Original Paper

Biology *of the* **Neonate**

Biol Neonate 2004;86:81–84
DOI: 10.1159/000077782

Received: August 7, 2003
Accepted after revision: January 9, 2004
Published online: April 8, 2004

Power Spectral Analysis of Heart Rate in Relation to Sleep Position

Magali Jean-Louis Mujahid Anwar Har'el Rosen William Craelius
Mark Hiatt Thomas Hegyi

Division of Neonatology, UMDNJ-Robert Wood Johnson Medical School and St Peter's University Hospital,
New Brunswick, N.J., USA

Key Words
Autonomic tone · Sleep position · Power spectral analysis · Heart rate variability

Abstract
We used spectral analysis of heart rate variability, as a measure of autonomic tone, to determine spectral power differences in infants sleeping supine and prone. We studied 29 infants with a birth weight of 1,915 ± 939 g, at the postconceptional age of 36 ± 2 weeks. We then calculated total power (TP), low-frequency power (LF, 0.03–0.15 Hz), and high-frequency power (HF, 0.5–1.0 Hz). TP corresponds to overall heart rate variability, LF to both sympathetic and parasympathetic activity, and HF to parasympathetic activity only. Median (25th, 75th percentile) TP (beats/min^2) in the supine position was 32.60 (23.12, 59.90), which was significantly higher than the prone position of 25.87 (14.94, 35.57). Similarly, LF (beats/min^2) in the supine position of 13.82 (8.63, 23.31) was significantly higher than the prone position of 9.79 (5.46, 14.33). No significant difference was seen in the HF. We conclude that the prone position is associated with decreased heart rate variability and probably decreased sympathetic tone, which imply decreased autonomic stability in this position.

Introduction

The prone sleep position in infancy increases the risk of sudden infant death syndrome (SIDS) [1]. The mechanism of this increased risk is not clear. Postulated mechanisms have included genetic susceptibility, suffocation, decreased arousal, abnormal control of breathing and abnormal autonomic control [2]. Brainstem lesions such as gliosis, hypomyelination and hypoplasia in victims of SIDS support a role of autonomic dysfunction and abnormality of arousal in these infants [3, 4]. Autonomic tone can be assessed non-invasively by spectral analysis of heart rate variability (HRV). Spectral analysis of HRV is a mathematical technique that quantifies the cyclic variations in the heart rate tracing. In animal studies [5], as well as in humans [6, 7], the power spectrum of HRV falls into two main peaks. The first is a low-frequency peak (LF) between 0.03 and 0.15 Hz, which is multifactorial in origin (thermoreceptors, baroreceptors, chemoreceptors), and is a reflection of both sympathetic and parasympathetic activity. The second is a high-frequency peak (HF) occurring between 0.5 and 1.0 Hz, solely mediated by the parasympathetic system and is a reflection of respiratory sinus arrhythmia. We, therefore, decided to use spectral analysis of HRV to determine differences in sleep positions with regard to autonomic control in a group of growing preterm infants approximately 1 week before hospital discharge.

KARGER
Fax +41 61 306 12 34
E-Mail karger@karger.ch
www.karger.com

© 2004 S. Karger AG, Basel
0006–3126/04/0862–0081$21.00/0

Accessible online at:
www.karger.com/bon

Mujahid Anwar, MD
Division of Neonatology, St Peter's University Hospital
254 Easton Avenue, MOB 4th Floor
New Brunswick, NJ 08903 (USA)
Tel. +1 732 7458523, Fax +1 732 2496306, E-Mail manwar@saintpetersuh.com

Methods

Subjects

This study was conducted in the Special Care Nursery at St. Peter's University Hospital and was approved by the Committee for Protection of Human Subjects in Research at the medical center. Infants were included in the study when they had reached full oral feeding and were weaned to a bassinet (36 ± 2 weeks postconceptional age). They were excluded from the study if they had any of the following: a history of birth asphyxia, any congenital anomalies, cardiac disease or central nervous system lesions, or if they were still requiring oxygen at the time of the study. Informed consent was obtained from parents of each infant before enrollment.

Data Collection and Heart Rate Variability Analysis

Each study period started at least 30 min after feeding and lasted for 2 h. All recordings were obtained during quiet sleep (regular respiration and absent body movement). Infants were randomly placed in the prone or supine sleeping position during the first period, and then switched to the opposite position in the second period. All recordings were made using a Log-a-Rhythm Signal Acquisition Unit (Nian-Crae, Inc., Somerset, N.J., USA). As described previously, this unit utilizes a conventional electrocardiographic monitoring technique at a sampling rate of 1 kHz [7, 8]. The EKG data were then digitized and RR intervals stored with a resolution of 4 ms. A tracing of instantaneous heart rate was generated digitally using the stored RR interval data. To obtain equally spaced samples, the final sampling rate of the instantaneous heart rate was 4 kHz. The EKG data were analyzed to determine the power spectrum of heart rate using IBM-compatible software developed by Nian-Crae Inc. For each infant, multiple 150-second artifact-free recording segments were used to generate power spectra. The area under each power spectrum was then calculated: 0.03–0.39 Hz (low frequency = LF), 0.5–1.00 Hz (high frequency = HF) and total area under the power spectrum as total power. For each infant the values from multiple segments of the same recording were averaged for LF, HF and TP.

