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Kangaroo care: cardio-respiratory relationships between the infant and caregiver

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ABSTRACT

Background: Kangaroo care, i.e., skin-to-skin cohabitation (SSC) between an infant and caregiver, is often used in neonatal intensive care units to promote bonding, breastfeeding and infant growth. The direct salutary effects of SSC on cardio-respiratory control in preterm infants remain equivocal; some reports suggest improved breathing stability, others indicate worsening of apnea, bradycardia and hypoxemia.
Aim: The purpose of this study was to investigate physiological relationships between the infant and caregiver during SSC. We hypothesized that respiratory stability of the premature infant is influenced by the caregiver's heartbeat.
Design: A prospective study was performed in eleven preterm infants (6 female; mean PCA 32 wks). SSC was compared to a preceding incubator-control period (CTL) matched for time from feed and condition duration. Abdominal respiratory movement, electrocardiogram, skin temperature and blood-oxygen levels were recorded from the infant and the caregiver.
Results: During CTL, infant interbreath interval variance (IBIv; respiratory instability) was directly related to its own heart rate variance (HRv; rho = 0.770, p = 0.009). During SSC, infant IBIv and apnea incidence were each related to caregiver HRv (rho 0.764, p = 0.006; rho 0.677, p = 0.022, respectively). Infant cardio-respiratory coupling was also enhanced during SSC compared to CTL in the eupneic frequency range (0.7–1.5 Hz, p = 0.018) and reduced for slower frequencies (0.15–0.45 Hz; p = 0.036).
Conclusion: These findings suggest that during SSC, respiratory control of the premature infant is influenced by the caregiver's cardiac rhythm. We propose that the caregiver's heartbeat causes sensory perturbations of the infant via somatic or other afferents, revealing a novel cohabitation-induced feed-back mechanism of respiratory control in the neonate.

1. Introduction

"Kangaroo care" (KC) is a natural, cost-effective intervention used to reduce mortality and morbidity of premature and low birth-weight infants throughout the world [1–9]. In its simplest form the infant is clad only in a diaper and placed upright and prone on its caregiver's chest, skin-to-skin [2,3,6]. Research suggests that KC improves physiological function, promotes breastfeeding and mother-infant attachment, and reduces developmental risks of the infant [1,4,7–17]. However, the direct salutary effects of KC on infant cardio-respiratory control remain equivocal. Some reports suggest thermal regulation and cardio-respiratory stability are achieved during KC; i.e., a reduction in the frequency of pathophysiological pause in breathing (apnea) and decreased heart rate (bradycardia) and improved oxygenation [4,12,16,18–22], whereas other studies report an increase in infant body temperature associated with an increase in the number of apnea, bradycardia and/or blood-oxygen desaturation events [23–25]. The purpose of this study was to investigate physiological relationships between the caregiver and the infant during KC to determine if cardio-respiratory stability of the premature infant was associated with that of its caregiver.

Despite a wide range of outcome measures that have been reported, including those affecting the infant's cardio-respiratory responses, temperature, pain response and sleep [12,13,15–30], there has been no integrative study to determine the essential physiological interactions between the infant and caregiver during KC necessary for improved infant response. The mechanisms for the therapeutic efficacy of KC that stabilize respiration and improve heart rate remain elusive. We propose that during KC, wherein the infant's head and chest wall overlay the chest wall of the caregiver, mechanical perturbations of the caregiver's heartbeat affect underlying receptors of the cohabitating infant. These receptors might include cutaneous, musculoskeletal, visceral and

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vestibular-cochlear receptors that project to brain centers that are involved in respiratory control [31–35]. This study tested the hypothesis that respiratory stability of the premature infant is influenced by sensory perturbations of the caregiver's heart beat during KC.

Though respiration and heart rate are under the control of two independent systems, coordination between the two has been shown to reflect health and maturation [31,32]. Cardio-respiratory coupling quantifies the interaction between respiratory and heart rhythms. The interdependence is related to reflex activity between pulmonary afferents and vagal outflow [33,34]. In infants, cardio-respiratory interaction is vital for providing optimal balance between gas exchange and metabolic demands [32,34]. A second purpose of this study was to determine whether cardio-respiratory coupling of the infant would be enhanced during SSC.

2. Methods

2.1. Human subjects

A prospective study was performed on 11 preterm infants (GA < 35 wks) at the University of Massachusetts Memorial Healthcare Neonatal Intensive Care Unit (NICU). Exclusion criteria were congenital malformation, chromosomal disorders, congenital or perinatal infection of the central nervous system, intraventricular hemorrhage > grade II and hypoxic-ischemic encephalopathy. Infants treated with methylxanthines were included if on maintenance dosing and the drug had reached steady-state. One additional subject who developed necrotizing enterocolitis was excluded. Hospital records and chart review were used to obtain demographic and medical information. All mothers denied smoking, illicit drug and alcohol use throughout pregnancy. Informed consent was obtained from the mother of each infant enrolled; one father also provided informed consent to participate in the study. The study was approved by the University of Massachusetts's Medical School Institutional Review Board for Human Subjects.

