Beat-to-Beat Heart Rate and QT Interval Variability in Patients Undergoing Coronary Artery Bypass Graft Surgery

S Frljak[1], V Avbelj[2], R Trobec[2], B Gersak[1]

[1]Department of Cardiovascular Surgery, University Medical Center, Ljubljana, Slovenia [2]Jozef Stefan Institute, Ljubljana, Slovenia

Abstract

Non - uniform recovery of myocardial excitability may be essential in triggering malignant ventricular tachycardia in patients after cardiac surgery. Beat – to – beat heart rate and QT interval variability was investigated in 27 patients scheduled for elective coronary artery bypass graft surgery (CABG) and 20 control subjects. 35 channel ECG was recorded for 6 minutes, followed by off line computer analysis. Heart rate interval duration, RR SD, QT SD and power spectra of RR variability were computed from 256-second stable heart rate and QT interval series using MECG software.

Study showed that CABG caused increased QT interval variability in face of nearly constant or slowly changing heart rate, suggesting a loss of autonomic coupling between heart rate and ventricular repolarization for sympathovagal modulation.

1. Introduction

Myocardial revascularization performed for patients with critical coronary artery stenosis can reduce the incidence of sudden cardiac death [1] and coronary artery bypass grafting (CABG) independently contributes to a favorable prognosis in survivors of cardiac arrest treated with specific antiarrhythmic treatment [2]. However, in some cases de novo occurrence of ventricular tachyarrhythmia after CABG has been reported [3-7]. Ventricular tachycardia (VT) following CABG is associated with high in – hospital mortality rate of 25% [8] and apart from history of myocardial infarction [8], significant left ventricular dysfunction [9] occurring more frequently with VT, there are no consistent clinical features predicting the development of malignant arrhythmia in patients after cardiac surgery. An identification of the patients who are at risk of sudden death due to arrhythmia therefore remains a challenge.

Although there have been many implications that non-uniform recovery of excitability may play an essential role in triggering malignant VT in different heart diseases [10,11], beat-to-beat oscillations of the QT interval have not been studied in patients undergoing cardiac surgery. The aim of this study was to evaluate and quantify heart rate and QT variability in patients prior and after CABG in comparison with a group of healthy individuals.

2. Materials and methods

2.1. Study population and data acquisition

A study population included 27 patients (age 58.2 ± 10.0, male / female: 22 / 5) scheduled for elective CABG and 20 healthy control subjects (age 50.6 ± 9.6, male / female: 17 / 3). Inclusion criteria were: stable sinus rhythm prior the cardiac surgery without atrioventricular or intraventricular conduction disturbances. The presence of atrial or ventricular ectopy was allowed unless such beats represented more than 5% of total beats over 6 – minute interval. Patients with ECG rhythm other than normal sinus, patients who were administered class I antiarrhythmic drugs and those with low amplitude T – wave were excluded from the study. All patients were operated on in University Medical Center in Ljubljana. Informed consent was obtained from all the subjects before the study.

2.2. Measuring protocol

Multi-channel ECG (MECG) equipment was used for ECG recording [12]. Two measurements were obtained from each patient: one day before the surgery and on the fifth to seventh day after the surgery recorded after 10 minutes rest in the supine position. Body surface potentials were measured with 35 unipolar leads. After electrode positioning the data acquisition started, collecting data for 360 s (14 bit precision at 1000 samples/second). Good quality data was saved on computer disc for further analysis.

2.3. RR and QT variability algorithm

The method introduced by Berger et al. [13] was used in analysis of RR and QT variability with the following modifications. Matching of beats to the template is

achieved by shifting the template in discrete steps rather than stretching. Baseline wander is removed by linear correction of ECG. The modified algorithm implemented on a personal computer (IBM PC compatible) is described in the following steps [14].

(1) The time t_R of each R wave is identified with an automated peak detection algorithm using a channel with high R wave amplitude.

(2) A channel with high T wave amplitude is selected by the operator and a typical T-wave (template) is determined by the following three points: the first point before P wave is used for baseline wandering removal, the second and the third point determine the beginning and the and of T wave template denoted by $\phi(n)$

$$\phi(n) = x(n) \qquad n = [n_0, \dots n_1] \qquad (1)$$

where n is the sample number, $x(n)$ is the ECG signal and n_0 and n_1 are the beginning and the end of T wave template. Template T waves $\phi(n)$ for all the other channels k are automatically identified from the same interval.

