# Changes in the Electrocardiogram Induced by Coronary Artery Bypass Grafting

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## Abstract

*ECG recordings of coronary artery bypass grafting (CABG) surgery patients have been collected: number of patients 20 (men 95%, age 64.4±8.4), records duration 10-15 minutes. The number of bypasses for each individual is from 1 to 4 (40% of the patients are with 4). ECG recordings are pre- and post-surgery, from 2 to 10 days after intervention. All parameters were measured on an average P-QRS-T interval in order to avoid accidental events or noise.*

*QRS amplitude, T-wave amplitude and ST elevation did not change, comparing pre- vs. post-stages. T-wave alternans (TWA) showed a clear upward trend (p=0.080) in the post-stage, and QRS-T angle in the frontal plane showed a clear downward trend (p=0.070) in the post-stage, although both have no statistical significance. Significant increase (p=0.0010) in the post-stage was obtained for the heart rate (HR). Four patients had negative T-waves in lead V2 in both pre- and post-stages, highly correlated with the number of TWA episodes: 5 ± 2.4 episodes per person with negative T-waves, vs. 2.9 ± 3.2 episodes in those with positive T-waves.*

*The observed increase in TWA and HR during the early postoperative period suggests that this period could be a more vulnerable one regarding cardiac complications.*

## 1. Introduction

Several electrocardiographic (ECG) parameters that are well-known risk markers of arrhythmias, incidental heart failure and sudden cardiac death (SCD) will be discussed in patients with coronary artery bypass grafting (CABG).

Pradeep at al. [1] claim that in cardiac surgery, and especially during coronary artery bypass grafting (CABG), high volumes of intravenous fluid are associated with increased 90 days' risk of cardiac mortality. Morin et al. [2] argue that fluid overload of ≥5 l increases the incidence of post-operative complications ($p<0.001$ in comparison with an overload of 1-5 l).

**QRS amplitude change** is an indicator of the risk of extracellular water and blood volume increase [3,4]. The mechanism involved is most probably a change of electrical resistance of tissues around the heart caused by increase of interstitial fluid.

In several studies Simova et al [3,5] have proved that the **T-wave amplitude change** was inversely dependant to sodium (Na), and directly dependant to potassium (K) concentration in blood. That is why T-wave amplitude shift can be used as an indicator for electrolyte concentration.

**T-wave alternans** (TWA) in ECG is an electrophysiological phenomenon and is a proven risk marker for occurrence of malignant arrhythmias, Torsade de Pointes, and cardiac death. TWA appears in ECG as a consistent fluctuation in repolarization morphology on every-other beat basis. In most cases, TWA is in the microvolt range, invisible to the naked eye, and can be detected only by a specialized computer ECG analysis [6]. It was found that TWA is more common among diabetics [7, 8] and patients who undergo CABG, and is predictor of postoperative atrial fibrillation [9].

The clinical significance of **QRS alternans** (QRSA) however is less well studied. There is some data that this ECG parameter may be of some value, determining the risk of SCD and the need for device therapy in selected patients [10], although other clinical trials do not confirm these results [11]. In a study of 107 subjects undergoing stress ECG test, Christov et al. [12] have found that TWA and QRSA were significantly higher in the percutaneous coronary intervention (PCI) group compared with the non-PCI one. Presence of diabetes attenuates the difference between PCI and non-PCI groups regarding TWA and QRSA values.

A wide **QRS-T angle** has emerged as an abnormal electrocardiographic repolarization marker in stratifying cardiac risk in various study populations. Wide spatial and frontal QRS-T angle values have been shown to be predictive of cardiovascular events, including incident heart failure, ventricular arrhythmias, and SCD. Wide QRS-T angle has also been found to be associated with cardiac mortality in the general population. Among CABG patients, it was found that wide frontal QRS-T angle is an independent correlate of postoperative hospital length of stay and an independent predictor of vasopressor agent/IABP support requirement postoperatively [13].

**ST-segment changes** are common during the early postoperative period after CABG in patients without enzymatic or echocardiographic evidence of preoperative myocardial infarction (MI). There are studies proving that these changes are not associated with increased postoperative morbidity or mortality [14], but probably their interpretation and prognostic value could be more precise in the context of other precise ECG parameters.

In a study with more than 30 years follow-up, Kannel et al. [15] have found that in both sexes, at all ages, all-cause, cardiovascular and coronary mortality rates increased progressively in relation to **hearth rate**. Fox et al. [16] compare a group with a heart rate of 70 bpm or greater, versus a group of less than 70 bpm. They have found significantly increased risk of cardiovascular death, hospital admissions due to heart failure or MI, and coronary revascularisation for the group of patients with heart rate ≥ 70 bpm.

