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Heart Rate Variability Responses of a Preterm Infant to Kangaroo Care

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Abstract

A 35-week old preterm infant's behavior was fussy and restless in the open crib, but he calmed and fell asleep immediately on being placed skin-to-skin on his mother's chest. Heart rate variability (HRV), a noninvasive method to assess the autonomic nervous system's influence on heart rate, was increased with fussy behavior in the open crib and decreased with sleep during kangaroo care (KC). KC produced changes in behavior and HRV that are illustrative of decreasing stress.

Keywords

Premature; heart rate variability; kangaroo care; behavior

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 post partum, and improved breast feeding 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.; Cleary, et al.; Ludington-Hoe, Anderson, Swinth, Thompson, & Hadeed, 2004) and increases in quiet sleep (Chwo et al.). Another physiologic benefit from KC may be to promote autonomic nervous system regulation in preterm infants (Feldman & Edelman, 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 Variability

Heart rate, measured by counting the heart beats/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. 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 analysis. (A time series is any measure obtained over sequential points in time.) Computer software for doing the mathematical calculations online makes the analysis possible for clinical research.

The EKG analogue signal from a cardio-respiratory monitor is fed into a computer housing the HRV software. The EKG analog signal is converted to digital values reflecting cyclic changes in the heart period, or the R-to-R interval, and generates two power spectra of clinical interest. The first is a low frequency (LF) power spectrum in the frequency range of 0.04 - 0.15 Hz that is mediated by sympathetic and parasympathetic influences. The second is a high (respiratory) frequency (HF) power spectrum in the frequency range of > 0.15 - 1.00 Hz that is predominately influenced by parasympathetic inputs.

Only two studies of HRV and KC have been done to date. HRV was examined for preterm infants 30 - 31.5 weeks post-conceptual 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 two-hours on two days of incubator care and for two-hours on two-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 (van Ravenswaaij-Arts et al., 1995; Zernikow & Michel, 1996). In a non-randomized, two group design (n=70), KC was provided for an average of 24 days to a treatment group of preterm infants, while the control group who were matched for sex and birth weight received no KC (Feldman & Edelman, 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 in order 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.

Callout #¹

The Case Study

This case study was conducted as part of a larger study (principal investigator - S.L.), and had IRB approval. The mother gave written, informed consent.

Infant boy B was born to an 18 year old Caucasian primipara who had graduated from high school. The Mother was hospitalized 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 2586 grams. His Apgar scores were 8 and 9 at one and five-minutes respectively. Thirty-minutes after birth he started exhibiting signs of respiratory distress and was placed under an oxygen hood at 32% FiO₂. Four hours later CPAP at 32% was started and continued for 18 hours. He was then transferred into an open air crib and remained there without supplemental oxygen support until hospital discharge. On day five of life, Infant B was being

¹KC may promote maturation of the preterm infant's autonomic nervous system.

fed breast milk by breast and/or bottle every three hours. He had consumed 35 cc of breast milk two hours prior to KC, which began at 11:00 a.m. This was the first KC session for this mother and infant.

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 of data collection in KC. Two hydrogel electrodes were placed on the lateral sides of the infant's chest at nipple level in order to conduct an EKG signal from a cardio-respiratory monitor to the computer with the HRV software (ANSAR Inc., Philadelphia, Pennsylvania, U.S.A). One investigator (S.L.) assessed behavioral state once per minute with the Anderson Behavioral State Scale (ABSS). This categorical scale allows for classification of behavior into states from sleep to awake to crying. (Anderson et al, 1990; McCain & Gartside, 2002).

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 in order to try to console him. However, his behavior remained active and fussy for 77% of the 40-minute time in the open crib.

Following 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. There were 3-research staff members in the room (G.M., S.L., J. S.) monitoring the equipment and recording observations, but the mother spoke with us only if we initiated a question. 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.

Callout #²

Discussion

First, the HRV data were examined for accuracy. The HRV software identifies artifact interference with the EKG signal so this 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 (L/R), and heart rate (HR) were summarized for the time in the open-crib and for the time in KC. The geometric mean (GM) was calculated for each HRV index in the crib and in KC. The calculation for the $GM = (a_1 \cdot \dots \cdot a_N)^{1/N}$ was used instead of the arithmetic mean $M = (a_1 + \dots + a_N)/N$. The arithmetic means 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 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

²Overall, KC produced changes in behavior and heart rate variability that indicated a decrease in stress.

indices for LF during KC were 21.3, 16.4, 3.2, and 3.4. The arithmetic mean = 11.1, and the geometric mean = 7.9. Figure 1 illustrates the geometric means of the HRV indices in the crib and in KC, and table 1 gives both the geometric means and ranges.

During the open-crib period, the infant was in restless and fussy behavioral states 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 L/R = 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.

Following 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. Consequently, the L/R ratio rose dramatically from an average of 2.4 in the open crib to 11.7 in KC. 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 - 15 weeks of age increased infants' heart rates and decreased HRV compared to when the infants were sleeping alone (Richard & Mosko, 2004). The investigators posit that sensory stimulation from co-sleeping 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 - 1900 g at a mean age of 16 days post-birth (Davidson, Reina, Shefi, Hai-Tov, & Akselrod, 1997). The LF and HF indices, observed at body temperatures of 35.5, 36, 36.5, and 37 degrees centigrade, 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 25-35 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 was shown to decrease from active sleep to quiet sleep in 12 preterm infants at term age (Eiselt et al, 1993). The relationship of HRV to behavioral states other than sleep states is an area needing further study.

Callout #³

Conclusions

In our one subject, 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.

³Nurses may consider using KC for stressed infants on an individual basis.

