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Development and Evaluation of Neonate Physiological Index at Parental Contact

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Abstract Rooming-in is an arrangement that allows mothers and newborn babies in the same room during the postpartum hospital stay. This practice gives an opportunity for the parents to have more affectionate touching with their infants. However, the influence of intimate contact on a neonate's physiological changes has not been studied. Our study develops an evaluation system of neonate physiological changes during parental contact. The system recorded an electrocardiogram (ECG) in real-time and analyzed the heart rate variability (HRV). Thirty healthy neonates were recruited for this study. The paired t-test was performed for statistical analysis. The HRV of a baby with and without parental hold was compared. The HF power and HF/LF ratio are significant ($P<0.05$). However, there is no considerable difference in LF power. In conclusion, this research has developed a system to evaluate the neonate physiological index. The system can make available the long-term monitoring and recording of neonate physiological information for parents.

Keywords: *Rooming-in, Neonate, Electrocardiogram (ECG), Heart rate variability (HRV)*

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1. Introduction

Parents prefer rooming-in after birth with their infants rather than using the hospital nursery. Parents and their support persons can ask questions during assessments, and get to know their newborns, such as their feeding cues and other needs. Earlier studies show that babies are much calmer and cry less while rooming-in. Studies have shown that rooming-in has many benefits: babies cry less and are easier to calm [1,2], mothers have reduced anxiety and are more relaxed [3] with more capacity to respond to baby's feeding cues, mothers make more breast milk with reduced breast engorgement post-partum, there is improved breastfeeding duration [4,5], and the care of the baby is ensured with no fear of baby switching. Rooming-in can be done in various ways with skin-to-skin contact with the mother or father [6,7]. These practices significantly decrease the need for babies to be placed under a radiant warmer after birth and baths. However, the influence of intimate contact on a neonate's physiological changes with rooming-in has not been studied. Measurement of heart rate variability (HRV) is a non-invasive method that can be used to scrutinize the functioning of the autonomic nervous system (ANS), particularly the balance between sympathetic and parasympathetic activity [8]. HRV has been used in humans for research and clinical studies concerned with cardiovascular diseases, and psychiatric, psychological and environmental stressors, such as temperament and coping strategies [9]. Chatow et al. [10] studied the normative data for neonatal HRV. Their study showed that patterns of the heart rate power spectrum can be used to provide insight into maturation and the autonomic development of preterm and full-term neonates. Smith [11] studied the heart rate variability in 14 infants with very low birth weight (during incubator care) and the time period of mother skin-to-skin contact. Smith [11] showed that heart rate variability with spectral power analysis and time-domain analysis provides information about the control of the heart by the ANS. In this study, infants did not have any differences in heart rate variability between incubator care and skin-to-skin care. A lot of factors may have influenced these results. Mazursky et al. [12] studied the developmental changes in autonomic cardiovascular reflexes in preterm infants. Twenty-eight infants were studied, beginning at 28-32 weeks postconceptional age. Every week, heart rate variability in the supine position and after 45° head-up tilt was analyzed by spectral analysis. Results suggest that for infants, cardiac baroreceptor reflexes are more functional with postnatal development. HRV contributes to our understanding and estimation of the underlying neurophysiologic processes of stress responses. This study develops an evaluation system of neonate physiological changes during parental contact, observing the HRV responses of the neonates to intimate contact with and without parental holding.

2. Methods

2.1. Subjects

This study involved 30 physical healthy infants scrutinized from July 2014 to November 2014. The Institutional Review Board acknowledged the protocol of the study , and written assent was provided by their legal guardians. A set of data was collected and recorded in terms of: maternal and paternal age, infant gender, type of delivery (vaginal or cesarean), gestational age, baby birth weight, APGAR scores in the first and fifth minutes, Postnatal age and baby weight at the time of evaluation, breastfed or formula fed. This study involved postnatal 7-day and older asymptomatic infants. We grouped the infants for our study on the basis of the following criteria: 36 through 41 weeks gestational age, weight more than 2,500 grams, both clinically and neurologically healthy. We excluded infants with congenital anomalies, cardiac disease, and histories of intraventricular hemorrhage, asphyxia, or other complicated medical conditions. The data collection started at least 24 hours after birth. For each subject, 30 minutes of ECG readings were recorded at the end of feeding while: mother is holding, father is holding, and neonate sleeps alone in a crib. Repeated measurements were taken for the comparative study.

2.2. Hardware Signal Processing Initial Stage

An amplification of at least 1000 and filters with different cut-off frequencies were required to get a valid final ECG signal. The ECG module acted as a one channel system to store lead-I signals across the thoracic cavity. A measuring device with filtering and amplification circuitry was implemented using off-the-shelf components. Figure 1 shows the ECG signal detected by the device.

The electrical activity was recorded using surface electrodes. We used a general-purpose personal computer (PC) to perform the signal acquisition, storage, and processing. The raw ECG analog signals were transmitted to a PC and recorded using 12-bit analog-to-digital converter with a sampling rate of 1000 Hz by MSP430F6659 [13]. The system also sent physiological signals by a USB communication module [14]. The PC was used to record the transmitted data. The ECG signal was displayed and saved using a Borland C++ Builder program.

