to the cerebral cortex. Cleaners, disinfectants and alcohol (both wipes and hand sanitizers) represent the most common odors within the immediate vicinity of hospitalized infants. One small study (Bartocci et al, 2000) noted that the scent of NICU detergent triggered a response in neonates that actually reduced cerebral blood flow. The emotional context of different smells is significant because odors are processed by the limbic system, the same area of the brain that manages emotion and memories. Just as the scent of pine might prompt nostalgic memories of Christmas, the scent of hand sanitizer may elicit less pleasant emotions about the NICU experience.

Providing pleasant olfactory experiences can help to offset the negative exposures that are sometimes unavoidable. Skin to skin contact with mother offers an especially pleasant experience. Exposure to maternal odor is extremely important, and contributes to both sensory development and attachment. Maternal odor is also known to influence neonatal behavior by facilitating state regulation, the ability to transition gradually through the different levels of consciousness, from quiet sleep to full cry. **The ability to control states enables the infant to process and respond to information about the environment, and begins the brain's "hardwiring" of behavioral skills that will remain throughout that child's life.** Self-regulation helps now to coordinate and organize motor activity, levels of arousal, and attention, and is essential later for learning, planning, decision making, complex sequential actions and resisting temptation. As the child grows older, social interactions will depend upon the ability to self-regulate behaviors.

- Maintain a scent-free unit for staff, and encourage parents to limit use of fragrances
- Avoid the odor of smoke on caregiver clothing and bodies
- Provide mother's scent when possible with breast pad or soft cloth
- Offer "Pacifier dips" with mother's milk.
- Use colostrum for oral care (see SMC, *Colostrum: Oral Administration*)

**7E. Sound and Noise:** Auditory development is a slow process that begins early in gestation, with crucial stages of maturation occurring during the final weeks of pregnancy and well beyond. The structural components of the ear are formed by 20 weeks GA, but critical neurosensory development occurs from this point on until approximately 6 months of age. In the NICU and at home, care must be taken to **protect the fragile auditory system from loud or excessive noise** until neurosensory development is complete.

The immature auditory system is functional by about 25- 29 weeks GA, when ganglion cells begin to connect cochlear hair cells (nerves) to the brain stem and temporal lobe of the cortex. **Auditory input at this time is capable of stimulating a physiologic response, which is why loud noises in the NICU will trigger changes in autonomic stability.** Heart rate (HR), blood pressure (BP), respiratory patterns and oxygenation can all be affected as part of this autonomic response. **Increased cerebral blood flow in response to loud noise increases the risk of intraventricular hemorrhage (IVH)**

The neural connections between the cochlea and auditory cortex are fully intact by 30 weeks GA. At this point a complex “mapping” of hair cells (sensory receptors) begins to occur within the cochlea. Each hair cell is responsible for picking up a different frequency or tone. This is similar to keys on a piano, but much more detailed, as the newborn ear is capable of recognizing more than 300,000 distinct sounds. The hair cells work in concert to code incoming sound and send it to the auditory cortex of the temporal lobe, where sound is heard and understood. The process of mapping cochlear nerves in specific patterns with specific nerve pathways to the brain creates “**tonotropic columns**”, which will continue to develop over the first 6 months of life. **These columns are essential in order to receive, identify and respond to language, music, and significant environmental sounds.** Tonotopic mapping depends upon appropriate stimuli from both internal (endogenous) and external (exogenous) sources. **Endogenous stimulation occurs only during REM sleep, which occupies much of fetal life.**

Within the womb and surrounded by amniotic fluid, the sounds the fetus hears are primarily low-frequency (for example, digestive noises). Higher frequency sounds from the external environment are filtered by passage through the maternal abdominal tissues and uterus, and sound levels are muted by 20-35 decibels (dB). Thus, low-frequency tonotropic regions of the cochlea are able to mature before high-frequency regions. This low-to-high frequency developmental gradient is supported by the acoustic makeup of the womb. As the walls of the uterine lining begin to thin towards the end of pregnancy, more high frequency sounds make their way through to the fetus. After term delivery and until about 6 months of age, the auditory system requires thoughtful external input (speech, music, and meaningful sound) in order to complete the essential “tuning” and mapping of the cochlear hair cells into functional tonotropic columns.

