HEART PERIOD VARIABILITY OF INTUBATED VERY-LOW-BIRTH-WEIGHT INFANTS DURING INCUBATOR CARE AND MATERNAL HOLDING

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Background
Heart rate has been used to measure infants’ physiological stability during skin-to-skin holding. Variability in heart period (interbeat interval), a more sensitive measure of autonomic nervous system tone, has not.

Objective
To describe heart period variability in intubated very-low-birth-weight infants during incubator care and during maternal skin-to-skin holding.

Design/Methods
An experimental, interrupted time series, crossover design was used; infants served as their own controls. Infants were randomly assigned to treatment order: 2 hours of intermittent skin-to-skin holding for 2 consecutive days followed by 2 days of incubator care or vice versa. The analog signal representing heart period was sampled and quantized at 5 Hz via a dedicated computer system in multiple 300-second epochs each day.

Results
Fourteen infants with similar characteristics completed the protocol. The mean interbeat interval was 332 ms during skin-to-skin care and 368 ms during incubator care. Power within the low- and high-frequency regions of heart period was not significantly different between skin-to-skin holding and incubator care. Mean low-frequency power was 124.6 ms² during skin-to-skin holding and ranged from 51.9 ms² to 71.4 ms² during all periods of incubator care. Mean high-frequency power was similar during skin-to-skin holding and incubator care (8.8 ms² and 6.1 ms²). Infants of 32 to 34 weeks’ corrected gestational age had increased power in the low- and high-frequency regions.

Conclusions
Heart period variability did not improve during skin-to-skin holding. Gestationally older infants had increased power in the low- and high-frequency regions, suggesting a maturing autonomic nervous system. (American Journal of Critical Care. 2003;12:54-64)

Skin-to-skin care is a method of holding infants during which the parent holds the diaper-clad infant prone on the parent’s chest such that the infant’s skin is in contact with the parent’s skin. Several studies have been published on responses of healthy, nonintubated infants to skin-to-skin care; however, no clinical trials establishing the safety or efficacy of skin-to-skin care compared with routine incubator care in intubated very-low-birth-weight (VLBW) infants have been reported. In a crossover study of intubated VLBW infants, central and peripheral body temperatures and measured fraction of inspired oxygen were higher and oxygen saturation was lower during skin-to-skin care than during incubator care. In this article, I describe heart period variability, a unique and previously unreported measure of physiological stability in intubated VLBW infants during incubator care and skin-to-skin care.

Background and Significance
Heart rate has been used by numerous researchers as a measure of physiological stability in infants during skin-to-skin care. Heart rate is used because (1) data on heart rate are easily obtained from cardiac monitors, and (2) bradycardia (heart rate <100/min) and tachycardia (heart rate >160/min) are used in the clinical setting as indicators of physiological instability.

Various investigators reported mean heart rates within the accepted range of 120/min to 160/min during skin-to-skin care; however, the healthy, nonintu-
bated, premature infants studied also had increases in heart rates during skin-to-skin care that were greater than the accepted normal high heart rate of 160/min.4,10 Some infants had heart rates as high as 179/min to 197/min, suggesting increased activity from the sympathetic nervous system stimulating the heart and contributing to physiological instability.7,8,9

Two groups of investigators reported an increased number of bradycardic episodes during skin-to-skin care.4,5 In 8 premature VLBW infants, the mean number of bradycardic events during skin-to-skin care was 2.9 (SD = 3.2), double the number of events that occurred during routine incubator care.6 Of these 8 infants, 7 were receiving continuous positive airway pressure via nasal prongs, and 1 was receiving oxygen via face mask.4 Similar findings were reported in 22 spontaneously breathing VLBW premature infants in a study that compared skin-to-skin care with incubator or crib care.4 These findings suggest that the studied infants had physiological instability during skin-to-skin care. One group of 15 intubated VLBW infants had increased heart rates during the transfer to and from skin-to-skin care, suggesting increased physiological instability during the transfer.11 Heart rate and number of bradycardic events are gross measures of physiological stability and are not sensitive enough for use in evaluating the underlying maturation of the autonomic nervous system in control of the heart. Measurement of heart period variability is a novel method that can be used to evaluate the maturity of the autonomic nervous system in premature infants.

