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Frontal Planar QRS/T Angle Can Be a Prognostic Factor in the Early Postoperative Period of Patients Undergoing Coronary Bypass Surgery

Kubilay Karabacak, MD,[1] Murat Celik,[2] Yalcin Gokoglan,[2] Murat Kadan, MD, [1] Erkan Kaya, MD, [1] Suat Doganci,[1] Vedat Yildirim,[3] Ufuk Demirkilic[1]

Departments of [1]Cardiovascular Surgery, [2]Cardiology, and [3]Anesthesiology, Gülhane Military Academy of Medicine, Ankara, Turkey

ABSTRACT

Background: Wide QRS/T angle reflects the ventricular repolarization heterogeneity and has been found in association with cardiac morbidity and mortality in various study populations. However, literature data about the availability of QRS/T angle in patients undergoing cardiac surgery has not yet been available.

Methods: A total of 157 patients who underwent isolated coronary artery bypass surgery were included in this study. A preoperative 12-lead ECG was obtained one day before surgical procedure. The absolute difference between the frontal QRS wave axes and T-wave axes was defined as frontal planar QRS/T angle. Afterwards, patients were divided into two groups according to their frontal planar QRS/T angle (the cut-off value as 90°).

Results: Group 1 consisted of 109 patients with frontal planar QRS/T angle of <90, and the remaining 48 patients with frontal planar QRS/T angle 90 were placed into group 2. Mean EuroSCORE was much higher in group 2. There were significant differences for positive inotropic agent usage (27.5% for group 1 versus 58.3% for group 2, $P < .001$) and the prevalence of postoperative atrial fibrillation (11.9% for group 1 versus 31.2% for group 2, $P = .004$) between the two groups. In multivariate logistic regression analysis, used to determine the independent predictors of positive inotropic usage in the early postoperative period, only frontal planar QRS/T angle (OR: 0.989, 95% CI: 0.981-0.997, $P = .008$) and EuroSCORE (OR: 0.792, 95% CI: 0.646-0.971, $P = .025$) were found to be statistically significant.

Conclusion: We found that frontal planar QRS/T angle might be an important preoperative parameter in predicting the need for inotropic drugs in the early postoperative period following coronary artery bypass surgery.

INTRODUCTION

Various risk stratification schemes such as EuroSCORE (European System for Cardiac Operative Risk Evaluation) and STS (Society of Thoracic Surgeons) have been used to predict cardiac events or mortality in patients undergoing cardiac bypass surgery. Although the prognostic value of left ventricular ejection fraction (LVEF) has been frequently assessed in these risk stratification schemes, electrocardiographically ventricular depolarization and/or repolarization abnormalities have not been considered sufficiently.

Ventricular repolarization abnormalities represent heterogeneities associated with electrical instability and sudden cardiac death, and data detectable by rest electrocardiography (ECG) may be used to assess ventricular repolarization abnormalities. Electrocardiographic abnormalities such as ST depression, T-wave inversion, and duration of QRS have been shown to be valuable risk factors of cardiac morbidity and mortality [Kannel 1987; de Bruyne 1999]. In this context, QRS-T angle has been defined as the angle between the directions of ventricular depolarization (mean QRS vector) and ventricular repolarization (mean T vector), and has been proposed as a prognostic value for cardiac primary end-points in the last 10 years. Wide frontal planar QRS/T angle reflects the ventricular repolarization heterogeneity and may be associated with cardiac mortality [Macfarlane 2012; Aro 2012]. The frontal planar QRS/T angle has been found to carry prognostic value for various study populations groups such as general population, coronary artery disease, hypertension, heart failure, and elderly [Raposeiras-Roubín 2014; Kardys 2003]. However, there is no literature data about predictive value and availability of frontal planar QRS/T angle in patients undergoing cardiac surgery yet.

In this study, we aimed to investigate whether the measurement of preoperative frontal planar QRS/T angle has a prognostic value on major adverse cardiac events in patients undergoing coronary artery bypass surgery (CABG).

MATERIAL AND METHODS

Study Population and Data Collection

We analyzed 189 patients who had undergone isolated CABG for ischemic heart disease between February 2012 and March 2014. Demographic, clinical, and surgical data of patients were retrospectively obtained from the patients' medical records using the hospital's computerized database. Exclusion criteria were defined as history of previous cardiac surgery; cardiac valve disorder; congenital heart disease; pericardial heart disease; pulmonary heart disease; infective endocarditis; several arrhythmia; ventricular pacemaker (permanent or temporary); diagnosed right or left ventricular

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Correspondence: Kubilay Karabacak, MD, Gülhane Military Academy of Medicine, Department of Cardiovascular Surgery, Ankara, Turkey; +90-312-3042383; fax: +90-312-3042700 (e-mail: kubilaykarabacak@yahoo.com).

