

Heart Rate Variability in Children with Congenital Heart Disease Before and After Open Heart Surgery

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ÖZEREN ET AL.: Heart Rate Variability in Children with Congenital Heart Disease Before and After Open Heart Surgery. Background: Spectrum analysis of heart rate variability (HRV) is a noninvasive procedure that provides information on sympathetic and parasympathetic controls. Reduced HRV may indicate cardiac autonomic dysfunction and susceptibility to hemodynamic instability during anesthesia, after myocardial infarction or cardiac operations. **Aim:** This study was designed to investigate the effects of cardiopulmonary bypass on HRV variability in children with congenital heart disease and if HRV is turning to the normal in postoperative period and when, as well as the duration of the process. **Methods:** HRV data were obtained from 29 pediatric patients with congenital heart disease, who underwent elective cardiac surgery. Electrocardiographic data were collected with PC-based ECG acquisition system (PC-ECG 1200). ECG results were obtained by assessing 200 heart beats that recorded in supine position. Clinical data including age, type of cardiac lesion, type of surgical procedure, cardiopulmonary bypass (CPB) time, cross clamp time were recorded. **Results:** 16 male and 13 female patients mean aged 8.08 ± 3.8 (1-15), 27 had an acyanotic heart disease, 2 of them had a cyanotic heart disease. Standard deviation of all normal RR intervals (SDNN) ($p=0.048$) and HRV triangular index ($p=0.017$) were significantly lower in the postoperative first month than preoperatively. There were no significant preoperative differences in other time or frequency domain measures of HRV between the preoperative recordings and postoperative for the first month. SDNN, low and high frequency were found significantly low when compared between the postoperative first and third month, although HF was decreased in the first postoperative month, but did not reach statistical significance. **Conclusion:** Our findings showed that decreased HRV is a nonspecific marker of cardiovascular stress just after the cardiac operations, reflecting an alteration in autonomic nervous system input to the heart and turning to the normal in the third month.

Cardiopulmonary bypass, heart rate variability, spectral analysis

摘要

背景：心率變異性的光譜分析（HRV），是一種能獲得交感和副交感控制資訊的非創傷性方法。麻醉過程中、心梗後及心臟手術後心率變異性的下降，可能說明了心臟自主功能障礙和血液流變學不穩定性的敏感性。**目的：**本試驗研究了心肺分流術（體外轉流）對先天性心臟病患兒心率變異性的影響，以及術後過程及間期HRV是否恢復正常。**方法：**採集29例選擇性心臟手術後的先天性心臟病患兒心率變異性數據。心電圖採用PC-ECG 1200，採集200次臥位心搏。記錄其他臨床指標包括年齡、心臟病變類型、手術方式、體外轉流時間（CPB）時間和十字鉗閉時間。**結果：**16例男性和13例女性平均年齡 8.08 ± 3.8 （1-15）。27例患有非發紺性心臟病，其餘2例患發紺性心臟病。術後一月的正常RR間期的標準差（SDNN）（ $p=0.048$ ）及心率變異性三角指數（ $p=0.017$ ）較術前顯著降低。術前和術後一月的其他時間和心率變異頻率域無顯著差異。比較術後一月及三月SDNN、低頻、高頻顯著降

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低。術後一月HF有所降低，但尚未達到顯著意義。**結論：**該研究表明，心率變異性是一項心臟手術後心血管應激的非特異性指標，反映自主神經系統至心臟傳導改變，並於術後三月恢復正常。

關鍵詞：心率變異性 心肺轉流術 光譜分析

Introduction

Heart rate variability (HRV), which reflects autonomic nervous system activity, is useful for assessing autonomic control under various physiologic and clinical conditions.¹ Spectrum analysis of HRV is a noninvasive procedure that provides quantitative information on sympathetic and parasympathetic controls. Reduced HRV may indicate cardiac autonomic dysfunction and susceptibility to hemodynamic instability during anesthesia, after myocardial infarction or cardiac operations.²⁻⁴

Reduced HRV has been observed in patients before and after operations of the congenital heart disease.⁵ Previous studies have mainly demonstrated HRV changes between preoperative and postoperative values. Little is known about course of HRV after the open heart operations for congenital heart disease. Consequently, the aim of this study was to investigate the effects of cardiopulmonary bypass on HRV variability in children with congenital heart disease and if HRV is turning to the normal in postoperative period, as well as the duration of the process.

were recorded for all patients. Postoperative data included duration of mechanical ventilation, inotropic support, pleural drainage, and hospitalization period.

