More than a half million infants are born preterm each year in the United States and subsequently admitted to the Newborn Intensive Care Unit (NICU) (National Center for Health Statistics, 2006). Medical advancements over the last decade have increased the survival rates of premature infants, pushing the limits of viability as low as 23 weeks gestation. However, for many, survival comes with a price of lifelong disabilities. The rates of severe intraventricular hemorrhage (IVH) and cerebral palsy in this population have remained stable. It is increasingly recognized that preterm infants are at increased risk for significant neurobehavioral and cognitive impairments (e.g., academic underachievement, behavioral problems, and poor executive function) (Aarnoude-Moens et al., 2009; Anderson & Doyle, 2007; Delobal-Ayoub et al., 2009). Brain growth and organization is exponential during the last half of pregnancy. Premature infants admitted to the NICU lose the protection of the uterus, placing them at risk for nutritional compromise, environmental toxinitoxins, drug exposures, and chronic stress, which may have deleterious effects on neuromaturation. Therefore, health care professionals and families need to partner in developing strategies to optimize and adapt the NICU environment in order to protect the preterm brain during its most vulnerable period.

Brain development and maturation is a sophisticated process that begins at conception and continues to be refined through adolescence and beyond. The formation of the brain's basic architecture, neuronal proliferation and neuronal migration to the cortical surface occurs by approximately 20 weeks gestation. These processes are genetically driven or preprogrammed and are not likely affected by external sensory stimulation (Graven & Browne, 2008; Liu et al., 2007). However, following this stage of development and maturation is a “critical period” of brain growth. This “critical period”, from approximately 22 weeks gestation through the first two years of life, is a period of great expansion, synaptogenesis and apoptosis, myelination, and neuronal organization and alignment. During this period of brain development, in response to endogenous and exogenous stimulation, the sensory systems (visual, auditory, touch, chemosensory, kinesthetic, proprioception, limbic system [emotional learning] and the hippocampus [memory formation]), motor systems, social/emotional systems, and cognitive systems become connected and integrated, allowing them to communicate and function in a coordinated manner. These neuronal circuits continue to be refined and reorganized through adolescence. This refining and reorganization process is exquisitely sensitive to the presence and sensory stimulation (Graven & Browne, 2008; Lagercrantz & Ringstedt, 2001; Liu et al., 2007; Volpe, 2008; Westrup, Sizun, & Lagercrantz, 2007).

References


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The sequence of neurosensory development and the process of neumaturation is neither altered nor accelerated by preterm birth. However, experience and sensory input is essential for neumaturation and development. Sensory input that is unexpected, intense, or out of order is detrimental to the normal progression of brain development (Aucott et al., 2002; Butler & Als, 2008; Graven & Browne, 2008). Advance magnetic resonance imaging (MRI) has allowed researchers to identify significant differences in brain architecture of preterm infants at term equivalent when compared to term newborns.

Preterm infants may have regionally specific decreases in gray matter, thought to represent neuronal loss, and decreases in myelinated white matter, representing diffuse white matter injury (Boardman et al., 2006; Inder et al., 2005; Sweeney & Gutierrez, 2002; Thompson et al., 2007). Medical factors such as BPD, postnatal steroids, and intrauterine growth retardation (UGR) are associated with some of these regional differences. However, medical factors did not explain the impact on the frontal and sensorimotor regions of preterm infants at term equivalent (Thompson et al., 2007). The preterm infant’s sensory environment includes movement, smell, sound, light, and pain (Graven and Browne, 2008). Preterm infants are at risk for poor neurodevelopmental outcomes (Als et al., 2004; McAnulty et al., 2009).

To successfully deliver neurodevelopmental care, healthcare professionals must understand the interplay of the NICU environment, family, and neumaturation and their influence on long term outcomes.

### The Physical Environment

Each component of the infant’s environment plays an integral part in supporting/not supporting neumaturation. The infant’s physical environment, the micro-environment immediately surrounding the infant, affects body position and alignment, allowing or restricting movement (Graven & Browne, 2008). The preterm infant loses the experience of the restrictive intrauterine environment that promotes flexion (the basis for all future movement) and proprioceptive feedback from the flexible uterine wall that promotes muscle learning. Supportive positioning and handling of the infant in flexion optimizes skeletal development and biomechanical alignment, supports posture and movement, provides controlled exposure to proprioceptive and tactile stimuli, and promotes self regulation. Supportive positioning promotes physiologic and behavioral stability, reduces stress, and promotes the well-being of each infant (Aucott et al., 2002; Sweeney & Gutierrez, 2002).

### The Sensory Environment

The preterm infant’s sensory environment includes the exposure to and experience of touch/handling, movement, smell, sound, light, and pain (Graven and Browne, 2008). Too often, the NICU environment bombards the infant with sensory stimulation that is unexpected, overstimulating, disruptive, and stress producing. This environment can be adapted by providing filtered light, decreased noise, maternal scent, positive touch (e.g., containment, massage, skin-to-skin holding by parents), and care that is paced and based on infant cues and signals. Many of the life sustaining interventions in the NICU result in repetitive pain and noxious stimuli that may potentially disrupt brain development. Ameliorating pain is the goal and can be achieved with physical, behavioral and pharmacologic interventions. Physical and behavioral interventions can be provided to support and maintain physiologic stability. Depending on the type of procedure and the infant’s response, pharmacologic therapies may be necessary. Some evidence suggests that analgesics may disrupt sleep cycles which may interfere with normal brain development (Graven & Browne, 2008; Liu et al., 2007). It is vital for caregivers to continuously evaluate the need for painful interventions and reduce the number if warranted. The protection of sleep and sleep cycles is also an important component of the infant’s sensory environment. Protected sleep and sleep cycles are important for neurosensory maturation, memory/learning, long term brain connectivity, and the preservation of brain plasticity (Graven & Browne, 2008; Liu et al., 2007). Care givers (including parents) must be sensitive to the infant’s communication and alter interactions/environment to match the infant’s competence; ensuring autonomic, motor, and state stability.