2.2. Measures and procedures

To test the hypothesis that respiratory stability of the premature infant is influenced by sensory perturbations of the caregiver's heart beat during Kangaroo Care infants participated in two conditions: 1) *Skin-to-skin cohabitation (SSC)*. Infants were clad only in a diaper and placed in a prone position on its parent-caregiver to provide skin-to-skin contact in accordance with Kangaroo-Care guidelines [3,6]. Blankets and a knitted cap (positioned above the infant's ear surfaced to the caregiver's body) were used to maintain warmth. Caregivers remained semi-supine (~15–30°) in a stationary, cushioned recliner chair. 2) *Control Period (CTL)*. To provide a thermo-regulated environment, infants were studied in their assigned incubator; one infant with mature thermoregulation was studied in his open crib using routine coverings. All infants were placed prone with the mattress tilted head up at ~15–30° to best mimic the positioning during SSC stimulation.

2.2.1. Physiological measurements

For each infant and caregiver, respiratory inductance plethysmography (RespIPleth) was used to record thoracic and abdominal respiratory movements (Somnostar PT; Viasys Healthcare, Yorbalinda, CA; Embla). Electrodes placed over the skin surface of the chest (Hewlett Packard), 3-lead configuration, were used to record electrocardiographic activity (ECG). Transcutaneous arterial-blood oxygen saturation (SaO_2) was measured using a separate pulse oximeter attached to the infant's foot or wrist, and to the parent's index finger (Nellcor, Hayward, CA). Skin temperature was recorded continuously using disposable adhesive temperature probes attached to the infant's and parent's axilla via separate electronic monitoring thermometers (Physitemp TH-5, Clifton, NJ). Cardio-respiratory signals, SaO_2, and skin temperature were recorded continuously throughout both conditions for each infant and throughout SSC for the caregiver.

2.2.2. Environmental and behavioral measurements

For each condition a sound meter (ExTech Instr) placed near the infant's head was used to measure changes in sound intensity (dBA). A light meter (AEMC, Industrial Process Measurements) placed by the infant's head was used to measure changes in light levels (lux). Overt behavioral data were recorded using a camera with a wide-angled lens (MicroCamera, Panasonic) within the infant's incubator or crib, or set to capture infant and parent during SSC stimulation, synchronized with the physiological, audiometry and light signals.

2.2.3. Data acquisition

Infant and adult ECG signals were sampled at 2000 Hz, RespIPleth at 50 Hz, SaO_2 at 10 Hz, transcutaneous pulse-oximeter plethysmographic activity at 100 Hz, and temperature, environmental light and sound signals at 20 Hz. The data were displayed during the experimental periods and stored on hard disk for offline analysis (Embla N7000, Broomfield, CO). Observations by the investigators were recorded as time-stamped text comments along with the signals. Fig. 1 illustrates an example of recorded signals during SSC in one infant-caregiver dyad (Subject 9).

2.2.4. General procedures

Studies were conducted during daytime hours; CTL periods were conducted between 7 a.m. and 1:00 p.m., SSC periods were conducted between 11:00 a.m. and 5:00 p.m. For each infant the CTL condition preceded the SSC condition to control for potential carryover effects of the SSC experimental condition. After initial set up of equipment and attachment of all sensors, infants were given their routine feed (gavage or bottle); feeds were conducted either in the isolette, infant crib or in the caregiver's arms. For the CTL condition, following feed the infant was placed in their isolette/crib for the inter-feed interval (3–4 h, depending on the infant's routine feeding schedule). For SSC, infants were held for the maximum holding period that the caregiver could manage not to exceed the inter-feed interval. Caregivers were asked to use the bathroom prior to holding their infant, and mothers who were pumping breast milk were asked to pump prior to SSC. All caregivers were instructed to hold the infant in accordance with Kangaroo-Care guidelines [3,6], for as long as they could sit in the semi-reclined position. We did not control for conversation at the bedside, but sought to allow conversation that parents typically provide during holding in order to study response in real, NICU-bedside setting. For each condition, following the feed there was an observation period of 30-min to assure integrity of the recordings, reduce potential confounds of digestion and to allow the infant to resume sleep. Analysis periods for each infant were determined by the maximum duration of the SSC condition (following the 30-min feed adjustment period) so that CTL and SSC periods were matched for time from feed and duration.

2.3. Data processing and analyses

All data analyses involving manual measurements of physiological signals were completed offline. Investigators were masked to condition for analyses of infant data; caregivers were only studied during SSC.

2.3.1. Movement periods and condition time

For each condition, movement periods were defined by movement that generated distortion in the transcutaneous pulse-oximeter plethysmographic signal that exceeded 5 s. Movement artifact was defined by gross body movements that obscured the cardio and/or respiratory signals. Video recordings and text comments written at the time of the study were used to further confirm periods of movement and to identify nursing interventions and/or technical contamination, including infant RespIPleth contaminated by caregiver respiratory signal (indexed by