The anesthesia and surgical management of all patients were performed same manner. Anesthesia was induced and maintained with ketamine hydrochloride (Ketalar®; EWL Eczacıbaşı Warner Lambert Istanbul-Turkey) and Fentanyl (Fentanyl Citrate®; Abbott Laboratories, USA). After surgery, all patients were admitted to the intensive care unit (ICU) and ventilated mechanically. Patients received routine postoperative care, including administration of analgesic as needed for pain relief, and dopamine for cardiac support if necessary. When cardiopulmonary function was stable, the patients were transferred to the ward. Patients receiving cardiovascular medications (beta-blockers, digoxin, and calcium antagonists) in postoperative follow-up were excluded from the study. Measurements were obtained on the preoperative day and in postoperative months 1 and 3. All HRV measurements were taken in the afternoon (2:00-6:00 PM) to avoid influences of night/day differences.

Patients and Methods

HRV data were obtained from 29 consecutive pediatric patients with congenital heart disease, who underwent elective cardiac surgery. Informed consent from the patient's parents was taken before surgery to participate in the study. Exclusion criteria included: a) Patients with arrhythmia or pacemaker; b) Weight less than 6 kg; c) Preoperative instable clinical conditions; d) Preoperative cardiovascular medications.

Clinical data including age, type of cardiac lesion, preoperative medications, type of surgical procedure, cardiopulmonary bypass (CPB) time, cross clamp time

Heart Rate Variability

Electrocardiographic data were collected with PC-based ECG acquisition system (PC-ECG 1200; NORAV Medical Ltd. Yokneam, Iceland). ECG results were obtained by assessing 200 heart beats that recorded in supine position. HRV parameters were assessed with careful attention given to the rhythm in order to be sure that patient was in sinus rhythm, and all of the marked QRS complexes were controlled. Mistakenly marked artifacts were corrected manually. For ECG recordings in which more than 10% had artifacts, the process was repeated.

A short period analysis of HRV was performed

for both the frequency and time domain parameters by using PC-based ECG acquisition system (PC-ECG 1200) that allows automatic measurements.

Heart Rate Variability Analysis

HRV measurement is based on the sequence of RR intervals. SDNN is the standard deviation of all normal RR intervals (those measured between consecutive sinus beats). HRV indices described above are measures of variability in RR interval.⁷ Among time domain parameters; SDNN and HRV triangular index were measured separately.

HRV may similarly be broken into the frequency components that compose the overall variability. Frequency domain analysis is performed by taking a series of numbers along the axis and computing the Fourier transform.⁶ Akselrod et al showed that low frequency (LF) band (0.04-0.15 Hz) is related to both sympathetic and parasympathetic modulation, and the high frequency (HF) band (0.15-0.40 Hz) is related to parasympathetic effects. The ratio of LF to HF power is often used as a metric of sympathetic-parasympathetic balance.⁷ Low frequency and high frequency components of frequency domain parameters were also measured and LF/HF ratio was determined manually.

Statistical Methods

Descriptive statistics were given as mean \pm SD (Standard Deviation). Paired and unpaired Student's t tests were used for normally distributed data and Spearman analysis was used to establish correlations using the statistical package SPSS-10.0 for Windows. P value less than 0.05 was regarded as significant.

Results

Gender of the patients was 16 male and 13 female and their mean age was 8.08 \pm 3.8 (1-15). Twenty-seven had an acyanotic heart disease (15 ventricular septal defects, 12 atrial septal defects), 2 of them had a cyanotic

heart disease (Tetrology of fallot). None of the patients required any medications in the postoperative follow-up. Baseline HRV recordings were noted for seven days prior to the elective surgery. There was no operative or postoperative mortality. Sinusal tachycardia was encountered in two patients because of hypovolemia in the first hours of postoperative period and turned to normal with fluid and blood replacement. Low dose inotropic (dopamine 3 mcg/kg/min) support was required in 7 patients at the first two hours. Other operative data and postoperative data of all patients were shown in Table 1.

There was any significant difference between the heart rates of preoperative, postoperative first and third month (104 \pm 17, 106 \pm 20 and 103 \pm 20 respectively, $p>0.05$). Postoperative HRV recordings were obtained in one and three month period after surgery (Table 2). For all patients, SDNN ($p=0.048$) and HRV triangular index ($p=0.017$) were significantly lower in the postoperative first month than preoperatively (Figure 1). The magnitude of decrease was greater for HF than for LF power, resulting in a significantly ($p=0.01$) increase in LF/HF ratio (Figure 2). Mean RR values of third month were found significantly increased in order to preoperative and first month values (Table 2). There were no significant preoperative differences in other time or frequency domain measures of HRV between the preoperative recordings and postoperative for the first month.