Overall, KC produced changes in behavior and HRV that indicated a decrease in stress. Because this was a study of one 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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References

- Anderson, GC.; Behnke, M.; Gill, NE.; Conlon, M.; Measel, CP.; McDonie, TE. Self-regulatory gavage to bottle feeding for preterm infants: Effect on behavioral state, energy, expenditure, and weight gain. In: Funk, SG.; Tornquist, EM.; Champagne, MT.; Coop, LA.; Wiese, RA., editors. *Key Aspects of Recovery: Improving Nutrition, Test, and Mobility*. Springer; New York, NY: 1990. p. 83-97.
- Bier JB, Ferguson AE, Liebling JA, Morales Y, Archer D, Oh W, et al. Skin- to-skin contact improves physiologic states of breast-fed low-birth-weight (LBW) infants. *Pediatric Research* 1995;37:A103.
- Chwo M-J, Anderson GC, Good M, Dowling DA, Shiao S-HH, Chu D-M. A randomized controlled trial of early kangaroo care for preterm infants: Effects on temperature, weight, behavior, and acuity. *Journal of Nursing Research* 2002;10:129–141. [PubMed: 12119598]
- Cleary GM, Spinner SS, Gibson E, Greenspan JS. Skin-to-skin parental contact with fragile preterm infants. *Journal of the American Osteopathic Association* 1997;97:457–460. [PubMed: 9284613]
- Davidson S, Reina N, Shefi O, Hai-Tov U, Akselrod S. Spectral analysis of heart rate fluctuations and optimum thermal management for low birth weight infants. *Medical & Biological Engineering & Computing* 1997;35:619–625. [PubMed: 9538537]
- Eiselt M, Curzi-Dascalova L, Clairambault J, Kauffmann F, Medigue C, Peirano P. Heart-rate variability in low-risk prematurely born infants reaching normal term: a comparison with full-term newborns. *Early Human Development* 1993;32:183–195. [PubMed: 8486120]
- Feldman R, Eidelman AI. Skin-to-skin contact (kangaroo care) accelerates autonomic and neurobehavioural maturation in preterm infants. *Developmental Medicine & Child Neurology* 2003;45:274–281. [PubMed: 12647930]
- Feldman R, Weller A, Sirota L, Eidelman AI. Testing a family intervention hypothesis: The contribution of mother-infant skin-to-skin contact (kangaroo care) to family interaction, proximity, and touch. *Journal of Family Psychology* 2003;17:94–107. [PubMed: 12666466]
- Ludington-Hoe SM, Anderson GC, Swinth JY, Thompson C, Hadeed AJ. Randomized controlled trial of kangaroo care: Cardiorespiratory and thermal effects on healthy preterm infants. *Neonatal Network The Journal of Neonatal Nursing* 2004;23:39–48.
- Ludington-Hoe SM, Nguyen N, Swinth JY, Satyshur RD. Kangaroo care compared to incubators in maintaining body warmth in preterm infants. *Biological Research for Nursing* 2000;2:60–73. [PubMed: 11232513]
- McCain GC, Gartside PS. Behavioral responses of preterm infants to a standard-care and semi-demand feeding protocol. *Newborn and Infant Nursing Reviews* 2002;2:187–193.
- Mikiel-Kostyra K, Mazur J, Boltrusko I. Effect of early skin-to-skin contact after delivery on duration of breastfeeding: A prospective cohort study. *Acta Paediatrica* 2002;91:1288–1289.
- Pagani M, Rimoldi O, Pizzinelli P, Furlan R, Crivellaro W, Liberati D, et al. Assessment of the neural control of the circulation during psychological stress. *Journal of the Autonomic Nervous System* 1991;35:33–42.
- Schrod L, Walter J. Effect of head-up body tilt position on autonomic function and cerebral oxygenation in preterm infants. *Biology of the Neonate* 2002;81:255–259. [PubMed: 12011569]

- Shiau S-HH. Randomized controlled trial of kangaroo care with full-term infants: Effects on maternal anxiety, breast-milk maturation, breast engorgement, and breastfeeding status (Doctoral dissertation, Case Western Reserve University, 1997). Dissertation Abstracts International 1998;58/10:5332.
- Smith SL. Heart period variability of intubated very-low-birth-weight infants during incubator care and maternal holding. *American Journal of Critical Care* 2003;12:54–64. [PubMed: 12526238]
- van Ravenswaaij-Arts CM, Hopman JC, Kollee LA, Stoeltinga GB, van Geijn HP. The influence of artificial ventilation on heart rate variability in very preterm infants. *Pediatric Research* 1995;37:124–130. [PubMed: 7700727]
- Veerappan S, Rosen H, Craelius W, Curcie D, Hiatt M, Hegyi T. Spectral analysis of heart rate variability in premature infants with feeding bradycardia. *Pediatric Research* 2002;47:659–662. [PubMed: 10813593]
- Zernikow B, Michel E. Ventilator-associated sinus arrhythmia in a preterm neonate—an indicator for a mature autonomic nervous system? *Acta Paediatrica* 1996;85:505–507. [PubMed: 8740315]

Figure.1.
Spectral power $(ms)^2$ in open crib and KC

Table 1Spectral power (ms)² in open crib and KC

	LF	RF	L/R	HR
Condition	M (Range)*	M (Range)*	M (Range)*	M (Range)
Open-crib	21.9 (2.3 - 148.7)	9.2 (.2 -156.2)	2.4 (.2 - 19.6)	137 (125-149)
KC	2.9 (.6 - 26.6)	.25(.2 - 36.2)	11.7 (.5 - 99.3)	140 (135-147)

* Geometric mean