## 2. CABG Database

ECG recordings of CABG surgery patients were collected at the City Hospital, Sofia: number of patients 20 (men 95%, age 64.4±8.4), records duration 10-15 minutes. Number of bypasses for each individual is from 1 to 4 (40% of the patients are with 4 bypass grafts). Recordings were done pre- and post-surgery, from 2 to 10 days after the intervention.

## 3. Methods

ECG signals were preprocessed to eliminate or suppress powerline interference [17], drift [18] and electromyographic noise [19, 20].

QRS detection was applied [21] and fiducial points for the best matching of successive P-QRS-T intervals were achieved by cross correlation. The fiducial points' location was needed because QRS detection algorithm used triggers at arbitrary moment inside the QRS. The best fitting was achieved by correlation analysis and the average P-QRS-T interval is obtained in order to avoid accidental events or noise. The superimposition of several P-QRS-T intervals and their mean signal (white trace) are shown in Figure 1.

Identification of characteristic points as beginning and end of QRS and T-wave, etc. and all measurements were automatically done [22]. The method of Bortolan and Christov [6], approved at the PhysioNet/ Computers in Cardiology Challenge, 2008, Bologna has been used for detection of episodes of TWA.

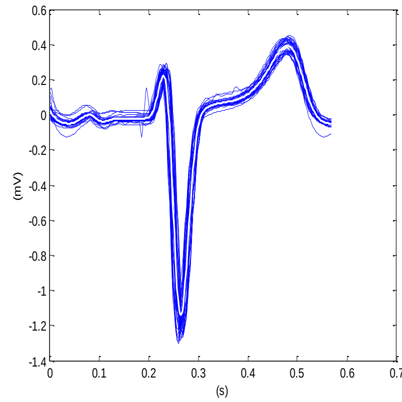


Figure 1. Superimposition of several P-QRS-T intervals (blue traces) and their mean signal (white trace)

## 4. Results

Pre- and post CABG mean measurements and standard deviation of QRS and T-wave amplitudes, ST deviation, TWA, QRSA, heart rate and QRS-T angle, are presented in Table 1.

Table 1. Changes in ECG parameters after CABG surgery (mean ± standard deviation), p>0.05: n.s.

| Parameter | Pre-CABG | Post-CABG | p-value |
|---|---|---|---|
| QRS ampl. (mV) | 1.12±0.51 | 1.07±0.59 | n.s. |
| T ampl. (mV) | 0.34±0.28 | 0.24± 0.24 | n.s. |
| ST deviation (mV) | 0.05±0.06 | 0.06±0.09 | n.s. |
| TWA (number) | 2.5±2.8 | 3.8±3.4 | 0.080 |
| QRSA (number) | 1.52±2.27 | 1.66±1.82 | n.s. |
| HR (beats per min) | 68.1±9.2 | 82.1±10.5 | 0.0010 |
| QRS-T ang (degr) | 83.7±53.8 | 52.2±54.0 | 0.070 |

Four patients had negative T-waves in lead V2 in both pre- and post-stages, highly correlated with the number of TWA episodes: 5 ± 2.4 episodes per person with negative T-wave, vs. 2.9 ± 3.2 episodes in those with positive T-waves.

## 5. Discussion

The results of our study suggest that there is an increase in HR and marginal increase in TWA and decrease in QRS-T angle in the early post-operative period, while other ECG parameters, like QRS and T wave amplitude and ST segment deviation were not affected by CABG surgery.

Saltykova et al. are directly relating the increase of QRS voltage with dehydration [23]. In our group the CABG-induced QRS amplitude changes were not significant which means that there is no increase of water and blood volume, and thus an increased cardiac risk [1-4]. The normal volume of fluid administration during

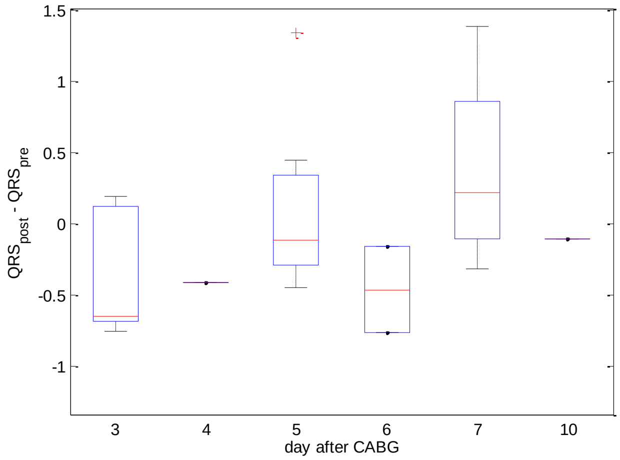


Figure 2. Boxplot of the variation of QRS amplitude (QRS_post – QRS_pre) with respect to the days after surgery. Red segments are the median values; the blue boxes are the 25th and 75th percentiles; the whiskers (black 'T' marks) extend to the most extreme data points that are not outliers; red '+' is an outlier.

