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The role of the microenvironment: the influence on touch patterns experienced by the vulnerable newborn

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At a Glance

A sizable number of newborns require intensive care. In 2001, there were 4,040,121 live births in the United States. Of these, 7.6%, or approximately 300,000 infants were born at less than 37 weeks gestation. Presumably, many of these infants required hospitalization in a Neonatal Intensive Care Nursery (NICU) for treatment of complications related to prematurity. To this census, several thousand term and postterm newborns must be added who required care for conditions such as meconium aspiration, infection, drug withdrawal, perinatal asphyxia, or congenital anomalies.[1]

More than 15 years has passed since experts like Als, and later, Gottfried and Gaiter introduced the notion of developmentally appropriate care to the field of neonatology.[2, 3] At a time when many practitioners were focused on technological achievements and treatment of abnormal medical conditions in a relatively young discipline, few recognized the importance of the environment. Advances in prenatal and neonatal care have markedly improved survival rates compared to a fifteen years ago, especially in infants born at <32 weeks gestation.[1] These reductions in mortality are at least partly because of better understanding of neonatal diseases, enhanced technology and medications, and improved care for extremely low birth weight infants. The development of surfactant therapy has probably accounted for the most significant increases in survival realized by extremely low birthweight (ELBW) infants. Despite these advances, a recent study shows an incidence of severe neurological impairment approximating 40% in surviving infants with birth weights <1000 grams.[4]

Developmental care is a concept that continues to receive the timely attention it deserves. Experts have suggested that contemporary management of newborns may be partially responsible for some of the morbidity seen after intensive care. Hence, there is a clear and present continuing trend towards environmental neonatology – a science that considers the ecological community surrounding the infant and its influence on morbidity and mortality. Certainly, environmental neonatology is less defined than traditional neonatology. Successful transition to this type of newborn care embraces a developmental focus and requires synthesis of certain tenets of the philosophy into the cultural fabric of the intensive care nursery. Among these components is knowledge of central and autonomic nervous system developmental processes, understanding of potentially detrimental aspects of the intensive care environment, and the ability to discern optimal and suboptimal individualized physiological and behavioral responses of the medically fragile infant as he or she interacts with the extrauterine environment and its caregivers.

Contrasting Environments: Intrauterine Versus Extrauterine Life

Development of human sensory pathways proceeds dynamically from conception through early infancy. Research shows that cutaneous, or tactile, pathways structurally and functionally develop during the first trimester of pregnancy. These are followed by evolution of vestibular-proprioceptive, olfactory (smell), gustatory (taste), and nociceptive apparatus during the early second trimester. Finally, the auditory and visual sensory modalities become differentiated, though not fully functional during late second trimester. Visual capabilities are probably not completely realized until 52 weeks postconception, upon myelination of the optic nerve.[5]

Throughout pregnancy, the fetus survives, and presumably thrives, in a warm, dimly illuminated, fluid-filled environment. This does not mean an absence of extraneous stimulation exists. The fetus is regularly subjected to considerable rhythmic acoustic stimulation from the mother's cardiorespiratory system through cardiac contractions, pulsatile blood flow, and ventilatory efforts. Intermittent noise emanates from her gastrointestinal tract as foodstuffs are digested. In addition, extraneous voices regularly permeate the uterine wall to reach the fetus. Vestibular-proprioceptive excitement occurs as the fetus is moved around a great deal. The gravid woman bounces, rocks, or gently turns her growing fetus each time she runs, walks, or turns. During the third trimester, tactile stimulation occurs almost constantly as the uterine walls come into direct contact with the fetus. All of these sources of stimuli are heavily influenced by maternal biorhythms and her sleep-wake cycles.[6]

