Recovery Assessment of Open-heart Cardiac Surgery Patients Using Heart Rate Variability Parameters

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Abstract

Surgical operation causes short-term stress changing the balance of the autonomic nervous system (ANS). The ANS activity can be assessed through heart rate variability (HRV). This work aims to evaluate the recovery process of open-heart cardiac surgery patients under two post-surgery physiotherapy interventions using HRV parameters. Ten-minute ECG recordings were performed on 17 open-heart cardiac surgery patients pre-operatively (PREOP) and during three consecutive post-operative days (POD1, POD2 and POD3). The recovery process was promoted using two different physiotherapy techniques: positive expiratory pressure (PEP, N = 9) and inspiratory training (IMT, N = 8). Common HRV parameters (SDNN, LF power and SD_1) were calculated for each patient and statistical analyses were performed.

The results show significant differences between HRV parameters pre- and post-operatively, and there was a reduction of all three investigated HRV parameters in the POD1 for both groups. HRV parameters average values increased between POD1 to POD3 for both intervention groups indicating that patients were eventually starting to recover from the surgery. Statistically significant difference between PEP and IMT interventions was not discovered (e.g., p = 0.54 for SDNN, PREOP vs. POD3). Based on the results, all studied HRV parameters are potential indicators of the short-term recovery after cardiac surgery.

1. Introduction

Autonomic nervous system (ANS) acts as a control system for the regulation of internal processes of body and is influenced by environmental and physiological factors. Its two branches, sympathetic (SNS) and parasympathetic (PNS) branch behave in an opposing way to maintain cardiovascular homeostasis. While SNS is responsible for the heart rate (HR) and blood pressure (BP) increase, PNS regulation leads to the decrease of HR and BP [1]. Cardiac surgeries as well as other major operations under general anesthesia can affect the status of ANS due to the short-term applied physiological stress [2]. Thus, non-invasively monitoring of surgical patients is of high importance in order to assess the recovery procedure. Heart rate variability (HRV) monitoring is a non-invasive monitoring technique which has been widely utilized as an assessment method for cardiac autonomic modulation [3]. It has been shown that HRV can be a useful tool for the predication of cardiac post-surgery complications [4] [5] [6], assessing arrhythmias [7], and evaluating the effects of post-surgery therapeutic intervention [8].

In order to boost the recovery period of surgery patients, different physiotherapy intervention techniques such as positive expiratory pressure (PEP) or inspiratory muscle training (IMT) can be utilized. PEP technique is based on applying a pressure to create resistance against expiration which can increase lung volume and reduce hyperinflation [9] whereas IMT method exercises diaphragm-based muscles with inspiratory function [10].

In this study we assessed the recovery procedure of the open-heart cardiac surgery patients under two different therapeutic interventions and see how surgical interventions and their effects on ANS can be reflected through HRV indices and how different therapeutic interventions can boost the recovery process.

2. Materials and methods

Ten-minute ECG recordings were performed for 17 open-heart cardiac surgery patients at Tampere University Hospital Heart Center in Tampere, Finland during 2013–2016. All patients participated in the study voluntarily and gave their informed consent in written. The study was approved by the regional Ethics Committee of Tampere University Hospital area, Finland.

For each patient the data was collected during one pre-operative day (PREOP) and three post-operative days (POD1, POD2 and POD3). Two different therapeutic interventions were utilized during the recovery process; positive expiratory pressure (PEP group, N = 9) and inspiratory muscle training (IMT group, N = 8).

2.1. Measurement procedure

The ECG was recorded with a small custom-designed impedance pneumography device and sampled at 256 Hz frequency [11]. Bipolar ECG measurement having disposable electrodes in the arms close to the armpit was used. ECG data was stored during ten-minute period of tidal breathing.

2.2 ECG signal processing

Baseline wandering and high frequency noise caused by powerline interference were removed from the raw ECG recordings using low-pass and median high-pass filters. This made the signals prepared for R-peak extraction. R-peaks were localized and extracted using the method proposed by Zhengzhong *et al.* [12]. The HRV tachograms were then formed to be further analyzed. Atrial and ventricular ectopic beats were detected and removed using time series artifact correction algorithm proposed by Lipponen *et al.* [13]. Matlab R2019b was used for the analysis.

2.3. HRV parameters and statistical analysis

Common HRV parameters, SDNN, LF power and SD_1, were calculated for 10-minute segments. Statistical analysis was performed between surgery days and between intervention groups. Normality distribution was assessed by Shapiro-Wilk test and independent Student's t-test or Mann-Whitney U test, and Paired Student's t-test or Wilcoxon Signed Rank Test were used to determine significance level. The significance level was considered 0.05.

3. Result

Table 1 shows cross-subject averages of SDNN, LF power and SD_1 values of PEP and IMT intervention groups pre-operatively and during three post-operative days.

Table 1. Cross-subject averages of SDNN, LF power and SD_1 pre- and post-operatively for PEP and IMT intervention groups.

	PREOP		**POD1**		**POD2**		**POD3**	
	PEP	IMT	PEP	IMT	PEP	IMT	PEP	IMT
SDNN [ms]	36,4	32	18	19	16,8	18	18,2	19,3
LF power [ms^2]	636	283	42,8	73	56,1	177	159	119
SD_1 [ms]	21	13	5,9	8,9	6,8	10	10.6	9,4

The difference between baseline values of intervention groups for SDNN, LF power and SD_1 were measured, and p-values were 0.603, 0.888 and 0.196, respectively thus no statistically significant difference was found in the investigated HRV parameter values between the groups pre-operatively.

The significance of differences between pre-operative day and three post-operative days for different HRV parameters is provided in Table 2. The last column of the table compares the intervention methods during the process of recovery (PREOP vs POD3) using parametric and non-parametric statistical tests.