3) Error function $e_k(n)$ is computed:

$$e_k(n) = \sum_{j=0}^{n_1 - n_0} [\phi(n_0 + j) - x(n + j)]^2 \qquad (2)$$
$$n = [1, \dots N - (n_1 - n_0)]$$

where N is the number of samples in each channel and k is the channel number. The low value of error function means that the difference between template and ECG signal is also low.

(4) The best match of ECG signal to T wave template is found for each beat. The best match is defined as time t_T where the error function has lowest value in an interval restricted to the T wave vicinity.

(5) Finally, the algorithm computes QT interval deviation from the first QT interval found in ECG. This deviation is defined as time series denoted by QTV_k

$$QTV_k(t_T(i)) = [t_T(i) - t_R(i)] - [t_T(1) - t_R(1)] \qquad (3)$$

where i is beat number, t_T is time where best match of T wave was found, t_R is the time of R wave peak and k is the channel number.

For further analysis we used only QTV of the channel with the highest T wave amplitude computed from the samples of T wave template. Root-mean-squares for channel templates are used as a measure of the channel accuracy.

Time series of R wave peaks $t_R(i)$ are used in analysis of RR interval variability. RR interval is defined as:

$$RR(i) = t_R(i) - t_R(i-1). \qquad (4)$$

Rectangular windowing and Fast Furier Transformation is used to compute power spectra density from RR interval series. The power spectrum is analyzed in three frequency bands: very low frequency (VLF = $0.01 - 0.04$Hz), low frequency (LF = $0.04 - 0.15$Hz) and high frequency (HF = $0.15 - 0.4$Hz). The power in each frequency band is obtained by summing the spectral components inside the band.

2.4. Statistical analysis

Comparison between the control group and group of patients was performed using a nonparametric independent sample t-test (Mann – Whitney U test) and in the group of patients using Wilcoxon matched pairs test. Statistical significance was accepted at probability value $p<0.05$.

3. Results

3.1. Patient characteristics

All 27 patients enrolled in the study fulfilled clinical and technical inclusion criteria. In post - operative period three patients developed a single episode of atrial fibrillation that was successfully coupled with amiodarone. None of the patients died before the discharge. Patients were hospitalized a median of 7 days.

3.2. Temporal RR and QT variability

Examples of RR and QT interval series during a 256-seconds epoch obtained in single channel analysis in control subject, patient before and after the surgery are shown in Figure 1.

Statistical data on all studied variables comparing patients after CABG with control group and results obtained before the surgery are presented in Table 1 and Figure 2.

After the surgery, patients exhibited significantly ($p < 0.05$) lower RR interval duration, heart rate variability (RR SD) and higher QT variability (QT SD) in comparison to the control group as well as to the results obtained before the surgery (Table 1, Fig 2.). Statistical analysis of RR power spectra showed significant decrease ($p < 0.001$) in RR VLF, RR LF and RR HF after CABG in comparison to the control group and also to the results obtained before the surgery.

4. Discussion

The principal finding of this study was that patients after cardiac surgery exhibit significantly higher QT variability in comparison to the control group and preoperative data, which suggests altered ventricular repolarization after CABG.