Extrauterine life changes the quantity, quality, and rhythmicity of the stimuli that reaches a neonate's sensory receptors. With the advent of birth, those characteristics of the NICU macroenvironment, which tends to be brightly lit and noisy, replace the characteristics of womb-like microenvironment. Furthermore, a radiant warmer or an incubator microenvironment replaces the convective thermal characteristics of the uterus. These changes occur a time when the human newborn is poorly equipped from a physiological and a behavioral perspective to cope with the experience offered by the extrauterine environment. Hence, some conceptualize the intensive care setting as an integration of stimuli that is simultaneously sensory deprivating, sensory over-stimulating, and sensory dissociating. The exposure of immature sensory apparatus to any of these types of insufficient, excessive and/or inappropriate extrauterine stimuli has the potential to promote formation of mal-adaptive responses in the medically fragile population, compromising optimal growth and development. As previously stated, it is the central nervous system that seems to account for the preponderance of postnatal morbidity. This morbidity may occur because some critical steps in human cortical brain development take place between 18 and 37 weeks gestation (see Table 1), the precise time when many infants are forced to make the premature transition to extrauterine life. Animal studies have shown that several of these steps can be modulated by environmental stimuli. Therefore, it is not difficult to understand that brain architecture may be permanently affected after birth if exposed to a combination of potentially deleterious factors.[5, 7, 8]

Table 1:
Critical Steps in Human Cortex Development

- Proliferation of neurons
- Migration of neurons
- Differentiation of cells
- Axonal growth
- Dendritic formation
- Synaptogenesis
- Programmed cellular death (selected neurons)
- Myelination

Handling and touch patterns are types of stimuli that evoke considerable controversy in the NICU. Some types of handling are medically necessary to ensure survival of the infant. Other types of handling and touch are to be encouraged, contingent upon the ability of the infant to cope with such an event. Still other experts suggest that handling should be "minimized" during the first few critical postnatal days, as one application of developmental care. In the absence of clear evidence, Peters (1999) noted that there has been little modification in the "handling frequency, patterns, and trends established in the mid 1970s, and that the principles of developmental care (e.g., 'decreasing infant disruptions and handling by caregivers, and modulating or attenuating infant responses to the care they receive.' p 86) are still not being followed.[9] To place this in the perspective of clinical practice, most infants receiving care in intensive care nurseries still making the transition to environmental neonatology continue to be subjected to a dry, bright, noisy setting that is largely free of diurnal variations in which excessive handling and detrimental touch is still a common practice in 2002, despite significant financial resources being spent on nursery design and/or re-design by hospital administrators.

Figure 1

A mother's gentle touch.

The Impact of Touch

Touch patterns and their impact on the newborn cannot be overemphasized. It is this sensation that provides the foundation for complex and intimate exchanges between the infant and his or her caregiver/parent. Touch offers the newborn with a fundamental interpretation of the world and the relationships on which he or she will come to depend upon for survival. For a term infant, touch serves to provide the foundation for a nurturing, protective attachment relationship between the primary caregiver (usually a parent) and the infant. In the absence of this foundation, problems surrounding learning as well as social and emotional competency have been documented.[10]

Does the absence of such positive interaction impact the preterm newborn or the term newborn that requires NICU admission? Researchers who study preterm human infants have reported that these infants receive very little comforting touch during their early days of life in the NICU. Most of the touch that preterm infants experience is associated with medical or nursing procedures (procedural touch), and is not contingent on the infant's cues indicating an ability to cope with such interaction.[11, 12, 13]

Essentially, observation and clinical experience suggests that there are two predominant types of touch in the intensive care setting. One type of interaction is recognized and encouraged: "beneficial " or non-negative touch in which no adverse physiological or behavioral effects are documented. Stroking, massaging, and comforting touch are subsumed within the category of "beneficial" or positive touch.[14, 15, 16, 17] It is generally social in nature (see Figure 1). Most developmental experts recognize the importance of this type of interaction in fostering optimal physiological and behavioral outcome.