Table 2. Significance levels (p-values) of baseline compared to post-operative days and comparison of interventions during the recovery period. P-values less than 0.05 were considered significant and are marked by asterisks (*).

	PREOP vs POD1		PREOP vs POD2		PREOP vs POD3		PREOP vs POD3 (PEP & IMT)
	PEP	**IMT**	**PEP**	**IMT**	**PEP**	**IMT**	
SDNN [ms]	0,02*	0,04*	0,02*	0,02*	0,07	0,05	0,540
LF power [ms^2]	0,06	0,02*	0,11	0,03*	0,16	0,01*	0,888
SD_1 [ms]	0,01*	0,06	0,01*	0,05	0,07	0,06	0,409

Figure 1 shows the SDNN, LF power and SD_1 for each subject. It can be seen that few subjects have different trends of recovery procedure.

4. Discussion and conclusion

The achieved results clearly show that there is a significant reduction of SDNN, LF power and SD_1 on the first post-operative day for both intervention groups which is a result of surgical stress caused by the open-heart cardiac surgery and its effects on ANS. It has been shown by Brown *et al.* that the full recovery of ANS can take approximately 6 to 12 weeks after the surgery [14]. In this study, the recovery process was only followed during 3 consecutive days after the surgical operation (POD1 to POD3), thus HRV parameter values cannot be expected to restore back to the baseline level within this time frame. However, it can be seen that most HRV parameters start to slightly increase during the recovery period (POD1 to POD3). There was also observed a large individual variation in pre-operatively HRV values as well as in the rate of the recovery. Due to the low number of participants in this study (N = 17), the average baseline values differ between the two intervention groups.

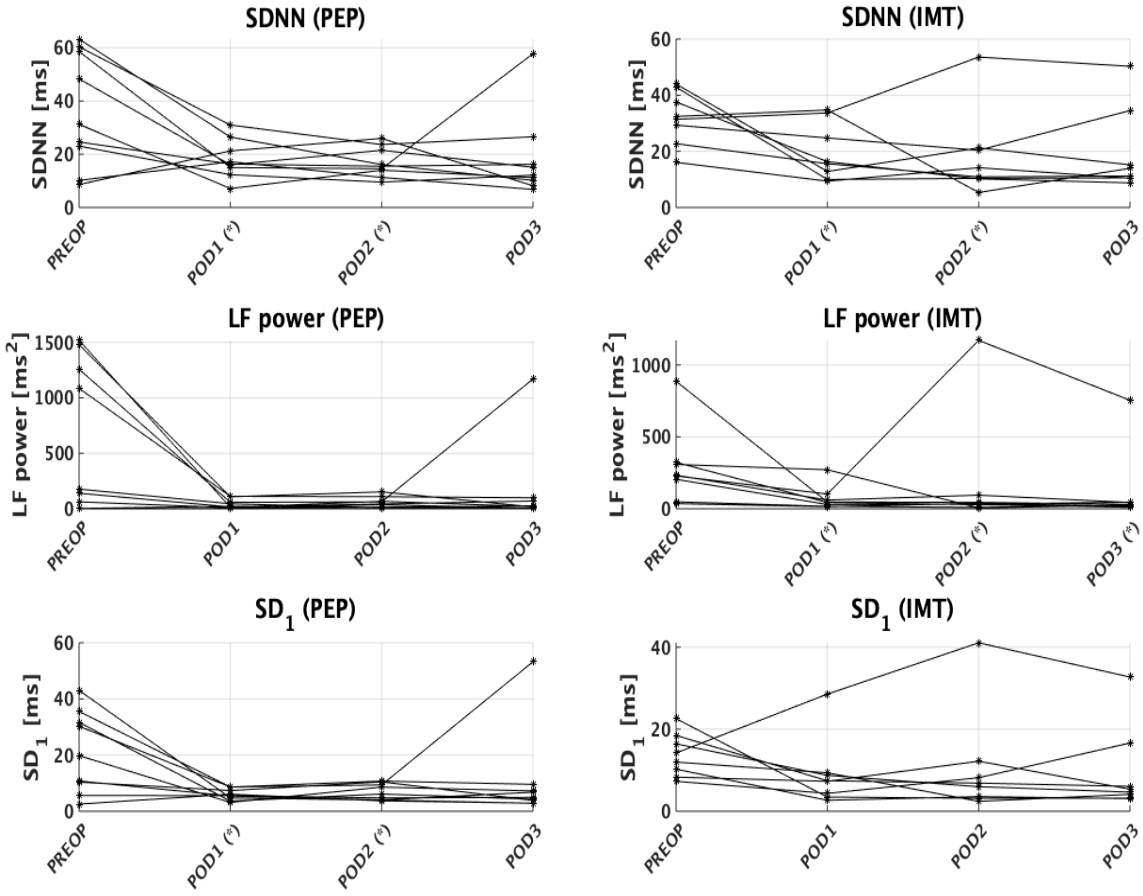

Figure 1. SDNN, LF power and SD_1 values for each subject pre-operatively (PREOP) and during three post-operative days (POD1-POD3) for both intervention groups. Statistically significant difference between pre- and post-operative days is determined by asterisks (p-value < 0.05).

However, not statistically significant difference was found between HRV parameters pre-operatively; making it possible to further compare the intervention groups on post-operative days. The recovery procedure of intervention groups was compared, and no significant statistical difference was found between PEP and IMT intervention groups for any of the HRV parameters.

In conclusion, it was found that HRV parameters can be utilized as a tool for monitoring of the recovery of open-heart cardiac surgery patients. It was also concluded that the effects of different therapeutic interventions on recovery procedure did not differ. However, in order to develop practical solutions for recovery monitoring, larger studies with more participants, longer monitoring period and various surgery groups shall be conducted.

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