2.3. Signal Processing

For heart rate fluctuations in ECG, the Heart Rate Variability (HRV) spectral analysis was performed offline. The method of heart rate extraction in the detection of QRS complexes utilized the Pan-Tompkins algorithm written in Matlab7.0.1 [15]. The algorithm used the digital analysis of amplitude, slope, and width of QRS complexes for successful detection. The ECG waveform first passed through a bandpass filter. The derivative of the ECG signal was taken. This was rectified by amplitude squaring with smoothing of the waveform by a moving window integrator. Finally, the R wave was detected by the dynamic threshold detection method to compute the RR intervals. The RR interval series was transformed into an evenly sampled signal using Berger's algorithm and re-sampled at 10 Hz [16]. It was shown that this technique outperforms other existing techniques in terms of the reduction of energy of harmonics and artifacts. The Fast Fourier transformer (FFT) algorithm was applied to decompose the amplitudes of the sequential series of RR intervals into the frequency domain. The power spectrum of HRV was estimated. The power spectral densities are statistically useful in determining the balance between the sympathetic and the parasympathetic nervous systems. The power spectra have been divided into low and high frequency regions of activity, with each region influenced by different physiological phenomena. The low-frequency (LF) region was influenced primarily by the sympathetic ANS. Variables that may influence the LF region include thermoregulation, peripheral vasomotor responses, and baroreceptor responses or fluctuations in blood pressure. The sympathetic nervous system accelerated the heart rate and can be viewed as the part of the ANS that is related to stress or activation. The high-frequency (HF) region reflects parasympathetic activity and is influenced by respiration. The parasympathetic nervous system is responsible for the recovering heart rate from sympathetic activation (decelerating heart rate) and can be viewed as the system responsible for relaxation or rest and healing [16]. Outcome measures in the present study included the LF power, HF power, and LF/HF ratio. As reported in the literature [17,18], the standard LF-frequency and HF-frequency ranges classified for adult HRV analysis do not apply to infants. For the purposes of this study, the frequency regions as defined by Rosenstock et al [20] were used. There are two different frequency ranges: Low Frequency (LF: 0.04-0.2Hz) and High Frequency (HF: 0.2-2.0Hz). The frequency regions are influenced by specific branches of the autonomic nervous system, and the ratio of low-frequency to high-frequency power indicates ANS balance.

2.4. Statistical Analysis

The design of this study used repeated inspections for each infant (measured in each section). Differences between the mean values for the different groups were analyzed by paired t-test. The significance level utilized by all analysis was 0.05.

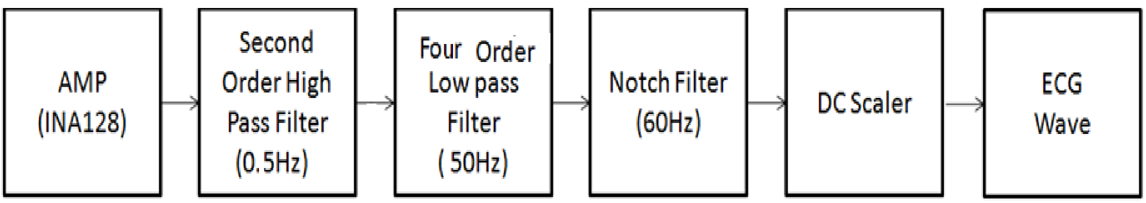

Figure 1. Flow diagram of ECG module for detecting ECG

3. Results

We examined the HRV data and manually identified object interference with the ECG signal. This study has involved 30 neonates with ECG data (30 minutes) analyzed in three states. The mean gestational age at birth is 38.9 weeks, while the mean postnatal age upon study enrollment is 2.4 days (range: 1 to 4 days). Additional infant characteristics are shown in Table 1.

For each subject, 30 minutes of ECG data were obtained by our system with mother holding, father holding, and without any holding. Table 2 shows the low-frequency power that is associated with sympathetic nerve activation; there is no significant change in holding infants and non-holding infants.

Table 3 is showing the high-frequency power that is associated with parasympathetic nerve activation. The result showed a noteworthy difference between infants sleeping alone and with someone holding them. Infants are calm when held by the parents.

Table 4 shows the LF/HF power ratios for the low frequency and high frequency. This result indicates that parasympathetic activation has more influence in holding infants.

Table 1. Demographic and medical characteristics of infants (n= 30)

Variables		Values
Mean maternal age		31
Mean paternal age		33
Gender	Male	15
	Female	15
Delivery	V	20
	C	10
APGAR score	1 min	8
	5min	9
Feeding	Breastfed	23
	Formula fed	7
GA (weeks)	Mean	38.9
BBW (g)	Mean	3072±329.2
Postnatal age (days)	Mean	2.4
BW (g)	Mean	2874.3±326.1
V, vaginal; C, cesarean; GA, gestational age; BBW, baby birth weight; PA, postnatal age at initial study; BW, baby weight.		