The other type of handling may be considered "aversive" or negative touch in which physiological and behavioral effects can be documented. This latter type of touch is generally connected to nonsocial, diagnostic, or procedural in nature (see Figure 2).[7, 18, 19] More recent evidence suggests that such "routine" procedures may be extremely complex. For example, successful first-attempt peripheral venipuncture requires a minimum of 7 steps:

- Site identification
- Tourniquet placement
- Site preparation
- Site cannulation
- Tourniquet release
- Site taping
- Site stabilization

Unfortunately, procedures represent the preponderance of contacts between caregivers and newborns. Experts have documented that these interactions may occur 40 to 100 times each day for 2 to 5 minutes each episode. Even more disturbing is that the interruptions have been documented as often as every 18 to 30 minutes. This means that a compromised newborn may be subjected to 2.5 to 3.5 hours per day of nonsocial touch.[7] Others have observed that this type of excessive handling is one of the most common causes of hypoxemia in the intensive care nursery and may heighten any pain associated with procedural interventions.[18, 19, 20] It is also not unusual for medically compromised infants to be handled and not talked to, or to be positioned in such a such that they cannot see their caregivers during handling. As previously reported, this results in disjunctive processing of multimodal sensory experiences which may have significant implications for formation of maladaptive behavioral responses.[11, 21]

Figure 2

Typical 1st day procedural touch.

Adaptation/Maladaptation to Noxious Stimuli

Whenever an infant is exposed to noxious environmental stimuli, there is some attempt on the part of the infant to modify physiological or behavioral responses in order to restore equilibrium between the self and the environment. However, the success of these self-regulatory actions without compromising the function of either the physiological or behavioral subsystems is largely dependent on the immaturity of the infant or severity of illness. That is, the more immature or sick the newborn, the less likely the infant will be successful at restoring balance without outside assistance. This is commonly referred to as maladaption. Maladaptive physiological and behavioral indicators may include clinical signs such as alterations in heart and respiratory rate and rhythm, color changes, random or erratic body movements, back arching, feeding intolerance, irritability, gagging, gasping, hiccupping, sneezing, finger splaying, hyperextension of extremities, staring, worried alertness, gaze aversion, increased crying or disorganized state control. This does not represent the full spectrum of maladaptive behaviors. For a more detailed list, one should consult a more comprehensive resource.[21]

Goals of the Study

The primary purpose of this study was to evaluate the effect of the type of microenvironment on the touch patterns experienced by newborns during the first three days of life. Despite the acceptance of developmentally focused, family-centered care, exposure to excessive handling in neonatal ICUs remains an important problem for critically ill newborns. While some types of touch are needed and/or may be beneficial to the infant, most handling is considered stressful. A few studies reporting frequency of touch exist, the touch pattern as a function of the type of microenvironment. For the purpose of this study microenvironments are defined as radiant warmers, incubators, or open cribs. Differences in touch patterns, as a function of the type of microenvironment is still to be determined. Three research questions were proposed for the purposes of this study:

- What are the touch/handling patterns of nonsocial/procedural touch versus social/comfort touch in the nursery during the first three days of life?
- Do touch patterns differ as a function of the type of microenvironment?
- Does physiological stability differ as a function of the type on microenvironment during procedural touch?

Figure 3
Baby #23.

Methods

Settings

This study was conducted in a uniform manner at two different tertiary, university-affiliated NICUs. Setting A was a 48-bed regional center located in a southeastern U.S. metropolitan hospital. Setting B was a 71-bed referral center located in a midatlantic academic facility. In both these settings, newborns are delivered in labor and delivery and transported by transport incubator (Airborne 185A) to the NICU. Thermostats and hydrostats controlled the thermal characteristics (temperature and relative humidity) of each respective NICU macroenvironment. Registered nurses cared for all infants. The attending physician and a pediatric resident or neonatal nurse practitioner managed the infants' medical care collaboratively.

Sample

A convenience sample of sixty-two infants was included in this study (Figure 3). Selection criteria included:

- 23 to 42 weeks gestation
- Appropriate for gestational age (birth weight greater that the 5th percentile and less that the 90th percentile for gestational according to Ballard methods)
- 1-minute APGAR score >1
- 5-minute APGAR score >3
- Intubated and mechanically ventilated
- Expected survival >14 days
- Written informed consent

