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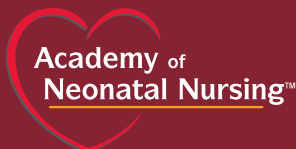
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# Brain-Oriented Care in the NICU: A Case Study

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## ABSTRACT

With the advances of technology and treatment in the field of neonatal care, researchers can now study how the brains of preterm infants are different from full-term infants. The differences are significant, and the outcomes are poor overall for premature infants as a whole. Caregivers at the bedside must know that every interaction with the preterm infant affects brain development—it is critical to the developmental outcome of the infant. The idea of neuroprotection is not new to the medical field but is a fairly new idea to the NICU. Neuroprotection encompasses all interventions that promote normal development of the brain. The concept of brain-oriented care is a necessary extension of developmental care in the NICU. By following the journey of 26-week preterm twin infants through a case study, one can better understand the necessity of brain-oriented care at the bedside.

**Keywords:** brain-oriented care; preterm infant development; brain development of preterm infant; outcome of preterm infant

LIKE MANY PREMATURE INFANTS, BABY A and Baby B were born at 26 weeks gestation. Their brains were less than two-thirds the size they would be at 40 weeks gestation with few synaptic connections and even fewer grooves made by necessary gyri and sulci.<sup>1</sup> Their brains were wiring at 40,000 connections per minute<sup>2</sup> during the four months they “developed” in the NICU, time that was meant to be spent in the comfort and “optimal” environment of their mother’s womb.

The twins had a difficult but somewhat normal course for micro-premature infants. Baby A was on the ventilator for two months and fought the continuous positive airway pressure (CPAP) so hard that he went straight to high-flow nasal cannula. Baby B was on the ventilator for more than two and a half months, then CPAP, and then high-flow nasal cannula. The first time the boys got to touch each other outside of the womb was Father’s Day, two and a half months after their birth.

Here are some of the well-researched risks Baby A and Baby B face as former premature infants:

- Fifty percent of healthy preterm infants have deficiencies in first grade in the areas

of judgment, visual-spatial, and executive control and have “nonverbal learning disorders.”<sup>3</sup>

- Twenty-five percent will need significant assistance in school.<sup>4</sup>
- Former extremely low birth weight (ELBW) infants (premature infants <1,000 g) score 11–22 points lower on IQ tests than their nonpremature infant peers.<sup>5</sup>
- Twenty-eight percent of former premature infants born at <1,250 g have a psychiatric disorder at age 12 years compared with nine percent of their peers.<sup>6</sup> The most common disorder was attention deficit hyperactivity disorder (ADHD), followed by generalized anxiety, depression, and oppositional defiant disorders.
- Approximately 50 percent of all premature infants have learning disabilities compared with 9 percent of their peers as reported by most studies.<sup>7</sup>
- Thirty percent of late preterms (32–36 weeks gestation) have a higher risk than term infants for developmental delay, suspension in kindergarten (19 percent), and more disability in prekindergarten (10–13 percent).<sup>8</sup>

Furthermore, Dunn proved that the brains of premature infants are quite different than the brains of full-term infants.<sup>9</sup> When the magnetic resonance images (MRIs) of 260 babies born more than ten weeks early were compared with those of full-term infants, the premature brain had 30 percent less grey matter (the brain's thinking cells) and 40 percent less white matter (connections in the brain). One goal of all NICU professionals should be that the brains of former preterm infants are similar to those of full-term infants. This concept forms the basis of "brain-oriented care." Developmental care in the NICU has paved the way for brain-oriented care, and it is essentially an expansion or "next step" in the world of developmental care. Few would argue the benefits of developmental care, and the research is extensive. To recognize the difference in brain-oriented care, one must first look at why Baby A's and Baby B's brains grew to be unlike the brains of full-term infants. Research shows that there is rapid change in the last trimester of pregnancy and in early life. Connections in the brain are made with dendritic growth, synaptic connections, apoptosis, myelination, and pruning.<sup>10</sup> The quality of these connections is based on experience, genetics, and nutrition.<sup>11</sup> Essentially, the progress in brain development is dependent on experiences in the womb or the NICU in the case of premature infants.<sup>12</sup> The phrase by neuroscientist Carla Shatz, "what fires together, wires together," is never more apparent than in the world of a premature infant in the NICU.<sup>13</sup>

