Heart Rate Variability Responses of a Preterm Infant to Kangaroo Care

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Objective: To examine the effect of kangaroo care on heart rate variability in a healthy preterm infant.

Design: Case study.

Setting: Private room on a postpartum unit.

Participant: A mother–preterm infant dyad.

Intervention: Kangaroo (skin-to-skin) care.

Main Outcome Measure: Heart rate variability, a noninvasive measurement of the sympathetic and parasympathetic components of the autonomic nervous system's influence on heart rate.

Results: Heart rate variability, especially the parasympathetic component, was high when the infant was fussy in the open crib, indicating increased autonomic nervous system activity. With kangaroo care, the infant fell asleep, and both sympathetic and parasympathetic components of heart rate variability decreased.

Conclusions: The wide fluctuations in the parasympathetic component of heart rate variability suggest immaturity of the sympathovagal response. Overall, kangaroo care produced changes in heart rate variability that illustrate decreasing stress. *JOGNN, 34,* 689–694; 2005. DOI: 10.1177/ 0884217505281857

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Measurement of heart rate variability (HRV) provides a noninvasive evaluation of the autonomic regulation of heart rate rhythmicity and is uniquely appropriate to study the immature autonomic system's influence on cardio-respiratory control in preterm infants. Kangaroo care (KC), the placement of an infant in prone position and skin to skin on the mother's chest, has been shown to have many benefits for the infant and mother. Benefits to the mother include reduced anxiety, reduced breast engorgement postpartum, and longer breastfeeding duration (Shiau, 1998) as well as improved breastfeeding exclusivity (Mikiel-Kostyra, Mazur, & Boltruszko, 2002). Mothers and fathers who participated in KC in the neonatal nursery used more affectionate touch with their infants compared to mothers and fathers who did not participate in KC (Feldman, Weller, Sirota, & Eidelman, 2003). Among preterm infants, KC has promoted optimal temperature regulation (Bier et al., 1995; Chwo et al., 2002; Cleary, Spinner, Gibson, & Greenspan, 1997; Ludington-Hoe, Nguyen, Swinth, & Satyshur, 2000), stability in respiratory efforts (Bier et al., 1995; Cleary et al., 1997; Ludington-Hoe, Anderson, Swinth, Thompson, & Hadeed, 2004), and increases in quiet sleep (Chwo et al., 2002). Another physiologic benefit of KC may be to promote autonomic nervous system regulation in preterm infants (Feldman & Eidelman, 2003). The purpose of this case study was to examine the HRV responses of one preterm infant to a KC experience with his mother.

Heart rate, measured by counting the heart beats per minute, is a net effect of the decelerating influence of the vagal (parasympathetic) fibers and the accelerating influence of the sympathetic fibers on the inherent rhythmicity of the heart's sinoatrial

node. Under resting conditions, the vagal effects vary with the respiratory cycle. During inspiration, vagal impulses reaching the heart decrease, producing an increase in heart rate; during expiration, they increase, producing a decrease in heart rate. The effect of these autonomic influences results in the beat-to-beat variability of the heart rate. These rate changes are too brief to be detected via a pulse or stethoscope but can be measured by creating and analyzing the beat-to-beat variation via a time series power spectral analysis. A time series is any measure obtained over sequential points in time. A power spectrum is a measurement of the energy content of an electrocardiogram signal and is expressed as the estimate of heart rate variation in a specific frequency. Computer software for performing the mathematical calculations makes the analysis possible for clinical research.

The electrocardiogram analog signal from a cardiorespiratory monitor is fed into a computer housing the HRV software. The electrocardiogram analog signal is converted to digital values reflecting cyclic changes in the heart period, or the R-to-R interval. The data are transformed into a waveform across a spectrum of different frequencies. Frequencies are measured in hertz (1 Hz = a frequency unit equal to 1 cycle/second). Frequency bands in the low ranges are slow, and those in higher ranges are faster. Applied to HRV, sympathetic influences appear at frequencies less than 0.15 Hz (rhythm patterns up to 25 seconds/cycle), and parasympathetic influences are faster rhythms (up to 7 seconds/cycle; Stein, Bosner, Kleiger, & Conger, 1994). The spectral power analysis fractionates the power of the sympathetic and parasympathetic components of the signal and generates two power spectra of clinical interest. The first is a low-frequency (LF) power spectrum in the frequency range of 0.04 to 0.15 Hz that is mediated predominately by sympathetic influence, with some parasympathetic influence. The second is a high-frequency (HF) power spectrum responsive to the rate of respiration, in the frequency range of greater than 0.15 to 1.80 Hz that is predominately influenced by parasympathetic inputs. The ratio of LF/HF is calculated to reflect sympathovagal balance and is dimensionless. (When a ratio is expressed as a whole number, it is read as if the denominator equals 1.)