SDNN ($p=0.05$) and LF ($p=0.05$) found significantly low when compared between the postoperative first and third month (Figure 3), although

Table 1. Operative and postoperative patient data

	Patient data (n=29)
Cardiopulmonary bypass time (min)	58.6 \pm 35.4
Cross clamp time (min)	37.34 \pm 30.1
Duration of ventilation (hour)	4.18 \pm 2.0
Number of patients with inotropic support	7
Postoperative bleeding (ml)	90 \pm 123
Mean \pm SD	

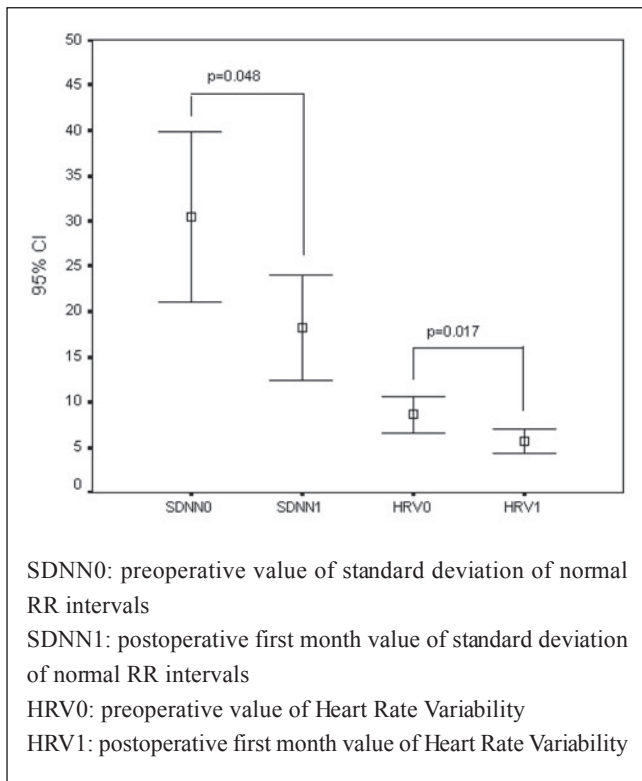


Figure 1. Comparison of SDNN and HRV between preoperative and postoperative first month.

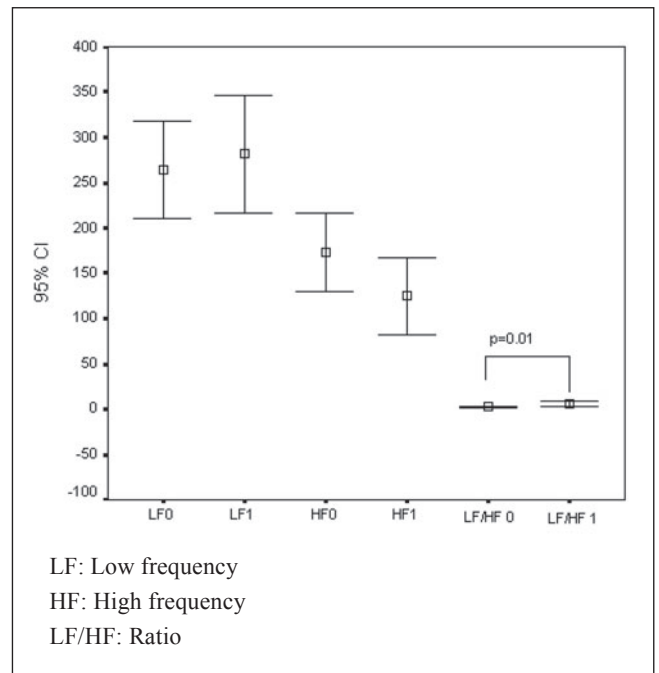


Figure 2. Comparison of LF, HF and LF/HF between preoperative and postoperative first month.

Table 2. Time related changes in HRV

	Preoperative	1 month	3 month	P1	P2	P3
Mean RR	593±16	598±32	685±32	0.1	0.002	0.007
SDNN (ms)	24,91±2,4	24,33±5,7	32,8±7,4	0.048	0.04	0.05
RMSSD (ms)	22,31±4,1	22,9±10	35,85±13,1	0.09	0.55	0.01
HRV triangular index	7,7±0,65	7,4±1,1	8,0±0,69	0.017	0.60	0.58
LF	303,6±44,1	244,4±37,3	186,79±22,1	0.64	0.69	0.05
HF	201,3±31,34	161,03±31,3	255,4±33,3	0.13	0.13	0.09
LF/HF	1,69±0,29	3,4±1,5	1,3±0,6	0.012	0.64	0.26

Mean±SD

P1: P value of preoperative and first month comparison.

P2: P value of preoperative and third month comparison.

P3: P value of first and third month comparison.