We also observed marked decrease in heart rate variability indexes in comparison to the control group and preoperative results. Since high frequency power mirrors efferent vagal activity and RR low power indexes
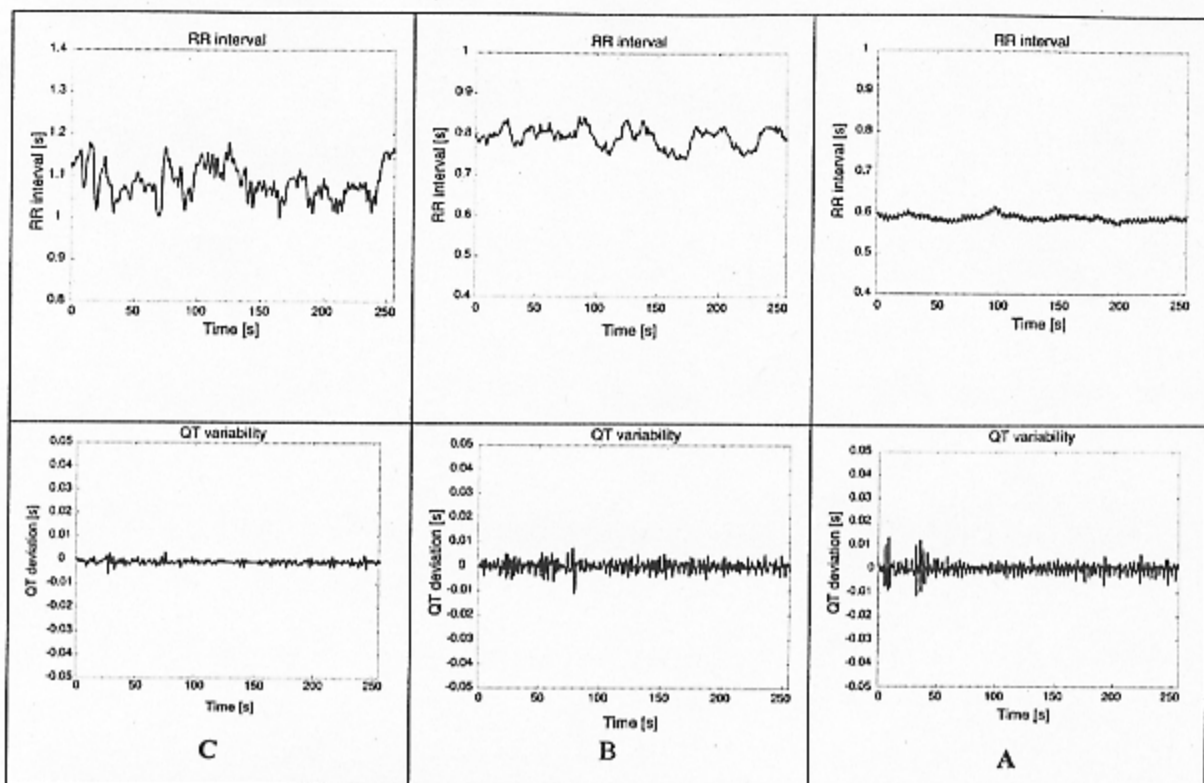
A = after the surgery, B = before the surgery, C = control

Figure 1. The single epoch of heart rate (RR mean) and QT interval (QT SD) fluctuations in control subject, patient before and patient after the surgery.

Table 1. Statistical data for study variables in control group, patients before and after the surgery.

	C	B	A	P C / B	P C / A	P B / A
RR mean (ms)	969.8 ± 141.9	977.7 ± 176.6	779.2 ± 130.9	0.983	<0.001	<0.001
RR SD (ms)	40.7 ± 14.5	31.9 ± 15.9	13.4 ± 6.3	0.071	<0.001	<0.001
QT SD (ms)	1.2 ± 0.3	2.1 ± 0.8	3.4 ± 2.5	<0.001	<0.001	<0.010
Power spectra (ms^2)						
RR VLF	421.9 ± 330.2	297.0 ± 214.6	73.2 ± 73.9	0.156	<0.001	<0.001
RR LF	624.9 ± 541.8	316.2 ± 412.9	42.9 ± 50.5	0.002	<0.001	<0.001
RR HF	466.4 ± 593.5	207.7 ± 261.9	33.2 ± 39.4	0.038	<0.001	<0.001

A = after surgery, B = before surgery, C = control group, RR mean = mean RR interval duration, RR SD = RR interval variability, QT SD = QT variability, VLF = very low frequency band (0.01 – 0.04Hz), LF = low frequency band (0.04 – 0.15Hz), HF = high frequency band (0.15 – 0.4Hz). Values are expressed as mean ± SD.

sympathetic baroreceptor reflex modulated activity [16], this decrease in heart rate variability indexes probably reflects withdrawal of parasympathetic tone and shift toward sympathetic predominance in early postoperative period.

The fact that heart surgery caused an increase of QT variability in that heart surgery caused an increase of QT variability in face of nearly constant or slowly changing heart rate suggests a loss of autonomic coupling between heart rate and ventricular repolarization for sympathovagal modulation after the heart surgery.

Clinical implication and importance of this finding for a purpose of risk stratification of developing malignant arrhythmia after heart surgery is yet to be determined.