Table 2. LF power during neonate sleep: neonate sleeps alone in crib and with parent intimate holding. A paired t-test analysis was used for comparison.

Characteristics	sleep alone in crib	Mother intimate holding	Father intimate holding
Mean LF Power	0.207±0.03	0.202±0.024	0.201±0.025
Comparison of sleeping alone with mother holding		p value	0.38
Comparison of sleeping alone with father holding		p value	0.337
Comparison of mother holding with father holding		p value	0.756

Table 3. HF power during neonate sleep: neonate sleeps alone in crib and parent intimate holding. A paired t-test analysis was used for comparison.

Characteristics	Neonate sleeps alone in crib	Neonate with mother intimate holding	Neonate with father intimate holding
Mean HF Power	0.369±0.034	0.395±0.043	0.395±0.038
Comparison of sleeping alone with mother holding		p value	0.001
Comparison of sleeping alone with father holding		p value	<0.001
Comparison of mother holding with father holding		p value	0.97

Table 4. LF/HF power ratio during neonate sleep: alone in crib and parent intimate holding. A paired t-test analysis was used for comparison.

Characteristics	Neonate sleeps alone in crib	Neonate with mother intimate holding	Neonate with father intimate holding
Mean LF/HF Power Ratio	0.570±0.115	0.522±0.11	0.516±0.103
Comparison of sleeping alone with mother holding		p value	0.019
Comparison of sleeping alone with father holding		p value	0.019
Comparison of mother holding with father holding		p value	0.74

4. Discussion

In this research, HRV indices provide a non-invasive measure of sympathovagal balance during rooming-in among 30 neonates (36-41 weeks GA) for sleeping alone in a crib and parents intimate holding. A neonate's behavior is too fussy in an open crib, but they were calm and fell asleep very soon on being placed skin-to-skin.

Consistent with previous studies [20], LF is shown to decrease and HF is shown to increase from active sleep to calm sleep in preterm infants. Our study's decreased mean LF and increased mean HF during parental holding may be related to an infant changing from a fussy and restless sleep state while in an open crib to a constant sleep state while in parental holding. Neonatal HRV variations between skin-to-skin contact and sleeping alone signify that LF/HF is lower with skin-to-skin contact at baseline than in the sleeping alone situation. Previous studies showed that mother-infant bed-sharing decreased HRV compared to when the infants are sleeping alone [21]. However, the possibility exists that sensory stimulation from co-sleeping may account for these physiologic differences. Neonates may have received sensory stimulation from being in skin-to-skin contact with the mother.

The change in neonate HRV index during rooming-in may be related to a lot of factors such as temperature, environment, and behavioral state when infants sleep with parents. We used a microphone to measure the environmental sound level (in decibels). The average sound level in the rooming-in environment is below 42 dB. Our research staff activity has visitors entering and exiting the room, telephone ringing, talking, staff nurses checking on the mother, and infant background noise at a level of 55-75 dB in the rooming-in environment. Higher mean noise levels increase the heart rate. This has been shown in previous infants' heart rate variability studies that show stress [22]. Another study showed [23] that the neonate LF/HF ratio increased significantly with a noisy environment, suggesting that the sound level stimulates the infants ANS system, accelerating the heart rate. Infants are stressed when exposed to sound in the rooming-in atmosphere. Therefore, decreasing the sound in the rooming-in environment is suggested.

During intimate contact, the mother is sensitive and responsive to infant needs. A number of participating mothers attempted to breastfeed. Our study analyzed the effects of maternal feeding behavior on neonatal HRV during feeding. A previous study has shown that a mother's interactive behavior may affect her infant's HRV.

The heart rate variability showed the same pattern for infants. Beat-to-beat heart rates are increased from the pre-feeding baseline to feeding and for the post-feeding recovery time period. The LF power in the post-feeding period remained similar to the LF power with feeding. The HF power decreased from pre-feeding to feeding and remained at feeding levels in the post-feeding period. The LF and HF ratios are higher during feeding and post feeding than in pre-feeding [24,25]. Our study is consistent with the findings of previous research. This finding may signify that parasympathetic withdrawal allows the sympathetic influence to predominate, increasing the heart rate for maintenance of cardiac stability related to the exertion of feeding and during recovery after feeding. A neonate's physiological system balances parasympathetic and sympathetic activity during a feeding interaction. An infant is skin-to-skin with a parent holding the blanket folded in fourths across his/her back. The parent's body heat may have increased a neonate's body temperature as has been documented in a previous Kangaroo Care study [26]. The relationships of neonate HRV to the rooming-in temperature and air conditioning system is an area that needs future research.

This research has designed and implemented an evaluation system for a neonate physiological index. The system can be made available to parents for long-term monitoring and recording of their neonate's physiological information. Our result shows the influence of parental holding on rooming-in and long-term neonate HRV. Our result provides information for clinical staff and parents to promote neonatal health with an understanding of the influence of skin-to-skin contact on the neonatal autonomic nervous function. Parental affectionate touch may benefit cardio-respiratory stability. Further investigation is recommended.

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