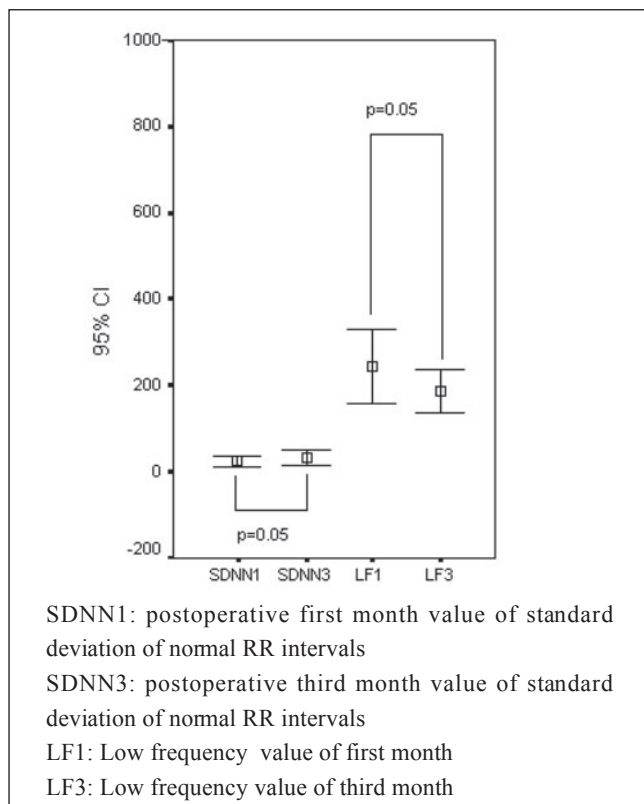


Figure 3. Comparison of SDNN and LF between postoperative first and third months.

other parameters were decreased in the first postoperative month, these did not reach statistical significance.

Significant statistical changes of all HRV parameters could not be found significant between preoperative and postoperative third month recordings. Correlation analysis between HRV parameters and cardiopulmonary bypass and cross clamp time did not show any significance. Effect of other operative parameters including ventilation time, volume of the postoperative bleeding and inotropic support could not be found significant.

Discussion

CPB was introduced during the 1950's and has since then been used extensively in congenital cardiac

operations. Despite its extensive use, CPB has been associated various problems such as cardiac dysfunction, electrolyte disturbances, catecholamine stimulation, irritative scar and sutures in the myocardium, residual hemodynamic impairment, as well as pain and anxiety.⁸ These and other unknown factors, may effect HRV.

There have been limited reports on HRV in pediatric patients with congenital heart disease before and after cardiopulmonary bypass. In the first study, Heragu and Scott found reduced HRV in acyanotic and cyanotic patients postoperatively.⁴ Similar to this study, recordings of patients operated for tetralogy of Fallot particularly with ventricular arrhythmia showed reduced HRV.⁵ Kaltman et al evaluated only frequency domain HRV analysis in neonates with single ventricle and two ventricles physiology, despite early difference after cardiac surgery, HRV indices become indistinguishable between two groups by 3-6 months of age.⁹ In our study, reduced HRV was found in first month according to preoperative measurements (Figure 1).

We know from the literature that measures of HRV is changing with the age and Heragu and Scott measured HRV in healthy controls and found that time domain measures of HRV increase with age throughout the pediatric age range, achieving adult values by adolescence and also found that the quotient of SDNN and mean RR intervals tended to remain stable across most of the pediatric age range.⁴ Their findings were similar to those of Massin and von Bernuth.¹⁰ In our study, spectral indices of HRV were measured in different congenital cardiac defects and compared with same patient before and after cardiopulmonary bypass, therefore, we were not able to commend on the effect of age.

LF/HF ratio is an indirect indicator of sympathetic – parasympathetic balance.⁷ Significant change in the LF/HF ratio of our patients were explained as an operative stress and sympathetic hyperactivity in the first month and turned to preoperative values in the third month measurement, so any significant change could not be found between preoperative and third month measurements.

Significant changes were found in parameters mean RR, SDNN between the first and third month. These results in the postoperative period suggest that further parasympathetic withdrawal is an important component of these changes. This could partly be the result of decreased sensitivity of the sinus node to autonomic nervous input immediately after surgery for congenital heart disease. Heragu and Scott found similar results in their study.⁴

Type of cardiac lesion, preoperative medications, type of surgical procedure, cardiopulmonary bypass time, cross clamp time, did not correlate with the HRV recordings because of our homogenous and small patient group but in the literature Gordon et al demonstrated in a heterogeneous population of congenital heart patients that decreased LF and decreased LF/HF ratio, in the postoperative time period, which was associated with cardiac arrest. These reduced spectral indices were postulated to represent a diminished capacity for cardiac autonomic control.¹¹

Conclusion

Our findings showed that decreased HRV is a nonspecific marker of cardiovascular stress just after the cardiac operations, reflecting an alteration in autonomic nervous system input to the heart and turning to the normal in the third month.

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