### The Chemical Environment

The chemical environment includes nutritional support and toxic exposures; specifically drugs implicated in poor neurodevelopmental outcomes (Graven & Browne, 2008). Adequate nutrition is critically important to the developing brain. While nutritional support can be challenging, parental nutrition may provide the protein and calories necessary for brain growth and maturation until enteral nutrition is achieved. Breast milk is the preferred nutritional support with increasing evidence that it may provide important protection to the developing brain. It is shown to enhance cognitive and motor development (Blaymore, Ferguson, & Vohr, 2002; Sacker, Quigley, & Kelly, 2006; Vohr et al., 2007; Vohr et al., 2006). Additionally, infants within the NICU often receive multiple medications that may interfere with normal brain development and synaptic connectivity such as analgesics, sedatives, and corticosteroids (Durrmeyer, et al., 2010; Wyatt, 2007).

### The Social Environment

The social environment includes all human relationships that the infant experiences. The most important social relationship for the infant in the NICU is the parent-infant relationship. A strong parent-infant attachment is the foundation for the infant’s development of self-confidence, security, emotional stability, readiness to learn and social competence (Talmai and Harmon, 2003). Admission to the NICU can strip parents of control and confidence as they are separated from their infant and are faced with a world of unknowns. Neonatal professionals need to recognize that each infant is a dynamic member of a family and it is the family who will ultimately nurture and support the infant throughout childhood. Therefore, a welcoming neonatal environment where families are treated with dignity and respect and their needs are assessed and supported is imperative. Neonatal professionals are encouraged to facilitate parental presence, both physically and psychologically. Integrating families into a neurodevelopmentally supportive environment in the NICU may be key in optimizing neurodevelopmental outcomes.

### Summary

Neonatal professionals need to be cognizant of the growing body of research regarding the impact of the NICU environment on neurodevelopmental outcomes. Neurodevelopmentally supportive care promotes parent-infant relationships, physiologic and behavioral stability, and may potentially prevent long term neurobehavioral and cognitive impairments.
The sequence of neurosensory development and the process of neuromaturation is neither altered nor accelerated by preterm birth. However, experience and sensory input is essential for neuromaturation and development. Sensory input that is unexpected, intense, or out of order is detrimental to the normal progression of brain development (Aucott et al., 2002; Butler & Als, 2008; Graven & Browne, 2008). Advance magnetic resonance imaging (MRI) allows researchers to identify significant differences in brain architecture of preterm infants at term equivalent when compared to term newborns.

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Neurodevelopmental Care

Neurodevelopmental care is a holistic, family-centered philosophy of care that promotes neuromaturation of preterm infants by providing supportive strategies to decrease the discordance between the womb and the NICU environment. This approach to care recognizes the individuality and competence of each infant and his/her family and alters the micro- and macro-environments to match the infant’s capabilities. Critical to this philosophy of care is the development of a positive parent-infant relationship that is life-long and essential for optimal long term development. In this model of care, parents are recognized as partners of the health care team. Providing parents with the knowledge to recognize and be responsive to their infant’s signals and behavioral cues can empower them to actively support their infant’s development. Neurodevelopmentally supportive care has been shown to produce improved neurodevelopmental outcomes (Als et al., 2004; McNamul et al., 2009).

To successfully deliver neurodevelopmental care, healthcare professionals must understand the interplay of the NICU environment, family, and neuromaturation and their influence on long term outcomes.

The Physical Environment

Each component of the infant’s environment plays an integral part in supporting/ not supporting neuromaturation. The infant’s physical environment, the micro-environment immediately surrounding the infant, affects body position and alignment, allowing or restricting movement (Graven & Browne, 2008). The preterm infant loses the experience of the restrictive intrauterine environment that promotes flexion (the basis for all future movement) and proprioceptive feedback from the flexible uterine wall that promotes muscle learning. Supportive positioning and handling of the infant in flexion optimizes skeletal development and biomechanical alignment, supports posture and movement, provides controlled exposure to proprioceptive and tactile stimuli, and promotes self-regulation. Supportive positioning promotes physiologic and behavioral stability, reduces stress, and promotes the well-being of each infant (Aucott et al., 2002; Sweeney & Gutierrez, 2002).

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Neonatal professionals need to recognize that each infant is a dynamic member of a family and it is the family who will ultimately nurture and support the infant throughout childhood. Therefore, a welcoming neonatal environment where families are treated with dignity and respect and their needs are assessed and supported is imperative. Neonatal professionals are encouraged to facilitate parental presence, both physically and psychologically. Integrating families into a neurodevelopmentally supportive environment in the NICU may be key in optimizing neurodevelopmental outcomes.

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