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Neurophysiologic assessment of brain maturation after an 8-week trial of skin-to-skin contact on preterm infants ☆

Mark S. Scher [a,*], Susan Ludington-Hoe [c], Farhad Kaffashi [b], Mark W. Johnson [a], Diane Holditch-Davis [d], Kenneth A. Loparo [b]

[a] Department of Pediatrics, Rainbow Babies and Children's Hospital, Cleveland, OH, USA
[b] EECS Department, Case School of Engineering, Case Western Reserve University, Cleveland, OH, USA
[c] Frances Bolton School of Nursing, Case Western Reserve University, Cleveland, OH, USA
[d] School of Nursing, Duke University, Durham, NC, USA

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ABSTRACT

Objective: Skin-to-skin contact (SSC) promotes physiological stability and interaction between parents and infants. Analyses of EEG-sleep studies can compare functional brain maturation between SSC and non-SSC cohorts.

Methods: Sixteen EEG-sleep studies were performed on eight preterm infants who received 8 weeks of SSC, and compared with two non-SSC cohorts at term ($N = 126$), a preterm group corrected to term age and a full-term group. Seven linear and two complexity measures were compared (Mann–Whitney U test comparisons $p < .05$).

Results: Fewer REMs, more quiet sleep, increased respiratory regularity, longer cycles, and less spectral beta were noted for SSC preterm infants compared with both control cohorts. Fewer REMs, greater arousals and more quiet sleep were noted for SSC infants compared with the non-SSC preterms at term. Three right hemispheric regions had greater complexity in the SSC group. Discriminant analysis showed that the SSC cohort was closer to the non-SSC full-term cohort.

Conclusions: Skin-to-skin contact accelerates brain maturation in healthy preterm infants compared with two groups without SSC.

Significance: Combined use of linear and complexity analysis strategies offer complementary information regarding altered neuronal functions after developmental care interventions. Such analyses may be helpful to assess other neuroprotection strategies.

1. Introduction

Neonatal electroencephalographic–polysomnographic studies have been performed for over half a century (Scher, 2006). From the earliest days of the development of the neonatal intensive care unit, EEG-sleep studies have been proposed to assess brain organization and maturation, determine the severity and persistence of a neonatal encephalopathy, detect neonatal seizures, and identify associations with serial clinical examinations and neuroimaging studies. Serial EEG-sleep assessments can include both visual and computer analyses to assess brain organization and maturation (Scher, 2004).

Since the establishment of the modern neonatal intensive care unit, there has been a growing incidence of premature infants. A recently published report estimates that 12.3% of all live births in the United States are children less than 37 weeks gestation (Behrman and Butler, 2006). Altered brain structure and function due to conditions of prematurity have been presented. Such changes may influence long-term outcomes (Isaacs et al., 2003; Scher et al., 2003; Skranes et al., 2007; Srinivasan et al., 2007; Thompson et al., 2007).

Emphasis is now focused on optimizing environmental factors in the neonatal intensive care unit as a form of neuroprotection, particularly light, sound, tactile stimulation and sleep during the long convalescence, in an attempt to shorten hospitalization and improve short-term outcome (Blackburn, 1998; Aucott et al., 2002; Gray and Philbin, 2004). During this extended convalescent time period, environmental alterations include adjustments of light, sound, tactile stimulation and sleep length and quality. The most immature neonates will spend as long as three to

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* Corresponding author. Address: Rainbow Babies and Children's Hospital, University Hospitals Case Medical Center, 11100 Euclid Ave., RBC 6090, Cleveland, OH 44106, USA. Tel.: +1 216 844 3691; fax: +1 216 844 8444.
E-mail address: Mark.Scher@UHhospitals.org (M.S. Scher).

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four months in the neonatal intensive care unit and are subjected to environmental effects for a longer period of time. Developmentally sensitive care paths for nurses and physicians have been developed to improve ongoing care for neonates as assessed by sleep, growth and age at discharge (Bertelle et al., 2005, 2007).

One developmental care path is skin-to-skin contact (SSC) or kangaroo care (Ludington-Hoe et al., 1994; Tessier et al., 2003). Past studies demonstrated that this specific developmental care program promotes physiologic stability and parental–infant interactions to facilitate health and improve short and long-term outcomes (Feldman et al., 2002; Feldman and Eidelman, 2003; Bergman et al., 2004). Developmental care practices for the newborn are supported by experimental evidence that maternal care epigenetically programs stress responses in offspring with later effects on adult behavior (Szyf et al., 2007).

Electroencephalographic/polysomnographic (EEG-sleep) studies are one method by which one can judge the effectiveness of a neuroprotective protocol such as SSC on neonatal brain organization and maturation. Behavioral and neurophysiological parameters must be rigorously defined to accurately assess neonatal sleep state and transitions between active and quiet sleep segments within the sleep cycle. These parameters can then form the basis for comparing neonates with and without therapeutic interventions. For the comparison of SSC and non-SSC cohorts, we have chosen a neurophysiologic approach using serial EEG-polygraphic data files that were submitted for computational analyses.