**Preterm delivery impacts the development of the auditory system by eliminating the natural sound barrier provided by the womb and exposing the infant to an acoustic stimuli which is often at higher frequencies than anything experienced in the womb.**

Constant exposure to noise transmitted through air rather than amniotic fluid can have significant short and long term consequences for the preterm infant. On a short term basis, close attention to vital signs such as HR, BP and oxygen saturations will reveal an infant’s autonomic reactions to loud or unexpected noise. **The brain registers sound even during sleep, so noise causes frequent arousals that disrupt both the quality and quantity of sleep.** Beyond the short term impact of noise upon sleep, serious long term functional changes can occur. **Since endogenous stimulation of tonotropic columns occurs only during REM sleep, it is essential to protect sleep in order to assemble the complex neurosensory architecture that delegates different frequencies to various cochlear hair cells, and coordinates the neuronal migration that allows these messages to be carried to the brain for accurate interpretation.**

During the first six months of life, infants are ideally exposed to a variety of environmental sounds and speech that will be used to encode the tonotropic maps of the auditory system. Unfortunately, **infants are unable to recognize meaningful sounds when background noise levels exceed 60 dB (normal conversation is about 50-65 dB, laughter is 60-65 dB).** In the presence of loud or continuous background noise, fewer specific frequencies can be heard and used to “tune” cochlear hair cells. **The ability to understand speech and discriminate between various sounds depends upon frequency discrimination, easily lost as a result of excessive background noise.**

Noise is not only disruptive to neurosensory development, but can also cause permanent structural damage to cochlear nerves (hair cells). Loud noise can lead to sudden destruction of cochlear hair cells, while exposure to prolonged noise results in continual accelerated loss of cells. Hearing damage in adults can occur when sound is sustained at about 85 dB.

**When sensorineural hearing loss occurs in the NICU, it places the infant at risk for varying degrees of speech and language delays.** If loss is mild, the infant is unable to hear soft consonants, so words seem incomplete even when speech seems loud enough. Moderate hearing loss makes hard and soft consonants inaudible, so speech is difficult to understand. Noisy environments make hearing especially challenging. Severe hearing loss allow some loud sounds to be heard, but prevents communication without a hearing instrument.

**Despite American Academy of Pediatrics (AAP) recommendations to maintain noise levels below 45 dB, most NICU's have noise levels that average between 38 – 90 dB, with periodic bursts of higher noise levels.** Environmental noise studies indicate that NICU staff consistently underestimate the noise level in their own units, perceiving their units as “pretty quiet” when in reality, noise levels exceeded AAP recommendations (See table below). There are multiple sources of noise in any intensive care unit, but by far, **the greatest contribution to excessive noise comes from staff talking and conversation.**

Noise Levels in the NICU	
45 dB	AAP recommends that noise should be maintained below this level
48-69 dB	Humidifiers and nebulizers
50-60 dB	Normal speaking voice
47-55 dB	Incubator motor noise (Drager C2000 and 8000 = 47dB, Giraffe = 55db)
48-66 dB	Giraffe incubator alarm (level 1-4)
53 dB	Median noise level on conventional ventilators
55-88 dB	Average noise level in NICU (combined conversation, equipment, alarms)
68 dB	Raising Giraffe Canopy
70 dB	Background noise should not exceed this level
77-88 dB	Sensormedics HFOV
85 dB	Hearing damage possible for adult; (?) neonatal effects
90 dB	Peak sound intensity not to be exceeded
90 dB	Continuous adult exposure in workplace for 8 hrs requires protective device
93 dB	Sound level in incubator when porthole is opened
84-108 dB	Placing plastic formula bottle on top of incubator
80-124 dB	Sound level in incubator when closing one or both portholes
120 dB	Threshold for pain
Adapted from: Thomas & Uran. 2007. MCN American Journal Maternal Child Nursing 32:250, Salama et al. 2011. eJNR21606072v1i3p4y2011, Giraffe Omnibed and Drager Incubator Operating Specifications	

NICU Brain Sensitive Care Committee/Terrie Lockridge/ 11-2015/Swedish Medical Center – used with permission

The NICU is clearly a noisy environment, and a simple strategy to diminish excessive noise is to transfer infants from radiant warmers to incubators as soon as possible. Modern incubator walls are thought to attenuate and diminish excessive noise from the NICU. Older incubators do not protect infants from noise and may actually increase noise exposure. Unfortunately, even modern incubators have acoustic shortcomings. Newer incubators have quieter motors which average only 47-55 dB, an improvement over older models, but still greater than the recommended sound level of 45 dB. It is important to note that noise within the confined walls of the incubator is likely to be amplified. Amplified sound comes from infant crying, opening and closing of portholes or incubator cabinet drawers, and devices such as NCPAP. **Infants should be maintained in an incubator as long as needed for thermal support, but a well-managed NICU may be quieter than the continuous noise of an incubator.** In addition, human speech is both muffled and distorted within incubators.