There are two primary causes known for the alteration in brain development of premature infants: stress and pain. By definition, stress is a psychological or physiologic response to actual or potential threats to well-being.<sup>14</sup> A stress response is a cascade of hormonal and biochemical events meant to restore homeostasis and promote survival.<sup>15</sup> Premature infants have a decreased capacity to cope with or effectively achieve homeostasis. Research by Dr. Heidi Als demonstrated the fragile systems of premature infants.<sup>16</sup> Because their autonomic systems are so underdeveloped, their abilities to self-regulate are severely diminished. In the NICU, premature infants have prolonged exposure to cortisol, the hormone released when stress is encountered.<sup>17</sup> Premature infants have little to no opportunity to rest and recover before they must face a stressful event again whether it be environmental or procedural. Prolonged exposure to stress has been shown to damage parts of the brain.<sup>18</sup> In a longitudinal study, infants born 24–32 weeks gestation underwent brain MRI early in their NICU stay and at term-equivalent age. Higher pain-related stress from birth to term-equivalent age was associated with poorer neonatal brain development. "Our results demonstrate that higher numbers of skin breaks, which we have used as a surrogate marker for early neonatal pain-related stress, are significantly associated with reduced white matter and subcortical grey matter maturation."<sup>19</sup> Furthermore, prolonged exposure to cortisol actually lowers the threshold for activation of the amygdala.

Former preterm infants exhibit a sluggish response to and recovery from stress.<sup>20</sup>

Repeated stressful experiences in the NICU create a brain structure in which a maladaptive response is standard.<sup>7</sup> The brain actually wires itself differently, resulting in abnormal responses and outcomes. Preterm infants do not have a memory of their NICU stay, but the brain "remembers" and expresses itself later. Even momentary stressful experiences can create a stress response pathway in the brain.<sup>7</sup>

Pain affects the brain in a similar but just as damaging way as prolonged stress. Pain, as defined by the International Association for the Study of Pain, is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage."<sup>21</sup> Several studies have looked at the number of painful procedures NICU infants face. Cignacco and colleagues showed that neonates experience up to 14.3 painful procedures a day, and >65 percent of those are without appropriate analgesia.<sup>22</sup> A prospective chart review by Carbajal and colleagues of 431 neonates showed 42,413 (69.6 percent) invasive painful procedures and 18,556 (30.4 percent) stressful interactions over a two-week period with 56 percent of heelsticks having no intervention.<sup>23</sup> Although caregivers know that pain exists in this population, research has supported that pain continues to be undertreated up to 65 percent of the time.<sup>24,25</sup> The smallest and most preterm infants are at the greatest risk for adverse outcomes.<sup>24,26</sup> Grunau and colleagues<sup>20</sup> showed that, for infants born at <28 weeks gestation, the number of skin-breaking procedures correlated with higher basal heart rate (HR) and cautious response to novelty (the hippocampus is affected). Furthermore, infants with lower reactivity to pain scored lower on tests of neuromotor function at 8 months corrected age (CA). At 8 and 18 months CA, preterm infants showed higher basal HR and higher salivary cortisol than term counterparts—a compromised ability to shut down stress.

What does the research and science look like in real life? Through Baby A and Baby B, one can explore the issues, Baby A and Baby B began outpatient occupational therapy when they were 12 months of age (about 9 months CA; Figure 1). They were both still on oxygen, and Baby B had a G-button. Upon initial evaluation, Baby A and Baby B both presented with significant motor delays, and both exhibited decreased muscle tone, although Baby A was more hypotonic than Baby B. They had the motor skills of babies 4–5 months old instead of their corrected age of 9 months. In addition, what was quite remarkable were the very significant sensory issues both boys exhibited. When a textured toy was placed in Baby B's hand, he immediately started gagging. It was no wonder that food was going nowhere near his mouth. Baby A exhibited the same symptoms although not quite as "vocal" about them. Both boys feared novelty. They were extremely cautious of anything introduced to them. It took several weeks and significant help from their highly involved parents (and even