**Heart Period Variability**

Heart period is defined as the length of time between successive R waves or as the interbeat interval, and it is typically quantified in milliseconds.12 Heart period variability is the expected cyclical change in the length of each interbeat interval and the sinus heart rate over time.13,14 Short-term variability, that is, the change in successive interbeat intervals, is thought to be a result of innervation by the vagus nerve.14,16 Optimal short-term variability is defined as interval differences of 20 to 30 ms greater than or less than the infant’s baseline interval.14,15 For example, a premature infant could typically have an interbeat interval ranging from 345 to 405 ms over time (approximately equal to a heart rate between 174/min and 148/min).

Heart period variability is useful in evaluating the balance between the parasympathetic and the sympathetic branches of the autonomic nervous system. As such, heart period variability is a sensitive and useful measure for determining maturity of the autonomic nervous system and an infant’s ability to adapt to external events, maintain homeostasis, and conserve energy specifically during skin-to-skin care.14,15 The development of the autonomic nervous system is incomplete at birth. Sympathetic tone is dominant in premature infants, and parasympathetic tone (specifically vagus nerve tone) increases with gestational age.15,16,20,21 Improved parasympathetic tone may promote growth and restoration and conserve energy.14 Therefore, determining the balance between the parasympathetic and sympathetic nervous systems by measuring heart period variability becomes useful as a measure of physiological stability.

Power spectra can be derived from heart period time series and are statistically useful in determining the balance between the sympathetic and the parasympathetic nervous systems. The power spectra have been divided into 2 frequency regions of activity, with each region influenced by different physiological phenomena.15,20,22 For the purposes of this study, the frequency regions as defined by Chatow et al20 were used. These frequency regions are (1) a low-frequency region from 0.02 Hz to 0.2 Hz and (2) a high-frequency region from greater than 0.2 Hz to 2.0 Hz (Figure 1). The frequency regions are influenced by specific branches of the autonomic nervous system, and the ratio of low-frequency to high-frequency power indicates sympathovagal balance.20,21

The low-frequency region is influenced primarily by the sympathetic and somewhat by the parasympathetic branches of the autonomic nervous system.20,21

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**Heart Period Variability**

<table>
<thead>
<tr>
<th>Although frequently used as an indicator of physiological stability, general changes in heart rate (bradycardia or tachycardia) may not be sensitive enough to completely identify all stressful events in very-low-birthweight infants.</th>
</tr>
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<tbody>
<tr>
<td>Heart period variability is the change in the beat-to-beat interval and reflects the balance between the parasympathetic and sympathetic branches of the autonomic nervous system. In VLBW infants, it can help to determine the maturity of the autonomic nervous system.</td>
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<tr>
<td>Heart period variability, used as a method to measure physiologic stability, may provide more specific and more sensitive information about stressful events in VLBW infants than do changes in heart rate.</td>
</tr>
</tbody>
</table>
Variables that may influence the low-frequency region include thermoregulation, peripheral vasomotor responses, and baroreceptor responses or fluctuations in blood pressure.\textsuperscript{13,20} The high-frequency region reflects parasympathetic activity (vagal tone) and is influenced by respiration.\textsuperscript{13,19,20} A sharp peak in the high-frequency region at a typical respiratory frequency is suggestive of a mature parasympathetic nervous system.\textsuperscript{20}

In summary, the analysis of mean heart rate in intubated infants during incubator care and skin-to-skin care may not be a sensitive enough measure of the infants’ response to skin-to-skin care. Heart period variability with spectral power analysis and time-domain analysis provides information about control of the heart by the autonomic nervous system and may be a more sensitive measure of an infant’s response to skin-to-skin care than is mean heart rate. Power spectral analysis provides descriptive information about sympathetic and parasympathetic tone, whereas time-domain analysis provides information about overall maturity of the autonomic nervous system and the response to skin-to-skin care. The following research questions guided this study:

- What is the difference in low-frequency power during skin-to-skin care compared with routine incubator care?
- What is the difference in high-frequency power during skin-to-skin care compared with routine incubator care?
- What is the difference in the ratio of low- to high-frequency power during skin-to-skin care compared with routine incubator care?

