Recovery of Heart Rate Variability and Baroreflex Sensitivity following Open Heart Surgery

G Brockmann[1], N Wessel[3], H Malberg[2], R Lange[1], R Bauernschmitt[1]

[1]Department of Cardiovascular Surgery, German Heart Center, Munich, Germany
[2]Institute for Applied Computer Science, Forschungszentrum Karlsruhe (Karlsruhe Research Center), Karlsruhe, Germany
[3]Department of Physics, University of Potsdam, Germany

Abstract

Dynamic measures of heart rate variability (HRV) and baroreflex sensivity (BRS) may uncover the postoperative course of patients undergoing cardiovascular surgery.

162 patients participated in a prospective study; Cardiovascular signals were recorded the day before, 24h after surgery, one week and three month after surgery. Time domain parameters of heart rate variability showed a significant ($p=8,9\cdot10^{-9}$) decline 24h after surgery and a significant recovery (p=0,00049) first week after surgery. The bradycardic and tachycardic regulation strength regenerated similar. Furthermore the number of tachycardiac regulations decreased significant (p=) within the first week after surgery. The HRV and BRS parameters of the autonomic system obviously show a tendency towards recovery after coronary artery surgery.

1. Introduction

Earlier studies have shown that overall heart rate variability (HRV) is reduced after coronary artery bypass graft (CABG) surgery and has a tendency to recover within 3-6 months [1]. Recent studies suggest for more comprehensive evaluation of the autonomic system that measures of baroreflex sensivity can complement the traditional time and frequency domain HRV measures [2]. In this study we used HRV and spontaneous baroreflex parameters for evaluating the course of the autonomic response of patients undergoing cardiovascular surgery.

2. Methods

162 patients undergoing various types of open heart surgery were included. Patients with documented atrial fibrillation, history of more than 10% extra systolic beats, implanted pacemakers and recording time shorter than 10 minutes were excluded from this study. 162 patients 96 men and 66 women were included; age was from 25 years to 85 years. 96 undergoing valve replacement and 46 coronary artery bypass (CABG) surgery. 20 patients who had concomitant valve replacement were also included in the analysis. All patients underwent conventional extracorporeal circulation the duration ranged between 44 and 204 minutes. Anaesthesia was induced with midazolam, sufentanil and pancuronium. Anaesthesia was maintained with isoflurane and with continuous infusion of fentanyl and midazolam. Moderate systemic hypothermia (core temperature 30-33°C was used. Antegrade cold crystalloid cardioplegia or blood cardioplegia was used during cardiopulmonary bypass. After surgery, all patients were mechanically ventilated until they had stable hemodynamics and had recovered from the anaesthesia. Piritramid was administered intravenously in 5-mg increments for pain control. After an equilibration period of 10 minutes patients lay in supine position with both arms parallel to the body throughout the measurements. At the beginning of the measurements patients were connected to the following equipment: The Colin CBM-7000 system manufactured by the Colin Corporation in Japan. The Colin tonometer uses a pressure transducer (linear array of 15 pressure sensitive piezo-electric elements) applied firmly to the skin surface pressing and partially flattening an artery on to a bone surface. Arterial pressure waveforms are transmitted directly to the transducer. The system must be calibrated and this can be done with systolic and diastolic measurements from a standard arm cuff oscillometric technique. As default, the instrument performs a calibration at regular intervals (2,5 and 5 min). Continuous non invasive blood pressure and ECG were sampled during a 30min recording period. Special care was taken to perform the measurements (1d pre-OP, 1d post-OP, 7d post-OP and 3m post-OP) during the same time of the day in each patient. The signals were collected

at 1000 Hz and channelled into a computer (bed side laptop) through an analogue-to-digital signal converter. Data analyses were carried out off-line in accordance with the recommendations of the Task Force HRV [3]. In advance the original data were filtered removing premature beats, artefacts and noise, keeping the original time reference.

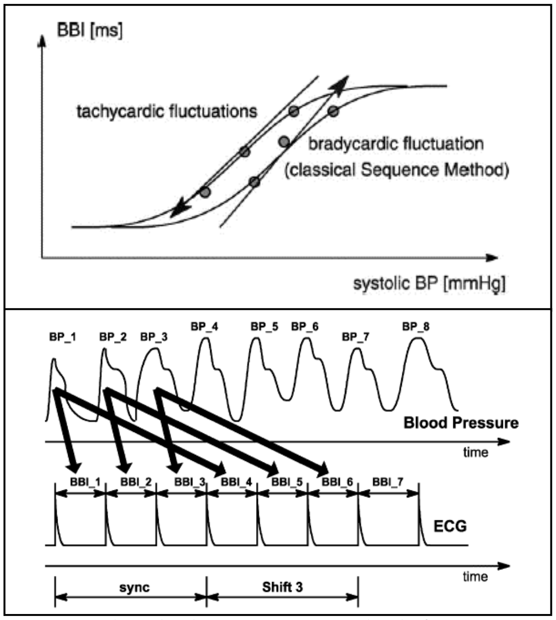

Figure 1: The dual sequence method for spontaneous BRS estimation includes the bradycardic and tachycardic blood pressure fluctuations. (upper panel) the slope sector distribution. (lower panel) delayed responses of heart rate to blood pressure increases are analyzed.