The use of different methods in studies of HRV precludes comparisons of HRV indices (LF, HF) from one study to another. Studies differ by the length of duration of recordings, from short (15 minutes) to long (24 hour monitoring), and in how the units of HRV indices are reported.

HRV has been used to evaluate the autonomic nervous system fluctuations in heart rate related to maturation in healthy infants and in infants with pathological conditions. Verklan and Padhye (2004) presented two cases from a power spectral analysis of fetal monitor recordings. They demonstrated that the preterm fetus had less HRV overall than the healthy full-term fetus did, reflecting immaturity of the autonomic nervous system in the preterm fetus. The autonomic nervous system undergoes significant maturation between 31 and 38 weeks gestation, represented by decreases in heart rate and increases in HRV (Sahni et al., 2000). For example, heart rates for 29- to 34-week-old infants (n = 35) were 152 ± 2 beats per minute (bpm) compared to heart rates of 135 ± 2 bpm for 36- to 48-week-old infants (n = 13; Chatow, Davidson, Reichman, & Askelrod, 1995). The decreases in heart rate with maturation represent increasing parasympathetic influence (vagal tone) on heart rate and better sympatho-vagal balance.

Although increases in HRV have been associated with maturation, decreases in HRV have been associated with morbidity. In a group of 68 term newborns who were exposed to cocaine in utero, their overall HRV indices were decreased compared to infants (n = 77) exposed to drugs other than cocaine and infants (n = 72) with no drug exposure (Mehta et al., 2001). Preterm infants (n = 41) with apnea of prematurity, followed up to 6 months of age, had higher heart rates and decreased HRV compared to healthy full-term neonates (Henslee, Schechtman, Lee, & Harper, 1997). Griffin et al. (2003) prospectively collected data from continuous heart rate monitoring for 633 newborns. Reduced HRV and decelerations in heart rate were found 24 hours before abrupt deterioration due to sepsis and sepsis-like illnesses in 194 of the 633 infants.

Only two studies of HRV and KC have been done to date. HRV was examined for preterm infants 30 to 31.5 weeks postconceptional age (n = 14) who had been artificially ventilated for an average of 34 days (Smith, 2003). In a randomized sequence, each infant was examined for 2 hours on 2 days of incubator care and for 2 hours on 2 days of KC. The HRV indices for LF power and HF power did not vary between the two conditions of care, perhaps because the effects from artificial ventilation on HRV were predominate over any possible effect from KC (i.e., HRV was "entrained" with ventilator rate; van Ravenswaaij-Arts, Hopman, Kollee, Stoelinga, & van Geijn, 1995; Zernikow & Michel, 1996). In a nonrandomized, two-group design (n = 70), KC was provided for an average of 24 days to a treatment group of preterm infants, whereas the control group who were matched for gender and birth weight received no KC (Feldman & Eidelman, 2003). HRV showed more rapid maturation of vagal activity between 32 and 37 weeks for the KC infants. The results from these two studies indicate the need for additional study to understand possible effects of KC on HRV. An increased understanding of the effects of KC on HRV may guide nurses' use of KC to promote development of the infant's autonomic nervous system.

KC may promote maturation of the preterm infant's autonomic nervous system.

Case Study

This case study was conducted as part of a larger study and had institutional review board approval. The mother gave written, informed consent. Infant Boy B was born to an 18-year-old White primipara who had graduated from high school. The mother was admitted to the hospital because of premature rupture of membranes at 28 weeks gestation and remained on bed rest for 6 weeks until delivery. Infant B was born at 34 weeks gestation and weighed 2,586 g. His Apgar scores were 8 and 9 at 1 and 5 minutes, respectively. Thirty minutes after birth, he started exhibiting signs of respiratory distress and was placed under an oxygen hood at 32% FiO_2. Four hours later, continuous positive airway pressure at 32% was started and continued for 18 hours. He was then transferred to an open-air crib and remained there without supplemental oxygen support until hospital discharge. On day 5 of life, Infant B was being fed human milk by breast, bottle, or both every 3 hours. He had consumed 35 cc of human milk 2 hours before KC, which began at 11:00 a.m. This was the first KC session for this mother and infant.