**Design and Methods**

An experimental, interrupted time series, crossover design was used; infants served as their own controls. Infants were randomly assigned to treatment order: intermittent skin-to-skin care for 2 days or standard incubator care for 2 days. During the intermittent skin-to-skin care phase, skin-to-skin care was provided by the infants’ mothers for 2 consecutive hours in the middle of each day. A 1-day washout period occurred between the 2 phases of the study; during the washout period, the infants received standard incubator care in the neonatal intensive care unit.\textsuperscript{1}

**Sample and Setting**

A purposive sample of 14 infants in a level III neonatal intensive care unit at the University of Utah Hospitals and Clinics was used.\textsuperscript{1} In the planning phase of the study, a projection indicated that a sample size of 13 infants was necessary to detect a medium effect size of 0.56 with a power of 80\% at an \( \alpha \) threshold of .05. This sample size was based on a power analysis that assumed a repeated-measures analysis and a mean correlation among heart period measures of 0.80.\textsuperscript{13} The more conservative sample size of 14 was used. Inclusion and exclusion criteria are in Table 1.

**Instruments**

Demographic and descriptive variables were collected by using an instrument developed by the principal investigator (SLS). The analog signal representing heart period was sampled and quantized from the Hewlett Packard OmniCare Neonatal Component...
Monitoring System (Andover, Mass) via the Strawberry Tree data acquisition system (Sunnyvale, Calif). Signal processing and conditioning were incorporated into the data acquisition system to optimize the signal of the variable and to eliminate artifact. Stability of the physiological instrument and the data acquisition system was established; the instruments were calibrated by the biomedical engineering department on the basis of the manufacturers’ recommendations for each instrument. The OmniCare Neonatal Component Monitoring System and the Strawberry Tree data acquisition system were calibrated before data acquisition each day. The OmniCare Neonatal Component Monitoring System electrocardiograph module is sensitive to 200 µV or more and is accurate to ±1%.

Procedure and Data Collection

Approval was obtained from the institutional review board before the start of the study. Informed consent was obtained from the mother of each infant no earlier than 10 days after delivery of the infant. Only mothers were selected for the skin-to-skin care intervention, in an effort to control for physical differences between mothers and fathers, which may influence infants’ responses to skin-to-skin care. For each infant, the study protocol was started when the infant weighed at least 750 g.

Each morning before data collection, the electrocardiographic electrodes were replaced with new electrodes (Klear-Trace No. 4800-S; CAS Medical Systems, Inc, Branford, Conn). Two electrodes were placed on the thorax, 1 at the right midclavicular line just below the clavicle and 1 at the left midclavicular line lateral to the left nipple. The ground lead was placed on the infant’s abdomen in the left-lower quadrant. The leads were adjusted on the thorax until an axis providing a clear signal was achieved.

Heart period (interbeat interval) data were acquired in multiple 300-second epochs at a frequency of 5 Hz (ie, 5 times per second) during each study day. The sampling rate was determined by using the Nyquist theorem and previous knowledge of the typical range of heart rates for VLBW infants. Four 300-second epochs of heart period were acquired at 30-minute intervals around 3 consecutive feeding times for a total of 12 heart period epochs each study day. A total of 48 heart period epochs were acquired for each infant, 24 during the skin-to-skin care phase and 24 during the incubator phase.

During the skin-to-skin care phase of the protocol, infants were held during the midday feeding. For example, an infant fed at noon was transferred to the mother at 11:15 AM and was held until 1:15 PM. Thus, 1 heart period epoch was collected 30 minutes before feeding, 1 epoch during the feeding, and 2 epochs after the feeding. Feedings were either 24-calorie premature formula or 24-calorie breast milk fortified with human milk fortifier. Feedings were warmed in a water bath per the standard of care of the neonatal intensive care unit and were given via nasal or oral gastric tubes. Feedings were via gravity and lasted 20 to 30 minutes. When the infants were in the incubators, nurses gave the feedings. During incubator care, infants were positioned prone on the mattress with