Table 2: Sample Characteristics			
Characteristics	**Giraffe N = 20**	**Incubator N = 21**	**Radiant Warmer N = 21**
Gender	12 girls; 9 boys	7 girls; 12 boys	11 girls; 9 boys
Birthweight	1421 + 833.8 g (535-2892 g)	1655.4 + 1016.2 g (545-3320 g)	1381 + 951.8 g (525-4100 g)
Gestational age	30.1 + 2.8 weeks (24-38)	30.8 + 3.9 weeks (25-28)	28.9 + 2.1 weeks (23-41)
Apgar @ 1	7.0 ± 2.0	6.2 ± 1.9	3.8 ± 2.1
Apgar @ 5	6.0 + 2.0	8.0 ± 0.9	7.0 ± 1.7
SNAP	14.0 ± 3.0	13.0 ± 4.0	15.0 ± 2.0

Exclusion criteria included:

- Major skin anomaly which might impact cutaneous sensation
- Major chromosomal disorder
- Major congenital anomaly

Subjects ranged from 535 to 4100 grams and 23 to 41 weeks postconceptual age at the time of birth. This was a pilot study; therefore no sample size calculation was undertaken. Characteristics of the infants are summarized in Table 2. All infants received a standard parenteral fluid regimen of 80 cc/kg/day and prophylactic antibiotics during the study period. Four infants required pressor support for hypotension, receiving 5 to 8 mcg/kg/minute. Chi-square analysis showed no difference in pressor requirements between the treatment groups. All subjects also required thermal support to maintain heat balance and prevent cold stress.

Design

A randomized, prospective experimental design was selected for the study. The independent variable was the type of microenvironment. Infants were assigned to receive nursing and medical care in either a radiant warmer (Ohio* IWS 4400), an incubator (Care Plus* 4000), or a newly developed combination type bed capable of converting from radiant warmer to incubator and back (Giraffe* OmniBed*). Data were collected from the time of transfer into the designated microenvironment and lasted for 72 hours. All subjects were retained for the length of data collection.

Procedure

Both hospitals institutional review boards approved the study proposal. All prospective infants admitted to the neonatal intensive care unit of each facility were evaluated for inclusion criteria. If the parents agreed to participate, they received an explanation of the study and informed consent was obtained within 4 hours after birth. Maternal and neonatal demographic information was collected from the infant's medical record. Subjects were randomly assigned by blinded envelope assignment to type of microenvironment. Infants were admitted and stabilized. Specifically, the letters RW for radiant warmer, I for incubator, or G for combination type bed were written on separate sheets of paper and sealed in letter-sized security envelopes. All initial invasive procedures were performed on a radiant warmer bed (IWS 4400). On completion of the admission procedures, the baby was placed into one of the three microenvironments. Frequency, duration, and reason for such intervention between caregiver or parent and infant were recorded on a data collection sheet developed for the purposes of this study. Each interaction was classified as nonsocial (negative and/or procedural) or social (non-negative and/or non-procedural). Additionally, the person involved in the intervention was also documented (parent caregiver or clinician caregiver). To verify the accuracy of such data collection methods, the primary investigator also manually coded intervention episodes and procedures with a descriptive even marker to record the initiation and completion of each episode. For the first ten infants enrolled in the study, percent agreement between self-report methods and bedside investigator observation methods was 0.96. Therefore, for the remaining 52 subjects, the self-report method of touch documentation was deemed acceptable. Infant physiological responses (heart rate, respiratory rate, blood pressure, and oxygen saturation) during such interventions were collected by automated methods from a Spacelabs Ultraview 1050 physiological monitor connected by an RS-232 serial port to a laptop computer every minute for 72 consecutive hours (Figure 4). All data were downloaded into a spreadsheet format for statistical analysis.

Analysis

Demographic data were collected on several maternal and neonatal variables and analyzed by descriptive means to provide information on mean scores, variance, and value ranges. Chi-square methods or analysis of variance was performed on demographic variables, as appropriate, depending on the level of data under consideration. Frequency and duration of each intervention episode were analyzed descriptively to yield information about category and type of touch as well as total number and duration of hourly touches. Differences in touch type (positive and or social touch) were analyzed by independent t-test. Analyses of Variances (ANOVA) were calculated to determine if differences between the groups as a function of microenvironment existed. Physiological data collection and analysis were facilitated by the computerized data acquisition system. All physiological comparisons were examined through Multiple Analyses of Analyses of Variance (MANCOVA), controlling for differences in illness acuity as measured by Scoring for Neonatal Acute Physiology (SNAP). All statistical and mathematical analyses were performed with Statistica for Windows (StatSoft Inc, Tulsa, OK) and SPSS-PC (SPSS Inc, Chicago, IL) software programs. A P value <.05 was considered statistically significant.

