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Infant Neurobehavioral Development

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The trend toward single-room neonatal intensive care units (NICUs) is increasing; however scientific evidence is, at this point, mostly anecdotal. This is a critical time to assess the impact of the single-room NICU on improving medical and neurobehavioral outcomes of the preterm infant. We have developed a theoretical model that may be useful in studying how the change from an open-bay NICU to a single-room NICU could affect infant medical and neurobehavioral outcome. The model identifies mediating factors that are likely to accompany the change to a single-room NICU. These mediating factors include family centered care, developmental care, parenting and family factors, staff behavior and attitudes, and medical practices. Medical outcomes that plan to be measured are sepsis, length of stay, gestational age at discharge, weight gain, illness severity, gestational age at enteral feeding, and necrotizing enterocolitis (NEC). Neurobehavioral outcomes include the NICU Network Neurobehavioral Scale (NNNS) scores, sleep state organization and sleep physiology, infant mother feeding interaction scores, and pain scores. Preliminary findings on the sample of 150 patients in the open-bay NICU showed a "baseline" of effects of family centered care, developmental care, parent satisfaction, maternal depression, and parenting stress on the neurobehavioral outcomes of the newborn. The single-room NICU has the potential to improve the neurobehavioral status of the infant at discharge. Neurobehavioral assessment can assist with early detection and therefore preventative intervention to maximize developmental outcome. We also present an epigenetic model of the potential effects of maternal care on improving infant neurobehavioral status.
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The prevalence of preterm birth in the United States is a significant public health problem that has increased in the last decade. Prematurity rates, which have increased steadily since the early 1980s, have shown a slight decrease in the United States to 12.3%. Even so, 1 in 8 infants, or more than 500,000 per year, are premature, and there continues to be a parallel increase in the risk of adverse health outcomes and multiple disabilities.[1-4] Advances in perinatal and neonatal care, such as administration of antenatal steroids and surfactant, have improved survival rates for preterm infants. However, the increase in survival is accompanied by a parallel increase in the risk of adverse health outcomes and multiple disabilities.[1-3,5] In 1991, Escobar and colleagues[6] reported on a meta-analysis of 111 outcome studies of very low birthweight infants (<1500 g at birth), citing a median incidence of disability of 25%.

During the past decade, as survival of infants <1000 g has become more prevalent, investigators continue to report a litany of sequelae related to prematurity and low birthweight, including respiratory, gastrointestinal, immunologic, central nervous system, hearing and vision, and longer-term motor, cognitive, behavioral, and social emotional problems.[3,7-12] Work from our group in the National Institute of Child Health and Human Development Neonatal Research Network found that nearly one-half (49%) of infants born at birth weights <1000 g went on to have abnormal neurodevelopmental and/or sensory findings at 18-22 months of age.[13] Thirty-seven percent of the study cohort had significant cognitive delays, and 29% had significant motor delays. These infants suffer serious health consequences and their families carry an enormous emotional burden.[13,14] In a more

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recent meta-analysis of very low birthweight infants the focus was on more narrow band behaviors and specific areas of function.[15] This analysis showed substantial effect sizes (d statistic) in areas, such as spelling ($D = 0.76$), attention ($D = 0.59$), and verbal fluency ($D = 0.57$). Thus, these infants are also at risk for more subtle deficits that could broaden the impact of very low birthweight on the individual and on society.

Although the range of morbidity in preterm infants is due, in part to the immaturity of their organ systems and their disease states, there is mounting concern that this morbidity may be compounded by an unfavorable environment in the neonatal intensive care unit (NICU). Large variations in outcomes exist among NICUs that cannot be explained by patient mix or other characteristics, such as volume and level of care.[16] The determinants of high-quality NICU care need to be better understood to improve the health and development of NICU survivors.