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Inclusion and exclusion criteria for intubated very-low-birth-weight infants to participate in skin-to-skin holding study (N=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inclusion criteria</strong></td>
<td><strong>Exclusion criteria</strong></td>
</tr>
<tr>
<td>Birth weight 600-1500 g</td>
<td>Oxygen desaturation &lt; 60% not because of mechanical failure or suctioning</td>
</tr>
<tr>
<td>24-30 weeks gestational age at birth</td>
<td>Severe congenital anomalies</td>
</tr>
<tr>
<td>Singleton or multiple gestation</td>
<td>Intraventricular hemorrhage of grade 3 or higher</td>
</tr>
<tr>
<td>Growth appropriate for gestational age</td>
<td>Multiple gestation with associated pathology</td>
</tr>
<tr>
<td>Intubated</td>
<td>Inborn errors of metabolism</td>
</tr>
<tr>
<td>Ventilator settings stable or weaning</td>
<td>Small or large for gestational age</td>
</tr>
<tr>
<td>Receiving full enteral feedings</td>
<td>Umbilical catheters present</td>
</tr>
<tr>
<td>Feedings given by bolus every 3 hours</td>
<td>Vasopressor drugs in use</td>
</tr>
<tr>
<td>Maternal consent</td>
<td>Paralytic drugs in use</td>
</tr>
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<td></td>
<td>Chest tubes in place</td>
</tr>
</tbody>
</table>
their heads positioned to the side and elevated. Mothers were present only during skin-to-skin holding. A standardized transfer protocol was used to transfer infants to and from the incubator during the skin-to-skin care phase of the study. Each infant was prone and upright on the mother’s chest during skin-to-skin care, with the infant’s head turned to one side; the infant remained in that position for the duration of skin-to-skin holding.

Statistical Methods

Data were analyzed by using S-PLUS 2000 and SPSS 10.0 for Windows. Demographic data were analyzed by using SPSS 10.0 to determine measures of central tendency and dispersion.

Heart period data were examined for aberrant data caused by signal interruption or electronic noise. Aberrant data points were isolated and were deleted from the data file as recommended by Kamath and Fallen. Deletion and local interpolation of small sections of grossly aberrant data for heart period were used rather than mean substitution, because surrounding interbeat intervals are better predictors of individual heart periods than are regional means or medians. The mean amount of aberrant data in all of the heart period files was 1.1%, less than the recommended threshold of no greater than 20%. After the data were cleaned, each heart period epoch used in the analysis was 256 seconds long.

Time-domain and frequency-domain (spectral) analyses of heart period were done by using S-PLUS 2000. Time series plots of the interbeat intervals across time were generated for each heart period epoch for each infant. Power spectral density plots were generated from each epoch’s 1280-point time series data for heart period by using an autoregressive spectral model with a fixed model order of 30. The autoregressive model was selected over its common alternative, the Fourier model, because autoregressive models tend to be more statistically stable when applied to short time series. Akaike information criterion analyses were done for each epoch’s time series, and the resulting estimates of optimal model order for the individual segments ranged from 11 to 28. For consistency, a fixed model order of 30 was then used for the autoregressive analyses of all the segments. Although this value might be considered a relatively high model order for an autoregressive analysis, the ratio of data points to coefficients (1280/30 = 42.7) in each segment is large enough to make reliance on asymptotic statistical theory credible. The power spectral density graph is a type of variance histogram that depicts the strength of physiological rhythms (y-axis) as a function of their periodicity or frequency (x-axis).

The y-axis can be expressed in natural power/variance units (for heart period time series, typically in milliseconds squared), or logarithmic units (log of milliseconds squared, or decibels: dB [ms²] = 10 x log₁₀[ms²]). The amount of power in the low- and high-frequency regions was obtained from the power spectral densities by integrating the power within the bands. These within-subject summaries were further analyzed in a multivariate ANOVA in SPSS 10.0.

Results

Description of the Sample

Subjects were recruited between October 1997 and December 1998. Twenty-eight infants were eligible for the protocol; 21 mothers consented and 7 declined to participate. Four of the infants no longer required mechanical ventilation before the protocol was started, a situation that made them ineligible for the study. Three infants were dropped from the study during the protocol, 2 because of gastrointestinal illness unrelated to the study and 1 because of removal of the endotracheal tube midway through the protocol (because the infant no longer required mechanical ventilation). The study protocol was completed by 7 boys and 7 girls (N=14).