Data Collection Procedures

Mother and infant did KC in their private postpartum room on the mother-baby unit of Kadlec Medical Center in Richland, Washington. The infant's HRV indices were obtained for 40 minutes in the open crib followed by 40 minutes in KC. Two hydrogel electrodes were placed on the lateral sides of the infant's chest at nipple level to conduct an electrocardiogram signal from a cardio-respiratory monitor to the computer with the HRV software (ANSAR Inc., Philadelphia, PA). One investigator assessed behavioral state once per minute with the Anderson Behavioral State Scale. This categorical scale allows for classification of behavior into states from sleep to awake to crying (Anderson et al., 1990; McCain & Gartside, 2002). Content validity has been established by a panel of neonatal clinicians/researchers and a developmental pediatrician (Gene Anderson, personal communication, 1999). Criterion validity has been established with the Brazelton Neonatal Behavioral Scale (Gene Anderson, personal communication, 1999).

In the open crib, the diaper-clad infant was swaddled in both a thermal blanket and a receiving blanket and tucked beneath a receiving blanket. He was positioned on his right side at the beginning of data collection but was awake and fussy and became progressively more agitated, moving his trunk and flailing his arms. At 13 minutes into the data collection, Infant B was placed into a prone position to try to console him. However, his behavior remained active and fussy for 77% of the 40-minute time in the open crib.

After the 40 minutes in the open crib, the infant was removed from the swaddled blankets and given to his mother, who sat in a recliner at approximately a 40-degree incline beside the crib. The infant was placed upright, prone, and skin to skin with his mother, who placed a receiving blanket folded in fourths across his back and her hospital gown over that. Infant B immediately snuggled onto his mother's chest and within 30 seconds went into a sleep state and sustained this sleep state for the entire 40 minutes of KC. The mother remained awake with her hands cradled around her infant and her eyes focused exclusively on her infant during the KC session. Three research staff members in the room monitored the equipment and recorded observations, but the mother spoke only in response to questions. The infant sustained his sleep state, and the mother sustained her entrainment with her infant despite our research staff activity, grandparents entering and exiting the room, the telephone ringing, and a staff nurse checking on the mother and infant.

Overall, KC produced changes in behavior and heart rate variability that indicated a decrease in stress.

Analysis and Findings

HRV data were examined for accuracy. The HRV software identifies artifact interference with the electrocardiogram signal, so these data can be eliminated before analysis. Movement creates artifact, and because Infant B was restless during the time he was in the open crib, only 25% of the data were useable (i.e., artifact free). Because the infant was in a quiet sleep state during KC, 56% of the data were useable.

The HRV indices for LF, HF, the ratio of LF/HF, and heart rate were summarized for the time in the open crib and for the time in KC. The geometric mean was calculated for each HRV index in the crib and in KC. The calculation for the geometric mean $= (a_1 \bullet \ldots \bullet a_N)^{1/N}$ was used instead of the arithmetic mean, $M = (a_1 + \ldots + a_N)/N$. The arithmetic mean results in an average value, as if each quantity contributing to the total had the same value. The geometric mean results in an average rate of

Condition	Low Frequency		High Frequency		Low Frequency/High Frequency		Heart Rate	
	M[a]	Range	M[a]	Range	M[a]	Range	M	Range
Open crib	21.9	2.3–148.7	9.2	0.2–156.2	2.4	0.2–19.6	137	125–149
Kangaroo care	2.9	0.6–26.6	0.25	0.2–36.2	11.7	0.5–99.3	140	135–147

[a]Geometric mean.
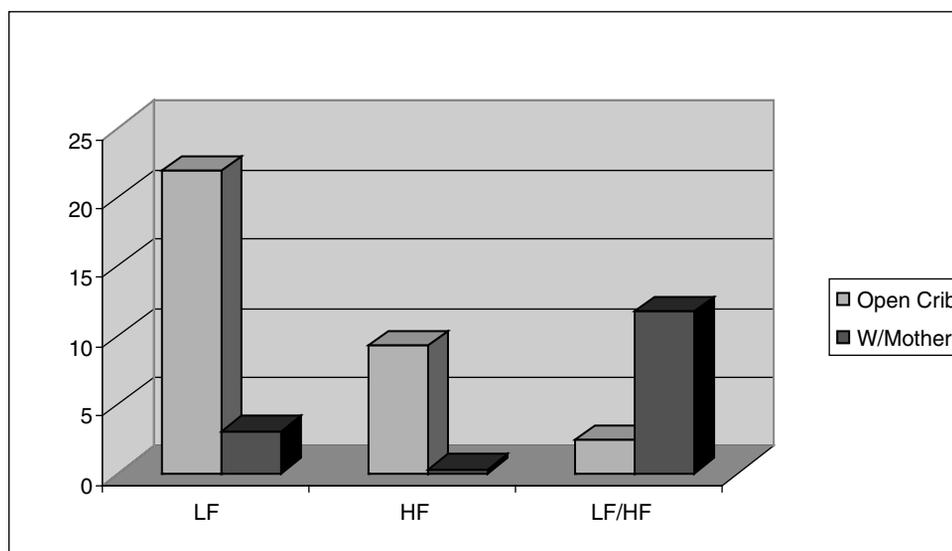
FIGURE 1
Spectral power (ms²/Hz) in an open crib and kangaroo care (KC).
Note. LF = low frequency; HF = high frequency.