Recommendations for NICU private rooms emerged in the 1990s.[17,18] It has been suggested that caring for infants in individual private rooms in a NICU, in contrast to the open-bay environment in which most infants are cared for, may provide the type of high-quality care and physical environment that will lead to improved infant outcome.[19,20] Some NICUs have designated a portion of their space for single-room care; however, there is some inconsistency in the types of patients assigned to these spaces. For example, some nurseries use the single-room spaces for their convalescing level II infants, allowing families an opportunity to room-in before discharge. In this model, infants are treated in the open-bay environment until they are physiologically prepared for discharge. Other units assign their more critically ill infants to the single rooms, moving them out to small open-bays when they become more stable. Still others assign most ventilator-dependent infants to the open-bay environment.[20] To date, only a modest number of NICUs in the United States have converted all levels of care exclusively to single-family-room care. In the first published report of the benefits of a single-room NICU, Walsh and colleagues[20] conducted a retrospective analysis after the move to a single-room NICU and reported a decrease in nosocomial infection rates. In surveys conducted in the same NICU, 6 months before and 6 months after the transition to the private room, nurses reported increased job satisfaction, team member support, and validation of individual opinions. Parents reported improvements in privacy, noise, and lighting in the NICU.[21] Clearly there is a paucity of research in this area.

The Single-Room NICU

The NICU is the first extrauterine environment for an increasing number of preterm infants. Critically ill infants require prolonged NICU stays; sometimes as long as 5 months, yet the typical NICU environment could be stressful for infants and their families.[22-24] Most NICU patients continue to be cared for in an open-bay environment, in which the sensory impact of the NICU may adversely affect infant outcome.[17,25-27] Stimulation in the NICU, such as light and sound, have been related to adverse outcome in preterm infants.[28-34] We[35] documented sound levels in our open-bay NICU and found that the sound levels rarely dropped to less than 60 dB and often exceeded 70 dB despite the American Academy of Pediatrics recommended maximum level of 45 dB.[36] Sound control and other interventions, for example, light reduction, may improve infant medical and neurobehavioral outcome.[37-39] The single-room NICU is a strategy that could address environmental concerns and minimize iatrogenic effects by reducing the risk of infection and stress on the preterm infant. Although participation of families in the care of family members receiving critical care has become the accepted standard, and single-room care has long been considered the optimal environment for critically ill adults,[40] only in the past decade has this consideration been expanded to include neonatal intensive care.

Our primary interest is the impact of the single-room NICU design on improving the medical and neurobehavioral outcome of the preterm infant. The single-room NICU provides control over several factors that could improve these outcomes, such as those associated with hospital-acquired infections.[17,25,41] Rates of nosocomial infection increased significantly when infants were moved to a less-spacious, temporary NICU, and subsequently decreased when infants were moved to a newly constructed facility with an improved sink-to-bed ratio.[42-49] Late-onset bacterial sepsis, a serious complication of NICU care, is known to be related to prolonged treatment with central catheters, prolonged time on parenteral nutrition, delayed initiation of enteral feedings and a prolonged period to reach full enteral feeds.[17,25,50] Care of high-risk infants in a single family room may promote care practices that impact some of these associations and ultimately impact rates of late onset sepsis. The Vermont-Oxford Neonatal Network has used a quality improvement approach to identify best practices related to nosocomial infection (eg, practices related to hand washing, nutrition, skin care, respiratory care, vascular access, etc) and were able to demonstrate a reduction in late-onset sepsis in participating NICUs.[50] Single-family rooms promote better practices for infection control by avoiding overcrowding, providing areas for hand washing within each room, creating an atmosphere that promotes breastfeeding, and providing a more controlled environment for placement of intravascular catheters. In 2 unpublished reports, Oelrich noted an increase in nosocomial infection with the change to single family room care, whereas Rosenblum reported an 11.8% reduction in documented bacterial and fungal infections.[51,52] Clearly, there is question of whether single-room NICU design is a significant factor in reducing hospital-acquired infection.

There are other medical outcomes that may also improve in a single-room NICU. Necrotizing enterocolitis (NEC) is a serious condition of unknown etiology that is more prevalent among the smallest and most fragile infants. Ischemia and/or reperfusion appear to play a significant role in the development of NEC. Temporal and spatial clustering is often present in an outbreak in the NICU, suggesting the possibility of an infectious etiology. Human milk-fed infants seem to be protected from fulminant NEC.[53,54] The single-room NICU aim of reducing infant stress has the potential to im-