**FIGURE 1** ■ Baby A and Baby B at 9 months.



grandparents) just to get the twins used to the therapy process. OT began by giving the mother a sensory program for home. The process was a slow and deliberate regimen of desensitization. This included massage and deep pressure and the introduction of various textures graded from soft to textured. Speech therapy would see the twins immediately after their OT session. The idea is that, when other sensory systems are stimulated (e.g., vestibular and proprioceptive), the task of feeding becomes easier. Speech therapy treatments consisted of oral stimulation and feeding (trying various foods and textures of food) as well as an intensive home program. The speech therapist and occupational therapist worked very closely together.

The twins were seen once a week for about two years. They were reevaluated every three months, and home programs were consistently reviewed and issued. At five years of age, the twins today are happy, well-adjusted boys attending preschool, eating meals, and playing as other children their age do. The following is a summary of what the boys' mother Deb stated when asked about the boys' behavior and "idiosyncrasies":

- Anything new is scary for the boys.
- They cannot stand having a dirty mouth or hands while they are eating.
- They have never said they are hungry or want to eat.
- At Halloween, we had to make sure we had a costume with no hat or mask for Baby B. The boys will not wear full-face masks.
- Both boys seem overreactive to pain; even the tiniest of scratches are bothersome.
- They seem to be doing well in preschool. Baby A has a special cushion and box for his feet so he fits better in chairs and gives him better posture. I think his trunk strength is still lacking a little.
- Both boys are on individualized education plans because they are behind in some areas—mostly social and some physical.

OT reinforced to Deb that her focus should be on those things that really matter and let some of the other things go.

Does it matter that the boys will not wear a mask or that they do not want to be messy when eating? Many full-term children have their own set of idiosyncrasies parents must deal with daily. It is important to work on those skills that will impair the daily living of these young children.

It is significant to keep in mind that these boys developed in a superb environment. The family was highly involved, highly educated, and persistent beyond imagination. They exposed the twins to various experiences and showered them with love and attention. And yet, the process was slow and deliberate. Not all former preterm infants are in this type of engaging environment.

What can NICU professionals do to improve outcomes for premature infants like Baby A and Baby B? The answers are actually quite numerous. The idea of neuroprotection is not new to the medical field but is a fairly new idea to the NICU. Neuroprotection encompasses all interventions that promote normal development of the brain and prevent disabilities after neuronal injury and allow the brain to heal itself by developing new pathways and connections.<sup>27</sup> The long-term developmental types of disability in premature infants can be described, perhaps, as a disease of neuronal connectivity.<sup>27</sup> Interventions and treatments that support adaptive neuronal connectivity or "mapping" are best for these infants. Therefore, it is the job of NICU personnel to support those processes that protect the developing brain by decreasing stress through facilitating of coping skills (flexion, containment, hands to head or mouth, non-nutritive suck, grasping, leg/foot bracing), promoting sleep through proper positioning, educating parents and NICU staff to read infant cues, providing positive touch techniques, and promoting kangaroo care and parent involvement. Brain-oriented care allows caregivers to impact the developing brain with each and every interaction, keeping in mind that the brain is wiring at 40,000 connections per minute.<sup>2</sup> Brain-oriented care allows the brain to wire in an adaptive versus maladaptive way. Here are specific techniques one can use to facilitate brain-oriented care:

1. Nurses and other NICU medical personnel can decrease pain through the use of sucrose<sup>28</sup> on the pacifier and/or facilitation of coping skills every time the infant encounters a painful experience—not just when the parents are watching. It is important to note that sucrose used often over a long NICU stay has not been well studied. Before clinicians decide on the repeated use of sucrose for pain management in preterm infants, more research is needed because the mechanisms of action of sucrose in human infants are not well understood.<sup>29</sup> In the meantime, Holsti and Grunau urge clinicians to use sucrose "cautiously and to use other nonpharmacologic comfort measures."<sup>29</sup> Other nonpharmacologic measures (coping skills) include but are not limited to non-nutritive suck, grasping a finger, flexion of the body, containment, hands put to the head or mouth and leg/foot bracing.<sup>16</sup>
2. Promote kangaroo care. The research is extensive, and the benefits to both baby and mother are numerous.