Statistical Analysis

Continuous data is shown as mean ± SD. Power spectra were not normally distributed and they are shown as median (25th, 75th percentile). Effect of sleep position was analyzed using the Wilcoxon matched pairs test. All statistical analyses were performed by using Statistica for Windows, version 5.5. A p value of <0.05 was considered to be statistically significant.

Results

Our study included 29 subjects. Patient characteristics are shown in table 1. Power spectral data are shown in table 2. The number of segments averaged to obtain these data were 11 ± 8 in the supine position and 15 ± 9 in the prone position. As seen in table 2, infants in the prone position had significantly lower TP and LF ($p < 0.05$) in comparison to the supine position. No significant difference was seen in HF ($p = 0.32$).

Table 1. Demographic features of study subjects (n = 29)

Sex (males)	10 (34%)
Race	
White	15 (52%)
Black	9 (31%)
Hispanic	4 (14%)
Indian	1 (3%)
Gestational age, weeks	32 ± 4
Postconceptional age, weeks	36 ± 2
Birth weight, g	1,915 ± 939
Weight at study, g	2,290 ± 688

Categorical data is expressed as numbers, continuous data is expressed as mean ± SD.

Table 2. Spectral power (beats/min^2) in the two positions

	Supine	Prone	p value
LF	13.82 (8.63, 23.31)	9.79 (5.46, 14.33)	0.001
HF	0.67 (0.31, 1.56)	0.50 (0.26, 1.02)	0.315
TP	32.60 (23.12, 59.90)	25.87 (14.94, 35.57)	0.001

LF = Low frequency (0.03–0.15 Hz); HF = high frequency (0.5–1.0 Hz); TP = total power (total area under the power spectrum curve).

Discussion

The main findings of our study are decreased total power and decreased low-frequency power with no significant difference in high-frequency power. Total power in the frequency domain is equivalent to overall HRV in the time domain. Decreased HRV in the prone position is consistent with previous studies, most of which used time series analysis. Franco et al. [9], in a study of the cardiac response to auditory stimulation, showed decreased HRV both before and after auditory challenge in the prone sleeping position in a group of 20 infants with a median age of 11 weeks. Goto et al. [10] found increased HRV and arousal in the supine position in a group of 16 asymptomatic preterm infants studied at 36 weeks postconceptional age. Using both time series and power spectral analysis, Sahni et al. [11] studied a group of premature infants ranging from 30 to 38 weeks' gestational age and also found decreased HRV in the prone position. In a subsequent study, Sahni et al. [12] found the same results with use of time series analysis in 51 preterm infants between 26 and 37 weeks' postconceptional age.

In contrast to similar changes in overall HRV in relation to sleep position, the data on the component of frequency spectrum responsible for this change in HRV is more discrepant. We found a decrease in LF power without any change in HF power in the prone position in comparison with the supine position. As HF power is solely due to parasympathetic activity and it does not change significantly in the prone position, we assume that a decrease in LF power in the prone position is a reflection of decreased sympathetic tone in the prone position. Sahni et al. [12] found a decrease in both LF and HF in the prone position in comparison to the supine position, whereas Franco et al. [9] found no differences with regard to sleep positions. These differences in results may be in part due to the different bandwidth chosen by different investigators. We chose the traditional bandwidth of LF of 0.03–0.15 Hz and HF of 0.5–1.0 Hz, which have been correlated with differential sympathetic and parasympathetic tone in newborn infants. Sahni et al. [12] used a larger HF bandwidth of 0.5–2.0 Hz and Franco et al. [9] used HF bandwidth centered over 0.4 Hz and LF bandwidth centered over 0.1 Hz.

Our findings of decreased HRV and decreased sympathetic tone in the prone position are consistent with previous work showing decreased vasomotor tone in the prone position. White et al. [13] reported a greater change in blood pressure in infants lying prone during head tilt compared to infants lying supine. Chong et al. [14] demonstrated a lower blood pressure but a higher peripheral skin temperature in infants sleeping prone compared to infant sleeping supine. In response to head tilt, the prone sleeping infants had greater reduction in blood pressure and greater increase in body temperature than infants sleeping supine. By measuring cutaneous blood flow by Doppler flowmeter, Galland et al. [15] showed less vasoconstriction in response to tilt in the prone position compared to the supine position. These findings are consistent with decreased sympathetic tone in the prone position. The mechanism of decreased sympathetic tone in the prone position is not known. Kahn et al. [16] have suggested that decreased sympathetic tone in the prone position may be related to altered sleep pattern. In their study, infants in the prone position had an increased sleep duration and increased amount of time spent in quiet sleep.