All statistical analyses were performed by software SPSS 11.5 (SPSS Inc., Chicago, IL, U.S.A.) Mann-Whithney-U test was applied to find differences within the calculated parameters. Results are given as mean +/- standard deviation. Student t-test was used for comparison of groups.

Baroreflex sensivity (BRS): Dual Sequence Method (DSM) The BRS is defined as the instinctive change of the heart frequency (beat-to-beat interval) related to increasing or decreasing values in systolic blood pressure and is expressed in ms/mmHg. The most relevant parameters for estimating the spontaneous baroreflex are the slopes of the regression line between SBP and BBI. The DSM is based on standard sequence methods with several modifications. Two types of beat to beat interval responses were analyzed:

bradycardic: blood pressure increase causes RR-interval increase

tachycardic: blood pressure decrease causes RR-interval decrease

The bradycardiac fluctuations represent the vagal spontaneous regulation. The delayed tachycardic responses of heart rate (shift 3) are assigned to the slower beginning of sympathic regulation. The following parameter groups are calculated by DSM: (1) the total numbers of slopes in different sectors within 30 min; (2) the percentage of the slopes in relation to the total number of slopes in the different sectors; (3) the numbers of bradycardic and tachycardic slopes; (4) the shift operation from the first (sync mode) to the third (shift 3 mode) heartbeat triple; and (5) the average slopes of all fluctuations. DSM parameters are defined as described by Malberg et al [4].

Heart rate variability (HRV) HRV was assessed by two ways: time- and frequency-domain analyses.

In time domain analysis, the intervals between adjacent normal R waves (NN intervals) are measured over the period of recording. A variety of statistical variables can be calculated from the intervals directly and others can be derived from the differences between the intervals. Since many of the measures correlate closely with others, the suggestions by the Task Force HRV were respected and the following standard parameters calculated [3]: MeanNN (mean value of normal beat-to-beat intervals): Is inversely related to mean heart rate. sdNN (standard deviation of intervals between two normal R-peaks): Gives an impression of the overall circulatory variability. Rmssd (root mean square of successive RR-intervals): Higher values indicate higher vagal activity.

Spectral analysis consists in converting information in the time domain into information in the frequency domain. The most widely used method for processing the studied signal is the Fast Fourier Transformation. The HRV analysis focuses especially on two frequency bands of the power spectrum, high-frequency components (HF, 0.15-0.4 Hz, high values indicate vagal activity) and low-frequency components (LF, 0.04-0.15 Hz, high values indicate sympathetic activity). The following ratios were considered: LFn – the normalized low frequency (LFn=LF/(LF+HF)), HP/P - the to the total power P normalized high frequency as well as LP/P - the P-normalized low frequency.

Nonlinear dynamics Complex processes, inter-relations and new parameters can be described by methods of nonlinear dynamics. Condition is the transformation of the time series into a symbol sequences with predefined symbols. In this process some detailed information is lost but the coarse dynamic behaviour can be analysed. Several new measures of non-linear dynamics in order to distinguish different types of heart rate dynamics as proposed by Kurths [5] were used. The concept of symbolic dynamics is based on a coarse-graining of dynamics. The difference between the current value (BBI or systolic blood pressure) and the mean value of the whole series is transformed into four symbols (0; 1; 2; 3). Symbols '0' and '2' reflect low deviation (decrease or increase) from mean value, whereas '1' and '3' reflect a stronger deviation (decrease or increase over a predefined limit, for details see Voss et al [6]. Further, the symbol string can be transformed to 'words' of three successive symbols explaining the nonlinear properties and thus the complexity of the system. A high percentage of words consisting only of the symbols '0' and '2' ('wpsum02') reflects decreased HRV.

3. Results

Time domain parameters of heart rate variability showed (Fig.2) a significant decline 24h after surgery and a significant recovery one week after surgery.