Of the 14 infants, 11 were white and 3 were of mixed ethnicity. All infants were cared for in double-walled incubators with a mean air temperature in the incubators of 30.9°C (SD = 1.1°C) during both phases of the study. Characteristics of the infants did not differ significantly between crossover order groups (Table 2).

Heart Period Variability

Time Domain. Time series plots of heart period for each infant were generated to visualize the short-term variability of the infant’s heart period (interbeat interval across time) during incubator care and skin-to-skin care. Figure 2A is a time series plot of one infant during incubator care, and Figure 2B is the time series plot of the same infant during skin-to-skin care. The mean interbeat interval for this infant during skin-to-skin care (332 ms; SD = 8 ms) was shorter than the mean interbeat interval during incubator care (368 ms; SD = 9 ms). Additionally, the variability for this infant across time was less during skin-to-skin care than during incubator care. Time series plots of heart period were similar for all infants during incubator care and during skin-to-skin care; infants had shorter interbeat intervals and less variability during skin-to-skin care.

Frequency Domain. Spectral density plots for each heart period epoch for each infant were generated and were inspected for a peak within the high-frequency
This peak is indicative of respiratory sinus arrhythmia, which is suggestive of increased parasympathetic tone, as described previously. Figure 3A is a spectral series plot of an infant during incubator care, and Figure 3B is a spectral series plot of the same infant during skin-to-skin care. The respiratory peak for this infant is wide and dispersed rather than sharp and narrow.

Table 2 Characteristics of infants participating in the study*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Incubator phase first (n = 7)</th>
<th>Skin-to-skin phase first (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight, g</td>
<td>766 (174)</td>
<td>747 (148)</td>
</tr>
<tr>
<td>Gestational age at birth, weeks</td>
<td>25.7 (1.5)</td>
<td>25.6 (1.7)</td>
</tr>
<tr>
<td>Day of life entered study</td>
<td>34 (12)</td>
<td>35 (7)</td>
</tr>
<tr>
<td>Weight at entry into study, g</td>
<td>994 (183)</td>
<td>986 (256)</td>
</tr>
<tr>
<td>Gestational age at entry into study, weeks</td>
<td>31.5 (1.0)</td>
<td>30.0 (2.0)</td>
</tr>
<tr>
<td>Ventilator settings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak inspiratory pressure, cm H2O</td>
<td>18 (2.7)</td>
<td>20 (2.1)</td>
</tr>
<tr>
<td>Positive end-expiratory pressure, cm H2O</td>
<td>5.5 (0.7)</td>
<td>5.6 (0.9)</td>
</tr>
<tr>
<td>Inspiratory time, seconds</td>
<td>0.3 (0.02)</td>
<td>0.3 (0.02)</td>
</tr>
<tr>
<td>Ventilator rate, breaths per minute</td>
<td>24 (4)</td>
<td>29 (9)</td>
</tr>
<tr>
<td>Fraction of inspired oxygen</td>
<td>0.40 (0.13)</td>
<td>0.38 (0.12)</td>
</tr>
<tr>
<td>Inspired gas temperature, °C</td>
<td>34.5 (1.2)</td>
<td>35.1 (0.7)</td>
</tr>
</tbody>
</table>

*Values presented as mean (SD). No significant differences were found between groups in any of the variables (Mann-Whitney U test, P > .05).

Figure 2 Time series plot of an infant’s heart period variability (256-second epoch of R-R interval) during incubator care (A) and skin-to-skin holding (B). For incubator care, mean R-R interval is 368 ms (SD = 9 ms). For skin-to-skin care, mean R-R interval is 332 ms (SD = 8 ms).
The amount or level of variability of heart period was difficult to quantify via visual inspection because the visual judgment and memory of an observer limit the reliability of evaluating multiple data points across time in 14 subjects. Therefore, data were further analyzed by using multivariate repeated measures statistics to determine the type and level of change across time.

Repeated-Measures MANOVA. Heart period data were analyzed for differences between the 2 phases and among 6 periods by using repeated-measures MANOVA. Aggregated means of power in the low-frequency region, power in the high-frequency region, and the ratio of low- to high-frequency power for 14 infants were entered into the repeated-measures MANOVA model. Crossover order was entered into the analysis as a between-subjects factor. No significant crossover-order effect was detected; therefore, crossover order was removed from further analyses.