Specific recommendations from the Sound Study Group (Graven. 2000. Journal of Perinatology, 20(8):S88-93) outlined structural modifications within NICU's to reduce environmental exposure to noise. Because many NICU's were built prior to this publication, staff must work within the constraints of older units.

**Modifying the environment to support the development of the preterm infant's auditory system is the responsibility of every member of the NICU staff.** The following interventions are useful to decrease noise, encourage uninterrupted sleep, and facilitate normal auditory development:

- Speak as quietly as possible within patient bays, avoid loud laughter or conversations
- Avoid talking over incubator or allowing medical rounds too close to bedside
- Empty sloshing water in ventilator/NCPAP tubing
- Quiet alarms as quickly as possible, and remember to reset them
- Use blankets or covers over incubator to attempt to muffle noise
- Avoid placing items on incubator, do so gently if necessary
- Close incubator portholes, drawers and refrigerator gently
- If able, use pagers/cell phones on vibrate mode rather than audible alarm mode
- Transfer infants from warmers to incubators with quiet motors as soon as possible
- Infants should remain in incubators only as long as needed to maintain heat balance
- Use padding on trash can lids and cupboard doors
- Use ear muffs for infants on HFOV and in adjacent bed spaces
- Safeguard both REM and non-REM sleep, but especially REM sleep
- Provide day-night cycles when auditory stimulation is decreased

With such a focus on reducing noise exposure, some may wonder whether efforts should ever be made to enhance a preterm infant's auditory experience. Programs to supplement fetal auditory development are not recommended, and the fetus does not need additional stimulation beyond the sound of mother's voice as she goes about her daily activities. The same holds true for preterm infants in the NICU, especially for those less than 34 weeks GA who receive more than enough auditory input from their environments. However, when parents are available, opportunities should be provided for the infant to hear their voices. In utero, the fetus has heard the voices of mother, father and siblings from about 22-24 weeks GA. Since these voices are familiar, infants are able to recognize and differentiate them from strangers. **Caregivers should role model talking gently to the infant during caregiving, and encourage parents to talk to their infant while placing their faces within the infant's range of vision, as tolerated.** If the infant appears overstimulated, limit "talk and face time" as needed until better tolerated. For newborns, **hearing is more important than vision for attachment and bonding.** Newborns are able to connect mother's familiar voice with her face within seconds after birth, and then show a clear preference for mother's face.

There is little long-term evidence to support the use of recorded speech or music in the environment of the preterm infant, and audio recordings should not be used routinely or left unattended in the incubator. Music has been shown to soothe term infants, but its use has not been well studied in preterms. As the infant matures and becomes more interactive with his environment (usually between 36-40 weeks GA), the human voice remains the most preferred sound. Musical toys and tape recorders should be delayed until after term.

**7F. Lighting and Vision:** The sensory system develops in a specific order, with vision being the final sense to mature. The structural elements of the eye form early in fetal life, but the majority of essential neural mechanisms and connections develop during the final 12 weeks of pregnancy. During this time, endogenous brain activity stimulates spontaneous firing of neural cells in the retina. This prepares the retina and visual cortex for birth, when they will begin to receive visual stimulation from the extrauterine world. The endogenous neural activity is generated by the nervous system itself, long before there is any sensory input, and molds the precise circuits that are vital for the complex sensory functions of the maturing brain. **The fetus needs no outside light or visual stimuli, and is developmentally unprepared for any such exposure prior to birth at term.**

The visual cortex is located in the occipital lobe at the back of the brain, but the neurons of the visual cortex are actually formed in the germinal matrix at the center of the brain. During the final 8-10 weeks of gestation, these neurons must be stimulated so that they will migrate to their eventual home in the visual cortex, and create initial layers known as “ocular dominance columns”. These columns form the framework for “directional columns” which are ultimately necessary for seeing lines, patterns, and movement. Similar to development of the auditory system, the endogenous stimulation needed to trigger neural migration and formation of directional columns for vision occurs only during REM sleep, which occupies much of fetal life. **Adequate sleep is essential for healthy retinal development and intact pathways to the visual cortex.**

After 38-40 weeks GA the visual system is activated by light and requires a variety of visual experiences for sustained development. Directional columns are still forming that will help to distinguish lines, patterns, motion, and different light intensities. Color pathways from the retina to the visual cortex become functional between 2-3 months corrected GA. **The visual experience for term infants should include light directed onto objects rather than the infant’s face, novelty, and motion.** Since color perception begins to develop slightly later, exposure to color is not necessary in the infant’s visual field until after 2-3 months. The **focal distance for term infants is 10-12 inches**, and gradually increases with time and the ability to focus. The **cradling position** (en face) is ideally suited for the newborn’s limited visual function, and mother’s face is the most important source of visual input.