surgery is 1500-2000 ml. From the boxplot in Figure 2 it could be seen that the median difference between post- and pre-surgery QRS amplitude is predominantly negative at the 3rd and 4th days and increase to positive at the 7th day after CABG. If this could be interpreted in terms of fluid balance, then we could say that in the first postoperative days the fluid balance in this patient group is positive with a gradual shift towards neutral values during later hospital stay. The dehydration carried out at the City Clinic, Sofia is performed by the diuretics: Furanthril, intravenous, 20-100 ml daily, for the first 2-3 days, followed by Trifas Cor, 5-20 mg daily.

CABG-induced T-wave amplitude changes were not significant. It means that there is no considerable change of electrolyte concentration, and especially of those electrolytes in the blood that are responsible for the T-wave change - sodium (Na), and potassium (K) [3,5].

None of the patients showed significant ST deviation in the post-CABG stage, which contradicts the assertion that ST-segment changes are common during the early postoperative period after CABG. The reason for this controversy is probably our small database of 20 individuals, which we currently use. Anyway there are authors [14] proving that these changes are not associated with increased postoperative morbidity or mortality, and probably their interpretation and prognostic value could be more precise in the context of other precise ECG parameters.

TWA episodes were detected 2.5±2.8 times in the pre-operative group and 3.8±3.4 times in the postoperative group (p=0.08). Because of the small number of patients, significant statistical differences were not obtained, however, comparing pre-TWA with post-TWA there is a clear upward trend. The increase of post-TWA episodes compared to pre-TWA was associated neither with patients' age, nor with the number of bypasses. A fading away effect – reduction of post-TWA episodes related to the days passed from the coronary artery bypass surgery, was not observed at a sufficient rate.

The increase of TWA episodes after coronary bypass surgery could be associated with an elevated risk of malignant arrhythmias. Possible explanation of the post-TWA increase could be the increased HR

T-wave inversion (negative T waves) in precordial leads can be a sign of coronary ischemia, Wellens' syndrome or left ventricular hypertrophy. The frequency of the inverted T-waves depends on the lead (remissive from V1 to V6) and on age. For V2 in healthy subjects, the occurrence of negative T-waves is 7% in the age group 8-16 years, while in young adults (20-30 year-old) it is 0% for males, and up to 2.4% for females [24].

T-wave inversion was observed 5 times in our study: 2 were in both pre- and post-ECG of one and the same patient; 2 appeared in the post-stage only, without having them in the pre-stage; and 1 in the pre-stage only. The small number of inverted T-waves and their almost uniform distribution in the pre- and post-stage (2:3 respectively) does not justify the conclusion about the influence of CABG on the T-wave inversion. The relation between TWA and the inverted T-wave, however, is of interest: 5.0±2.4 episodes (mean±standard deviation) of TWA in subjects with negative T-waves vs. 2.9±3.2 episodes of TWA in those with normal T-waves.

Heart rate is the only parameter that demonstrates a significant change from pre-CABG (HR=68.1±9.2) to post-CABG (82.1±10.5), $p<0.001$. According to Kannel et al. [15] and Fox et al. [16], HR>70 is an increased risk of cardiovascular death, admission to hospital for heart failure, for MI, and for CABG. It should be noted, however, that there could be many factors potentially influencing post-operative HR, including inotropic medications, gradual up-titration of beta-blockers and pain.

The QRS-T angle was decreased from 83.7±53.8° in the pre-stage to 52.2±54.0° in the post stage, p=0.070.

The QRS-T angle between the maximal vectors of the QTS- and T-loops in vectorcardiogram is a well-recognised diagnostic factor. Kardys et al [25] specifies three groups in relation to the QRS-T angle: normal (0 to 105°), borderline (105 to 135°), and abnormal (135 to 180°). Karabacak et al. [26] are claiming that the QRS-T angle in the frontal plane can be a prognostic factor in the early postoperative period of CABG patients.

Our previous study on the same database [27] demonstrated an increased activity of sympatico-adrenal and pituitary-adrenal systems to provide a higher adaptability of the organism in the post CABG period.

## 6. Conclussion

CABG-induced changes in ECG were analysed. QRS amplitude, T-wave amplitude, ST deviation and QRS alternans changes were not significantly influenced. Two parameters showed an improvement in the patients' condition: QRS-T angle and the cardiac autonomic innervation, while two others (TWA and HR) indicated deterioration. We tend to assume that the deterioration in this early post-operative period is an effect of the pos-surgery trauma. We speculate that this effect will fade away in a period of a month and more after surgery, and we intend to conduct such research in the future.

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