5.   Conclusion

This study provides evidence of impact of CABG surgery on myocardial repolarization and confirms the findings of severe cardiac autonomous dysfunction in early postoperative period.
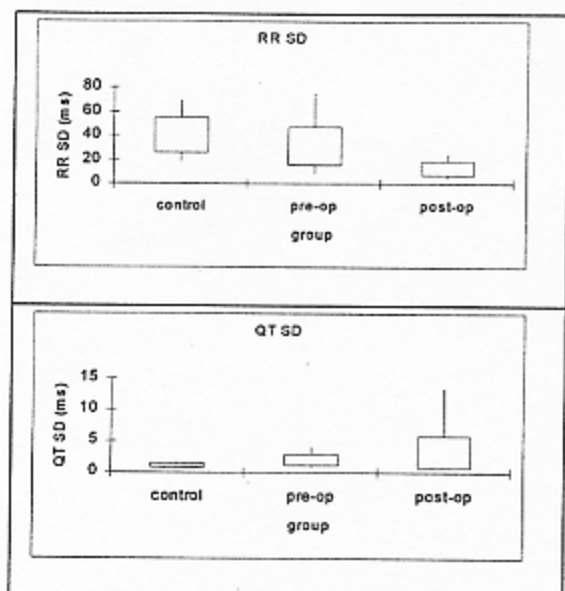
Figure 2. Group differences in heart rate variability (RR SD) and QT variability (QT SD).

References

[1]   O'Rourke RA, Role of myocardial revascularization in sudden cardiac death. Circulation 1992;85:112-7.

[2]   Wilber DJ, Garan H, Finkelstein D. Out of hospital cardiac arrest: use of electrophysiologic testing to predict long term outcome. N Engl Med J 1988;318: 19-24.

[3]   Smith RC, Leung JM, Keith FM. Ventricular dysrythmias in patients undergoing coronary artery bypass graft surgery: incidence, characteristics and prognostic importance. Am Heart J1992;123:73-81.

[4]   Ferraris VA, Ferraris SP, Gilliam HS, Berry WR. Predictors of postoperative ventricular dysrrhythmias: a multivariate study. J Cardiovascular Surg 1992;32:12-20.

[5]   Kron IL, Di Marco JP, Harman KP. Unanticipated postoperative ventricular tachyarrhythmias. Ann Thor Surg1984;38: 317-22 .

[6]   Costeas XF, Schoenfeld MH. Usefulness of electrophysiologic studies for new onset sustained ventricular tachyarrhythmias shortly after coronary artery bypass grafting. Am J Cardiol 1993;72:1291-4.

[7]   Sapin PM, Woelfel AK, Foster JR, Unexpected ventricular tachyarrhythmias soon after cardiac surgery. Am J Cardiol 1991; 68:1099-100.

[8]   Steinberg JS, Gaur A, Sciacca R, Tan E. New-onset sustained ventricular tachycardia after cardiac surgery. Circulation 1999;99:903 – 908.

[9]   Huikuri HV, Yli-Mayry S, Korhonen UR, Airaksinen KE, Ikaheimo MJ, Linnaluoto MK, Takkunen JT. Prevalence and prognostic significance of complex ventricular arrhythmias after coronary arterial bypass graft surgery. Int J Cardiol 1990; 27:333-9.

[10]   A.Bayes de Luna, X.Vinolas, QT dispersion and heart rate variability, Editorial, Eu Heart J 17, 165-166 (1996).

[11]   Maison Blanche P, Coumel P. Changes in repolarization dinamicity and assessment of arrhythmic risk. Pacing Clin Electrophysiol 1997;20:2614-24.

[12]   Gersak B, Trobec R, Avbelj V. Conduction changes after partial left ventriculectomy. In: Kawaguchi AT, LINDE LM . Partial left ventriculectomy: recent evolution for safe and effective application : proceedings of the 2nd International Symposium on Partial Left Ventriculectomy 1998. Amsterdam: Elsevier, 1999:99-111.

[13]   Berger RD, Kasper EK, Baughman KL, Marban E, Calkins E, Tomaselli GF. Beat – to - beat QT interval variability: novel evidence for repolarization lability in ischemic and nonischemic dilated cardiomyopathy. Circulation 1997;96:1557-65.

[14]   Frljak S, Avbelj V, Trobec R, Meglic B, Ujie T, Gersak B. Beat – to – beat QT interval variability before and after cardiac surgery. Comp Biol Med , in print.

[15]   D.L. Eckberg DL. Sympathovagal balance, A critical appraisal. Circulation 1997;96:3224-32.

Address of correspondence:

Sabina Frljak, MD
Department of Cardiovascular Surgery
University Medical Center
Zaloska ulica 7, Ljubljana, Slovenia
Tel: + 386 1 5222583
E – mail: Sabina.frljak@mf.uni-lj.si