change. Given that the HRV indices represent variation in heart rate over time, the geometric mean was used for these data. For example, the first four indices for LF during KC were 21.3, 16.4, 3.2, and 3.4. The arithmetic mean was 11.1, and the geometric mean was 7.9.

Infant B's LF and HF values were high during the open crib period compared to his HF and LF values during KC. Conversely, his LF/HF ratio was higher in KC than in the open crib. Figure 1 illustrates the geometric means of the HRV indices in the crib and in KC, and Table 1 provides both the geometric means and ranges.

Discussion

During the open-crib period, the infant was restless and fussy, indicating stress. Compared to a group (*n* = 10) of healthy preterm infants (mean gestational age 34.4 ± 0.8 weeks) with averages of LF = 19.7, HF = 0.7, and LF/HF = 35.3, Infant B had normal levels of predominately sympathetic activity (LF = 21.91) but very high levels of parasympathetic activity (HF = 9.23; Veerappan

et al., 2000). This suggests that activation of the infant's sympathetic system failed to inhibit activity of the vagal (parasympathetic) system, as would be seen in an adult under a stressful condition (Pagani et al., 1991). This inability to inhibit the vagal system response is likely due to immaturity.

After transfer of the infant from the open crib into KC, both LF and HF indices decreased as the infant was quietly asleep on his mother's chest. The LF/HF ratio rose dramatically from an average of 2.4 in the open crib to 11.7 in KC, primarily due to the greater decrease in HF from the crib period to KC compared to the decrease in the LF. The decreases in LF and HF during KC may be related to a number of factors including temperature, body position, and behavioral state. A recent study demonstrated that mother-infant bed sharing during sleep for term infants 11 to 15 weeks of age increased infants' heart rates and decreased HRV compared to when the infants slept alone (Richard & Mosko, 2004). The investigators posited that sensory stimulation from cosleeping may account for these physiologic differences. In Infant

B's case, he received sensory stimulation from being in skin-to-skin contact with his mother.

The mother's body heat may have increased Infant B's body temperature as has been documented in previous KC studies (Ludington-Hoe et al., 2000; Ludington-Hoe et al., 2004). The decrease in Infant B's LF and HF in KC is consistent with temperature-related changes in HRV indices for a group of preterm infants (n = 10), whose birth weights ranged from 890 to 1900 g at a mean age of 16 days postbirth (Davidson, Reina, Shefi, Hai-Tov, & Akselrod, 1997). The LF and HF indices, observed at body temperatures of 35.5°C, 36°C, 36.5°C, and 37°C, decreased as the infants' temperatures rose above 36 degrees.

The change from a horizontal position in the open crib to a head-up position in KC may explain the predominance of LF compared to HF for Infant B during KC. A change in position from horizontal to head-up produced an elevation in LF relative to HF in 36 preterm infants 25 to 35 weeks gestational age (Schrod & Walter, 2002).

The decreases in LF and HF during KC also may be related to Infant B's change in behavior from fussy and restless while in the open crib to a sleep state while in KC. LF decreased from active sleep to quiet sleep in 12 preterm infants at term age (Eiselt et al., 1993). The rela-

> **N**urses may consider using KC for stressed infants on an individual basis.

tionship of HRV to behavioral states other than sleep states is unknown and is an area needing further study.

Implications for Practice and Research

In our 1 participant, we saw a stressed infant immediately calm down in response to KC. We saw a marked change in the size of the HF response from very high during the fussy period in the open crib to very low with sleep in KC. The wide range of values for the HF on both the high and low sides of regulation suggests an immaturity of the vagal system and a decrease in the interactive component of the sympatho-vagal responses.

Overall, KC produced changes in behavior and HRV that indicated a decrease in stress. Because this was a study of 1 infant, we cannot conclude a direct effect from KC on decreasing stress. However, practicing nurses may use KC on a case-by-case basis when an infant is stressed and assess the infant's response for a calming effect. There is much to learn about the effects of KC on HRV and development of the autonomic nervous system. In a larger project, we have started to study the effects of KC on

HRV related to infant temperature, body position (supine to prone, horizontal to head-up), and behavioral state.

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