One weakness of our study and previous studies in preterm infants is a lack of objective evidence of sleep state. We evaluated sleep state by behavioral criteria rather than EEG criteria. Unfortunately we were unable to perform this EEG recording and cannot bring further information on this issue. Autonomic tone may change with REM, non-REM sleep and arousal. Arousal is easy to identify by behavioral criteria and it produces movement artifacts on the heart rate tracing which we eliminated from our analysis. The distinction between REM and non-REM sleep is more difficult. The investigators scoring these studies were blinded to sleep position and we assume similar number of epochs chosen for analysis in REM and non-REM sleep in the two positions. This assumption may not be true. However, our study aim was to determine HRV and the component of the autonomic nervous system responsible for this change and not the possible underlying mechanisms of these changes. Thus, from our study, we are not able to comment on the possible mechanisms involved.

In conclusion, we found decreased TP and decreased LF in the prone position in comparison with the supine position. These findings indicate decreased HRV and probably decreased sympathetic tone in the prone position, which imply decreased autonomic stability in this position.

References

1 Kattwinkel J, Brooks J, Keenan ME, Malloy M: Infant sleep position and sudden infant death syndrome (SIDS) in the United States: Joint commentary from the American Academy of Pediatrics and selected agencies of the Federal Government. Pediatrics 1994;93:820.

2 Hunt CE: Sudden infant death syndrome and other causes of infant mortality: Diagnosis, mechanisms and risk for recurrence in siblings. Am J Respir Crit Care Med 2001;164:346–357.

3 Filiano JJ, Kinney HC: Arcuate nucleus hypoplasia in the sudden infant death syndrome. J Neuropathol Exp Neurol 1992;51:394–403.

4 Naeye RL: Brain-stem and adrenal abnormalities in the sudden-infant-death syndrome. Am J Clin Pathol 1976;66:526–530.

5 Akselrod S, Gordon D, Ubel FA, Shannon DC, Berger AC, Cohen RJ: Power spectrum analysis of heart rate fluctuation: A quantitative probe of beat-to-beat cardiovascular control. Science 1981;213:220–222.

6 Pomeranz B, Macaulay RJ, Caudill MA, Kutz I, Adam D, Gordon D, Kilborn KM, Barger AC, Shannon DC, Cohen RJ: Assessment of autonomic function in humans by heart rate spectral analysis. Am J Physiol 1985;248: H151–H153.

7 Rosen H, Craelius W, Curcie D, Hiatt M, Hegyi T: Spectral analysis of heart variability in the newborn infant. Biol Neonate 2000;77: 224–229.

8 Veerappan S, Rosen H, Craelius W, Curcie D, Hiatt M, Hegyi T: Spectral analysis of heart rate variability in premature infants with feeding bradycardia. Pediatr Res 2000;47:659–662.

9 Franco P, Pardou A, Hassid S, Lurquin P, Groswasser J, Kahn A: Auditory arousal thresholds are higher when infants sleep in the prone position. J Pediatr 1998;132:240–243.

10 Goto K, Mirmiran M, Adams MM, Longford RV, Baldwin RB, Boeddiker MA, Ariagno RL: More awakenings and heart rate variability during supine sleep in preterm infants. Pediatrics 1999;103:603–609.

11 Sahni R, Schulze KF, Kashyap S, Ohira-Kist K, Fifer WP, Myers MM: Postural differences in cardiac dynamics during quiet and active sleep in low birthweight infants. Acta Paediatr 1999;88:1396–1401.

12 Sahni R, Schulze KF, Kashyap S, Ohira-Kist K, Myers MM, Fifer WP: Body position, sleep states, and cardiorespiratory activity in developing low birth weight infants. Early Hum Dev 1999;54:197–206.

13 White M, Beckett M, O'Regan M, Matthews T: Autonomic function and SIDS. Acta Paediatr Suppl 1993;82:105–106.

14 Chong A, Murphy N, Matthews T: Effect of prone sleeping on circulatory control in infants. Arch Dis Child 2000;82:253–256.

15 Galland BC, Taylor BJ, Bolton DP, Sayers RM: Vasoconstriction following spontaneous sighs and head-up tilts in infants sleeping prone and supine. Early Hum Dev 2000;58:119–132.

16 Kahn A, Groswasser J, Sottiaux M, Rebuffat E, Franco P, Dramaix M: Prone or supine body position and sleep characteristics in infants. Pediatrics 1993;91:1112–1115.