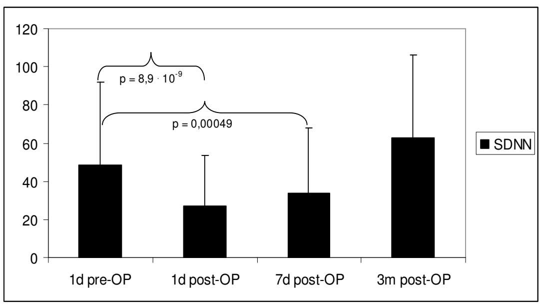

Figure 2: Mean SDNN

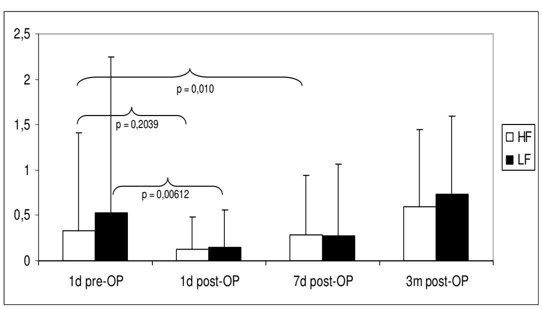

Figure 3: HF (high frequency) and LF (low frequency)

24h after surgery a comparable significant drop of heart rate variablility was showed for both frequency domain parameters. A significant partial recovery could be showed for the high frequency parameter 7 days after surgery (Fig. 3).

A similar behaviour showed the baroreflex sensitivity throughout the postoperative course. 24h after surgery the bradycardic regulations were depressed the quantity slightly more than the strength. Recovery established earlier in the number than the strength of regulation (Fig. 4). Both regulation properties were significantly increased one week after the operation. The strength of tachycardic and bradycardiac regulation behaved similar. There was a significant decrease in both strength parameters on the first postoperative day which remained steady until the third postoperative month.

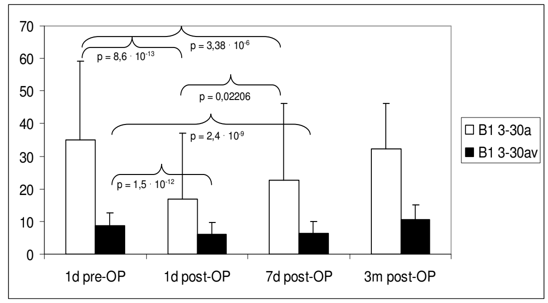

Figure 4: Bradycardic BRS (number (B1 3-30a) and strength (B1 3-30av)

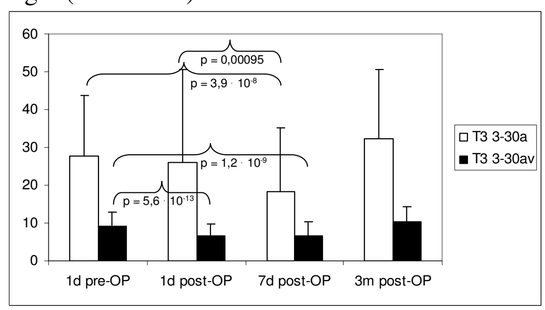

Figure 5: Tachycardic BRS (number (B1 3-30a) and strength (B1 3-30av)

The number of tachycardic regulations decreased significantly one week after surgery. One month postoperative the number of tachycardic regulations rised to its initial value (Fig. 5).

As a representative parameter of the nonlinear dynamics analyses, WPSUM13 and WPSUM02 were chosen as a parameters describing the variability (high WPSUM13 values represent large overall variability and high WPSUM02 values represent low variability see "Methods"). A remarkable minimum value can be found in the first post operative day followed by the significant recovery after one week and a further tendency towards recovery (Fig. 6). As expected the WPSUM02 values behave significantly inverse to the WPSUM13 values.

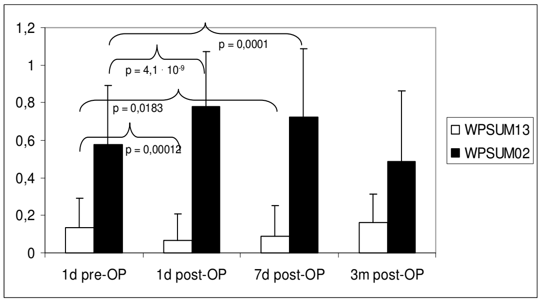

Fig. 6: Symbolic dynamics: WPSUM 13 and WPSUM 02.

4. Discussion and conclusions

The analysis of BRS and HRV provides additional information about the individual recovery of patients after cardiac surgery. This study examined measures of heart rate variability, spontaneous baroreflex and symbolic dynamics at different points of time (1d pre-OP, 1d post-OP, 7d post-OP and 3m post-OP) [2,3]. Our overall results show that there is an initial reduction for all examined parameters after surgery and a clear tendency for increasing values by three month the latest.

Our findings call into question the conclusion of other authors that cardiac surgery causes irreversible impairment of the parasympathetic modulation of heart rate [7].

Our results of significant functional recovery post-operative suggest that at least some of the autonomic dysfunction after CABG surgery is temporary. Similar results were achieved by other groups which postulated a recovery time between 6 and 12 weeks [1, 2]. In the future it would be of clinical interest to find out the course of continued improvement over a longer period of time, and if there is a certain subset of patients who do not recover.

References

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Address for correspondence

Gernot Brockmann, MD,
German Heart Center Munich, Lazarettstr. 36, 80636 Munich (Germany)
E-mail: brockmann@dhm.mhn.de