The repeated-measures omnibus multivariate F test revealed no significant within-subjects effects of phase (incubator care vs skin-to-skin care; \(F_{3,11} = 1.77, P > .05\)), time (morning, midday, afternoon; \(F_{5,8} = 5.47, P > .05\)), or phase by time interaction (\(F_{6,8} = 2.62, P > .05\)) on mean low-frequency power, mean high-frequency power, or mean ratio of low- to high-frequency power. The mean low-frequency power, the mean high-frequency power, and the mean ratio of low- to high-frequency power were higher during skin-to-skin care than during incubator care, but this difference was not significant.

Mean low-frequency power was 124.6 ms\(^2\) (SEM = 52.0 ms\(^2\)) during skin-to-skin care, 70.3 ms\(^2\) (SEM = 18.0 ms\(^2\)) during incubator care before skin-to-skin care, and 71.4 ms\(^2\) (SEM = 17.8 ms\(^2\)) during incubator care after skin-to-skin care (Figure 4). Mean low-frequency power during the incubator phase was between 51.9 ms\(^2\) (SEM = 8.4 ms\(^2\)) and 61.7 ms\(^2\) (SEM = 9.1 ms\(^2\)).

Mean high-frequency power was 8.8 ms\(^2\) (SEM = 2.1 ms\(^2\)) during skin-to-skin care, 6.5 ms\(^2\) (SEM = 0.7 ms\(^2\)) during incubator care before skin-to-skin care, and 7.1 ms\(^2\) (SEM = 0.8 ms\(^2\)) during incubator care after skin-to-skin care (Figure 5). Mean high-frequency power during the incubator phase was between 6.1 ms\(^2\) (SEM = 0.4 ms\(^2\)) and 6.3 ms\(^2\) (SEM = 0.5 ms\(^2\)).

The mean ratio of low- to high-frequency power was not significantly different during incubator care and skin-to-skin care: it was 6.7 ms\(^2\) (SEM = 0.7 ms\(^2\))

Figure 3 Spectral density plot of an infant’s heart period during incubator care (A) and skin-to-skin holding (B) using yule-walker autoregressive model (30).
determining the balance between the parasympathetic and sympathetic branches of the autonomic nervous system. Heart period variability is a useful tool for evaluating the physiological responses of premature infants to various stimuli. In this study, I evaluated the effect of a type of maternal holding, skin-to-skin care, on heart period variability in premature, intubated VLBW infants.

The infants in the study did not have any significant differences in heart period variability between incubator care and skin-to-skin care. A number of factors may have influenced these results. First, the low-frequency region of heart period variability is influenced not only by the sympathetic branch of the autonomic nervous system, but somewhat by the parasympathetic branch.22 Second, body temperature, sleep state, and the infant’s position, respiration, and gestational age may influence heart period variability through the effect they have on the autonomic nervous system.13,20,33 The potential effect of these variables on the autonomic nervous system as measured by heart period variability are addressed in the following paragraphs.

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The infants in the study had significantly higher body temperature and fraction of inspired oxygen required during skin-to-skin care than during standard incubator care, along with lower (albeit not significantly lower) oxygen saturation.7 Increased environmental temperature increases infants’ central and
peripheral body temperatures, with a concurrent increase in low-frequency power.34 The increase in low-frequency power during periods when the infants’ body temperatures were higher suggests increased activity from the sympathetic nervous system. The ratio of low- to high-frequency power is useful in determining balance between the sympathetic and parasympathetic branches of the autonomic nervous system. The ratio of low- to high-frequency power was minimal at environmental temperatures that maintain infants’ temperatures within the low normal range.34 A temperature stimulus applied to extremities of premature infants increases power within the heart period power spectra, suggesting entrainment of the autonomic nervous system to external thermal stimuli.35,36 However, a temperature stimulus alters peripheral vasomotor tone, which may also influence power in the heart period power spectra. Infants in the study reported here had increased low-frequency power during periods of increased temperature, similar to findings in previous studies, suggesting increased sympathetic activity.