Results

Patients Enrolled

Sixty-two newborns were enrolled in the study and all were retained throughout the 72 hours of data collection. Group #1 infants (n = 21) received 72 hours of continuous care in an IWS 4400; Group #2 infants (n = 21) received 72 hours of continuous care in an Care Plus Incubator, Model 4000; Group #3 infant (n = 20) received 72 hours of continuous care in a Giraffe OmniBed which could be transformed from radiant warmer to incubator and back again, at the touch of a button at the discretion of the clinician caregiver. No attempt was made on the part of the investigator to influence the choice of Giraffe bed modality (i.e., incubator versus radiant warmer).

Figure 4
Data collection system.

Baseline Data

Analysis of demographic data (Table 2) showed no significant differences between the three treatment groups on the target demographic variables.

Outcome #1: Touch/Handling Patterns – Nonsocial versus Social

Ninety-two percent (92%) of all touch during the first 72 hours was nonsocial, negative, procedural touch ($p = .0001$). Clinical caregivers were the total source for this form of touch. These types of interactions included, but were not limited to resuscitation, endotracheal intubation, suctioning, physical transfer of baby from one bed to another, intravenous cannulation, intramuscular injection, diaper changes, and bed linen changes. Only 8% of the touch offered during the period of data collection was social, positive, non-procedural touch. When examining the sources of the positive interaction, parent caregivers accounted for 95% of this form of touch while clinician caregivers accounted for only 5% of the positive touch ($p = .003$). These types of interactions included repositioning, nutritive and non-nutritive suckling, comfort touches such as facilitated tucking, cuddling, massage, and skin-to-skin contact between parent and child.

Outcome #2: Type of Microenvironment as an Influencing Factor

Data analysis (Table 3) showed infants were handled an average of 37% more in a traditional radiant warmer compared to a traditional incubator. In the Giraffe OmniBed, infants were handled an average of 39% more than when the bed was converted to incubator mode. It should be noted though, that in both modalities, the

Table 3: Touch Pattern Data					
Variables	**RW**	**I**	**Giraffe/RW**	**Giraffe/Inc**	**P-value**
Number of touches (hourly)	6.9	4.4	3.1	3.2	.005
Duration of touches (minutes)	1.5	2.8	1.6	2.1	.02
Total touch time (min/hr)	10.4	12.3	5.0	6.7	.001

Table 4: Physiological Responses to Handling				
Variables	**Pre-Procedural Touch**	**Intra-Procedural Touch**	**Post-Procedural Touch**	**P-value**
Mean heart rate	138	151	140	.03
Mean respiratory rate	44	51	45	.01
Mean blood pressure	38	44	39	.01
Mean SpO2	98	91	96	.02

infants in this study group were handled fewer times than in the traditional microenvironments. These differences in number of touches as a function of type of micro-environment were statistically significant (p = 0.005).

Findings duration of caregiver disruptions were significantly different depending upon the type of microenvironment. Though actual numbers of touches were less in both a traditional incubator as well as Giraffe OmniBed (incubator mode) compared to a traditional radiant warmer, the actual duration of each episode was actually longer in the incubator configurations compared to analogous radiant warmer configuration (p = 0.02). The net effect was that total touch time was significantly different as a function of the microenvironment (p = 0.001). Hourly touch time was actually greatest in a traditional incubator (12.3 minutes per hour) followed by a traditional radiant warmer (10.4 minutes per hour) and a Giraffe OmniBed in radiant warmer mode (5.0 minutes per hour). Total touch time in the Giraffe OmniBed, incubator mode was 6.7 minutes per hour. Post hoc analyses revealed that total touch time in both Giraffe configurations were significantly lower that traditional bed types.