“Kangaroo care is now considered an essential therapy to promote growth and development of premature infants and their brain development.”<sup>30</sup>

3. Teach parents and caregivers how to read infant avoidance cues and how to facilitate coping skills in response. In this way, stress is decreased, and the brain is protected.<sup>16,31</sup>
4. Teach parents positive touch techniques such as massaging their baby’s foot one time per day for one or two minutes as a “buffer” to the negative sensory experience of daily heelsticks.<sup>32</sup>
5. Teach parents to massage their infant’s face (once they can tolerate it) to buffer the negative sensory experiences the infant has encountered on the face and mouth.<sup>33</sup>
6. Involve parents in all aspects of their child’s care. In a longitudinal study where mothers were taught how to reduce stress in their premature infants, IQ scores were more than ten points higher than the nonintervention group.<sup>34</sup> Furthermore, Milgrom and colleagues showed enhanced brain development and connectivity on MRI scans at full-term equivalent age when mothers in the NICU were taught how to facilitate coping and decrease stress in their premature infants.<sup>35</sup>
7. Provide deep pressure and infant massage techniques to help develop the central nervous system while providing a positive touch experience. Touch and proprioceptive input actually allow the central nervous system to develop and grow.<sup>36</sup> Infant massage is critical to the success of any NICU program promoting developmental and family-centered care. This requires a nurse or therapist to be certified to teach infant massage. Certification programs are available nationally and internationally. Every family should learn infant massage prior to discharge. The research is extensive, and the gift to the baby is priceless.
8. Deliver therapeutic interventions by sensory system development. According to Blackburn, brain development and sensory development are closely linked.<sup>37</sup> The sensory/perceptual system develops in the following developmental sequence: tactile and proprioceptive, vestibular, chemoreceptive (taste and smell), auditory, and visual. Timing of sensory input and unimodal sensory input is important in the delivery of treatment. “If incoming stimuli are not timed appropriately, there may be effects on later developing sensory systems and behavior.”<sup>38</sup> Begin with static positive touch (e.g., containment holds) and work your way up to vestibular input (i.e., rocking in a chair) and even tummy time. Remind parents to not rock in the chair when first attempting to feed their baby. The baby should only have to simulate the sensory experience of feeding without integrating the vestibular input of rocking. Once the preterm infant is nearing 36 weeks of age, he should be able to “integrate” multimodal stimulation. However, every infant is different, and caregivers must follow infant cues when initiating multimodal stimulation.
9. Infant-driven not volume-driven feeding is critical in avoiding feeding aversions later on. “In an infant-driven culture, safety is the primary goal, and feedings are nurturing and engaging without signs of distress. In these units, feeders stop when the infant communicates being done, and the focus is on quality not quantity.”<sup>39</sup> Never force an infant to take increased volume. This must be continuously reiterated to nurses and families.
10. Caregivers and especially parents should talk to the preterm infant. Although it is known that alarms and high-decibel sounds are not good, soothing sounds and talking to the preterm infant are critical to auditory processing and language development.<sup>40</sup> Because nurses tend to be task-oriented, this may need to be practiced to become “routine” during caregiving tasks. Caskey and colleagues showed that infants whose parents talked to them had increased vocalizations while in the NICU.<sup>41</sup>

## NOTES

The preceding techniques are used in our NICU daily. It should be noted that Baby A and Baby B were not in our NICU. When infants come to me as outpatients from our unit, there are little to no sensory impairments, although motor impairments may be present (no formal research has been done, however). Most pediatric therapists would agree that sensory impairments are much more difficult to overcome, affect motor development, and make the length of time in outpatient therapy greater in many cases. Brain-oriented care is a practice all NICU caregivers should embrace for best developmental outcomes.

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