In one study,37 during deep sleep, healthy infants and children had increased power in the high-frequency region, suggesting dominant parasympathetic tone during this stage of sleep. Porges et al38 concluded that infants have greater vagal tone during quiet sleep, with a decrease in vagal activity as active sleep occurs. Infants in my study were in an irregular sleep state during the periods that heart period was measured in both phases of the study.37 Irregular sleep state was defined as irregular breathing with no movement or slight movement of the forearm, lower leg, toes, hands, or fingers.37 It is not surprising that the power within the high-frequency region was similar, because of the similarity in sleep states across all periods. However, sleep state does not account for the differences in variance across all time periods, specifically, the increased variance in heart period during skin-to-skin care compared with the other periods when the infants were in the incubator.

Infants have significantly less variability in heart period variability (ie, a significantly smaller SD) when positioned prone than when positioned supine.39 Although the variability in heart period differed, the variability was not quantified by frequency region, which made extrapolation of the findings to maturation of the autonomic nervous system difficult. Infants in my study were positioned upright on their mothers’ chests during skin-to-skin care, a position different from the slight elevation of the head of the bed while the infants were in the incubators. Further study of the effect that an infant’s position has on heart period variability is needed before conclusions can be drawn about the effect of position on heart period.

Gestational age influences heart period variability. Premature infants between 31 and 36 weeks’ corrected gestational age have less power in the low-frequency region than do term infants.21 Chatow et al20 described the increase in heart period variability, specifically vagal tone, in premature infants as the infants approach...
Heart period variability is a unique measure of tone of the sympathetic and parasympathetic branches of the nervous system. The purpose of this study was to describe heart period variability in intubated VLBW infants during incubator care and skin-to-skin care. Infants did not have any significant difference in the power in the low-frequency or high-frequency regions during incubator care compared with skin-to-skin care. A number of covariates could have influenced these results, including gestational age, temperature, oxygenation, and mechanical ventilation. Research describing the relationship between heart period variability and the aforementioned variables is necessary to more fully understand the balance between the sympathetic and parasympathetic nervous systems in VLBW infants. Nurses caring for these infants, however, must be aware that the infants may have immature autonomic nervous systems and that nursing care of all types, including skin-to-skin holding, may put undue stress on the infants.

Conclusions

Heart period variability is influenced by respiration and mechanical ventilation. Frazier et al reported that heart period variability in the low-frequency range increased significantly, with a concurrent decrease in power in the high-frequency range, in dogs treated with a combination of positive pressure and continuous positive airway pressure. Preterm infants in my study all received pressure-support ventilation with positive end-expiratory pressure. These infants had similar variabilities in heart period, except for the infants of 32 to 34 weeks’ gestational age, who had greater variability than the other infants. The infants of younger gestational age may be more sensitive than the infants of older gestational age to the influence of mechanical ventilation on heart period variability. However, this area of research must yet be explored. Heart period variability in the low-frequency region is influenced by the severity of respiratory distress in preterm infants, whereas ventilator rate reportedly influences the high-frequency region of heart period variability.

Infants in my study were all receiving mechanical ventilation, which probably influences the power within the low- and high-frequency regions of heart period variability.

Limitations and Recommendations

The study was limited by a number of factors. First, the sample size was modest, although it was adequate for detection of a medium effect size when repeated-measures MANOVA was used as described in the power analysis. Second, the infants completing the study were from 28 to 34 weeks’ corrected gestational age. The wide range of gestational ages confounded the amount of power within the low- and high-frequency regions. In addition, the sample sizes among the gestational age groups were too small for powerful statistical analyses. Despite these limitations, the data suggest that maturation of the autonomic nervous system, as indicated by the amount of power in the spectral regions of heart period, occurs around 32 weeks’ gestation. Studies of premature infants across various gestational age groups are needed to determine more accurately (1) normative values for each gestational age and (2) the gestational age at which maturation of the autonomic nervous system occurs, with improved balance between the parasympathetic and sympathetic branches.

The second limitation of the study is the number of infant covariates, such as temperature, oxygenation, position, gender, feeding, and awake-sleep state. These variables may have influenced the amount of power in the low- and high-frequency regions at any given time. A secondary analysis of the relationship between the confounding variables and heart period variability is needed to determine which variables have the strongest relationship to heart period variability and to identify the region (low or high frequency) of influence.

Acknowledgments

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