The purpose of this study was to extend our initial observations (Ludington-Hoe et al., 2006) that a single SSC session at 32 weeks postmenstrual age (PMA) significantly altered EEG-sleep organization in infants assessed. This present study provides evidence that SSC alters neurophysiologic maturation when EEG-sleep studies for a SSC cohort were compared with two non-SSC cohorts using linear and complexity analysis techniques at term ages.

2. Methods

2.1. Design

An institutional review board approved a pretest–test, randomized control trial of SSC. Seventy-five preterm infants were evaluated once between October 2002 and June 2004. Longitudinal data for eight infants were collected at both 32 weeks and 40 weeks PMA. Infants in this pilot study were assigned SSC while maintaining the pretest–test randomized assessment for later sleep scoring and analyses as previously described (Ludington-Hoe et al., 2006).

2.2. Subjects

Subjects were recruited before PMA of 32 weeks, following an examination by a neonatologist who determined that the infant had no encephalopathy, intraventricular hemorrhage of more than grade II severity, white matter lucencies on cranial ultrasound scans, seizures, meningitis, or congenital brain malformations. Infants also exhibited 5-min Apgar scores >6, were born at a gestational age $\geqslant$28 weeks, with a testing weight of >1000 g at the time of the study. Each infant was fed every 2 or 3 h by bolus gavage or oral feedings and experienced no painful procedures or sedative medication within 12 h of the testing protocol. Mothers had no history of prenatal substance use.

Two control cohorts were also recorded at term age. One cohort included healthy preterm infants studied when they reached a corrected term. The second control cohort consisted of healthy full-term infants who were studied 1–3 days after delivery. Both control cohorts were recruited for earlier studies at the University of Pittsburgh (Scher et al., 2003). EEG-sleep analyses of all infants were recorded on a relational database together with demographic and clinical information. Both the raw EEG-sleep recordings and the visual and digital calculations of physiologic measures were entered into the database.

2.3. Research setting

Infants in the SSC cohort were tested in one of the seven nursery rooms of the NICU or in the step-down unit at Rainbow Babies and Children's Hospital. Each room accommodates one to six infants. The step-down unit consists of private or semiprivate rooms that contain an incubator or crib and sleeping accommodations for the mother. Some rooms have large windows. Studies for the two control cohorts were similarly recorded in either a NICU setting or an EEG laboratory location at Magee-Women's Hospital of the University of Pittsburgh.

2.4. Recording conditions

Recordings were conducted during two consecutive inter-feeding periods, beginning at approximately 9:00 am. Each child received one and one-half hours of SSC, four days a week, for 8 weeks. Recording conditions, equipment, and procedures were identical to descriptions provided in earlier publications (Ludington-Hoe et al., 2006; Scher et al., 2003). All infants received a diaper change after a feeding, followed by a multiple hour inter-feeding EEG-sleep study. Studies were terminated when the next feeding was required. Infants receiving SSC were studied with an EEG-sleep study for at least one complete sleep cycle before and during skin-to-skin care.

2.5. Visually scored EEG-sleep measures

2.5.1. Measurement

Rudimentary quiet (non-REM) sleep (QS), active (REM) sleep (AS), and indeterminate sleep (IS) were identified through visual scoring of EEG continuity, discontinuity, and arousals previously defined (Scher et al., 2003). QS, AS and IS measures for term infants were similarly identified based on conventional pattern descriptions (Scher, 2006). Descriptions for QS, AS, IS, arousals and cycling architecture were identical to an earlier publication (Ludington-Hoe et al., 2006).

Active sleep segments for preterm infants consist of continuous EEG tracings with simultaneously recorded polygraphic parameters documenting rapid eye movements (REMs), body movements and irregular cardiorespiratory rhythms. Conversely, quiet sleep segments for the preterm infants consist of discontinuous periods of EEG consisting of bursts of EEG activity alternating with episodes of continuous EEG activity. Polygraphic parameters are simultaneously recorded to complete the sleep state identification and are comprised of minimal body movements, no REMs and regular cardiorespiratory rhythms.

Active sleep segments for infants at term consisted of two types of continuous EEG background rhythms consist of either moderate or low amplitude activities. Simultaneously recorded polygraphic measures recorded abundant body movements, REMs and irregular cardiorespiratory rhythms. Quiet sleep segments for infants at term consist of two types of EEG background rhythms, either a high voltage slow or a discontinuous type called trace′ alternant. Trace′ alternant consist of alternating EEG epochs of EEG bursts and quiescent intervals. Polygraphic measured during quiet sleep consist of minimal body movements, no REMs and regular cardiorespiratory rhythms. More completed descriptions of sleep architecture are presented elsewhere (Scher, 2006).