When the immature visual system is stimulated by contrasting colors (patterns) or movement (mobiles), it can induce an involuntary staring response in infants, from which they may not be able to disengage. While mobiles and other colorful toys are common fixtures in the cribs of term infants in the home setting, these infants typically spend little awake time in their cribs, and exposure to this kind of visual stimuli is limited. In contrast, hospitalized infants spend the vast majority of their awake time in their cribs, and are unable to escape from the intense visual stimulation provided by such items. **Mobiles and high contrast patterned toys are suitable for use with term infants only under supervision, and only for periods of 5-10 minutes at a time.** Mobiles do not provide reciprocal human interaction which reinforces positive and interactive behavior. Again, the human face (preferably parents) is the most important source of visual stimulation.

Since successful development of the visual system occurs largely between 24 and 40 weeks GA, without exposure to light or visual stimuli, both prematurity and the NICU environment can have a tremendous impact upon development of the visual system. Ophthalmic sequelae are a common finding in NICU graduates, and include retinopathy of prematurity (ROP), decreased visual acuity, refractive errors, strabismus, cortical visual impairment, deficits in color vision, and visual field defects. The visual development of preterm infants can be supported by three basic goals: **Safeguard sleep, protect eyes from direct light, and decrease excessive light levels whenever possible.** The existing literature is very clear that protecting REM sleep is crucial for the formation of appropriate visual neural architecture, and has a tremendous impact on later visual function. Sleep can be supported by reduced lighting, thoughtful handling practices and skin-to-skin care.

Preterm exposure to bright lights is not only painful, but is also associated with decreased oxygenation, disrupted sleep patterns, altered state organization, and poor circadian rhythms. **Preterms are often unable to protect their eyes from constant overhead lighting.** Smaller preterm infants may not be strong enough to keep their eyelids closed for extended periods, and their eyelids are very thin and may still permit light to pass through. Infants less than 32 weeks GA have minimal ability to constrict their pupils, which allows more light to enter the eye. Since they may be unable to turn away from the light, and are unable to communicate their discomfort, caregivers are responsible for protecting preterm infants from direct light. **For infants less than 28 weeks GA, it is most important to maintain ambient light at low levels and to protect from direct light exposure. For infants 28-36 weeks GA, lighting should be low enough to support undisturbed sleep.** Additional visual experiences should be limited to parental faces.

Neither continuous near darkness, continuous dim lighting, nor continuous bright lighting has been identified as being optimal for the visual development of preterm infants. Cycled lighting refers to lights on during the day and off at night, rather than constant bright or dim lighting. **There is mixed data about the use of day/night cycled lighting, however there is no evidence that it is harmful and some evidence that it may be helpful.** Improved weight gain, improved oxygen saturations, reduced crying, trends towards lower incidence of ROP, and shorter hospital stays have been noted in some research.

A 2013 Cochrane review observed that most studies on optimal NICU lighting may have lacked significance due to lack of statistical power, but that positive trends for outcomes favored cycled lighting. The previous edition of the AAP & ACOG Guidelines for Perinatal Care, 6<sup>th</sup> Edition (2007) supported cycled lighting, noting that “there is no rationale for continuing a chaotic non-circadian environmental approach to the neonatal nursery for the care of prematurely born infant”. The 7<sup>th</sup> Edition (2012) does not address cycled lighting, but stresses the necessity for lighting that can be individualized based upon the infant’s needs alone. There is much that remains unknown about optimal lighting exposure for preterm infants. The following interventions are thought to promote good visual function:

- Protect sleep, especially REM sleep
- Use adjustable lighting at each bedside, strive towards a day/night cycle for the NICU
- Use minimal amount of light needed to accurately assess and manage infant
- Consider the use of penlights and flashlights whenever possible
- Protect eyes from direct light during assessments, rest periods, and after pupil dilation for ROP exams
- Use heavy incubator covers to limit excessive light exposure during sleep, underside of these covers should be solid and dark colored to minimize unnecessary visual stimulation
- Mobiles and high contrast patterned toys are suitable for use under supervision only with term infants, and for periods of 5-10 minutes at a time
- Limit visual stimuli early on, with focus on parent’s faces

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