Outcome #3: Physiological Implications of Handling/Touch

Table 4 shows that untoward physiologic responses occurred during necessary medical interventions, reaching maximum impact at procedural midpoint. Results were statistically significant for each of the measured variables of heart rate (mean rise 13 beats per minute, p = .03), respiratory rate (mean increase 7 cycles per minute, p = .01), mean blood pressure (mean increase 6 mmHg, p = .01), and mean SpO2 (mean decrease of 7%, p = .02). Future data analysis will examine such data through repeated measures MANOVA with two between subjects factors (type of touch and type of microenvironment) and one within subjects factor (time).

Discussion

The results of our study suggest that type of micro-environment in which the infant receives his or her care during the first 72 hours of life clearly has clinical implications. It was demonstrated that parents play the most important role in providing social, non-negative, non-procedural touch in the first 72 hours of life. This supports the validity of their role in the early postnatal days with respect to care of their infant. Results also support commentary that notes that the patterns of clinical touch have not changed despite increased emphasis on developmental care. Clinicians continue to offer predominately procedural touch which little comfort interventions during the first 72 hours of life. The potential impact on blood pressure in a human without cerebral autoregulatory capabilities must be fully understood by clinicians going forward. It also seems prudent to recommend that clinicians must learn to balance their touch patterns based upon individualized responses displayed by the vulnerable newborn and to work towards a goal of providing more social, comfort measures to facilitate and promote physiological and behavioral stability. It is also not surprising that the number of touches and physiological responses differ between various types of microenvironments. Many nurseries around the world admit directly into an incubator micro-environment from the time of birth or transfer the infant into this type of bed soon after birth for the purpose of "protecting" the infant from the NICU macroenvironment and its sources of excess stimuli. The presence of the plexiglas wall probably acts as a physical barrier to sub-consciously inhibit unnecessary touches. A significant number of touches come during repositioning a baby during procedures such as IV insertion endotracheal intubation and suctioning. It was expected that findings would show that the number of touches in the Giraffe radiant warmer would parallel the number of touches in a traditional radiant warmer and that the number of touches in the Giraffe incubator mode would parallel the number of touches measured in the traditional incubator. Furthermore, it was expected that the true touch savings to the infant would be in the fact that for those nurseries that preferred radiant warmer care for sick newborns, the infant now could be enclosed within an incubator sooner and that the number of touches (negative, procedural, or non-social) would directly decrease as a function of the conversion from radiant warmer to incubator sooner compared traditional radiant warmer-to-incubator care practices.

Results showed some interesting patterns when data were examined in terms of total hourly touch time. It was expected that the amount of total amount of time spent in contact with an infant on an hourly basis would be greater in the radiant warmer than an incubator, whether traditional radiant warmer or Giraffe in radiant warmer mode. In fact, the analysis did not support such findings. Post hoc analysis showed that total touch time was less in the Giraffe microenvironment whether radiant warmer or incubator mode. Videotape and photographic analysis of procedural touches seems to suggest that the rotating mattress decreased a portion of these touches (Figure 5). Procedures were accomplished in a more timely fashion with greater success achieved on the first attempt by the clinician. Therefore, a simple product innovation may actually serve to decrease the difficulty of the procedure, a concept known as procedural ardor. Implications for future research suggest that future data analysis is still required. Such analysis will examine such data through repeated measures MANOVA with two between-subjects factors (type of touch and type of microenvironment)

Figure 5
Enhanced procedural success with Baby Susan.™

and one within-subjects factor (time) to determine if the current findings withstand more rigorous scrutiny. In addition, data analysis for impact of negative and positive behavioral responses to touch and handling should also be included in the next phase of the project.

Conclusion

In the NICU, medically fragile newborns are exposed to a variety of visual, auditory, and tactile stimuli that would be attenuated or absent within the mother's womb. The precise consequences of such stimulation are largely unknown. It seems reasonable to pursue the goal of avoiding excessive handling and inappropriate touches due to previously documented physiological effects of procedural handling. The hypothetical effects on architectural modeling of the brain cannot and should be minimized.[8] Therefore, it is prudent that device manufacturers recognize the important role that the microenvironment plays in the impact of excessive stimuli and seeks ways to purposefully design out such features which may have a detrimental impact on the infant and to incorporate features which might positively influence the developing extrauterine fetus.

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