Table 1. Demographic Data of Patients

	All patients (n = 157)	Group 1 (QRS/T angle <90) (n = 109)	Group 2 (QRS/T angle ≥90) (n = 48)	*P*
Age (year)	60.75 ± 11.31	59.82 ± 11.89	62.87 ± 9.67	.120
Male sex, n (%)	114 (72.6)	81 (74.3)	33 (68.8)	.297
BSA (kg/m^2)	28.54 ± 4.22	28.69 ± 4.49	28.19 ± 3.54	.497
Comorbidities				
Hypertension, n (%)	93 (59.2)	64 (58.7)	29 (60.4)	.492
DM, n (%)	67 (42.7)	42 (38.5)	25 (52.1)	.080
COLD, n (%)	39 (24.8)	23 (21.1)	16 (33.3)	.077
PAD, n (%)	31 (19.7)	20 (18.3)	11 (22.9)	.323
EuroSCORE. median (IQR)	2 (2)	2 (3)	3 (3.75)	.001*
Preoperative EF (%)	54.26 ± 10.85	54.33 ± 10.80	54.08 ± 11.07	.892

BSA indicates body surface area; DM, diabetes mellitus; COLD, chronic obstructive lung disease; PAD, peripheral artery disease; EF, ejection fraction; IQR, interquartile range.
*Mann-Whitney test was used.

hypertrophy; various cardiac rhythm disorders such as bundle blocks (left, right, or complete); premature extra systoles (atrial or ventricular); and other various cardiac disorders. A total of 32 patients who met the above criteria were excluded from the study. Ultimately, a total of 157 patients were included in the analysis. After data collection, patients were divided into two subgroups according to their frontal planar QRS/T angle.

Measurement of Frontal Planar QRS/T Angle

A preoperative 12-lead ECG was obtained one day before CABG procedure and postoperative ECGs were obtained on postoperative day 7 at 25 mm/sec paper speed and 10 mV gain (Hewlett Packard-M1770A-USA, Hewlett Packard, Palo Alto, CA). Frontal plane QRS-axis and T-wave axis were included in the standard 12-lead ECG in the reports from the automated ECG machine. The absolute difference between the frontal QRS wave axes and T-wave axes was defined as frontal planar QRS/T angle. If such a difference exceeded 180 degrees, then frontal QRS-T angle is calculated as 360° minus the absolute value of the difference between the frontal plane QRS axis and T axis [Raposeiras-Roubín 2014]. Although previous studies have been focused on the predictive value of frontal planar QRS/T angle in cardiovascular diseases, an absolute cut-off value has not been determined to distinguish the normal from the abnormal frontal planar QRS/T angle. Like Raposeiras-Roubín et al, we preferred the cut-off value for planar QRS-T angle as 90°.

Two investigators blinded to the patients' clinical and surgical data analyzed the ECGs. Afterwards, patients were divided into two groups according to their frontal planar QRS/T angle. Group 1 consisted of 119 patients who had frontal planar QRS/T angle of <90, and the remaining 24 patients with frontal planar QRS/T angle 90 were placed into group 2. The study was in compliance with the principles outlined in the Declaration of Helsinki, and the local ethics committee of our institute approved the study protocol.

Statistical Analysis

The data were tested for normal distributions using the Kolmogorov-Smirnov test. Continuous variables are presented as the mean ± standard deviation (SD) and the categorical variables as numbers and percentages. Chi-square and independent-samples t test were used to compare categorical and quantitative data between the two groups, respectively. Spearman and Pearson correlation coefficients were used to perform univariate correlation with frontal planar QRS/T angle. Following univariate correlations, the effects of various variables on major adverse cardiac events were evaluated with a backward stepwise multivariate logistic regression analysis. Differences were considered statistically significant when $P < .05$. The Statistical Package for Social Sciences (SPSS, Chicago, IL, USA) version 20 was used for all statistical analyses and calculations.

RESULTS

A total of 157 patients (114 male, mean age = 60.75 ± 11.31 years) undergoing CABG were included in this study. Mean frontal planar QRS/T angle was calculated as 36.30 ± 22.92 in group 1 and 117.95 ± 26.86 in group 2 ($P < .001$). The demographic and clinical data of patients are summarized in Table 1; there were no statistically significant differences except for EuroSCORE. Mean EuroSCORE was much higher in group 2 (3 [3.75]) (median [IQR]) than group 1 (2 [3]) (median [IQR]) ($P = .001$).

When we evaluated the early postoperative surgical data of patients, we observed that positive inotrope usage was necessary in 58 patients (36.9%) and a significant difference was present between the 2 groups (27.5% for group 1 versus

Table 2. Surgical Data of Patients

	All patients (n = 157)	Group 1 (QRS/T angle <90) (n = 109)	Group 2 (QRS/T angle ≥90) (n = 48)	*P*
Cross-clamp time, min	64.07 ± 27.10	66.50 ± 29.05	58.30 ± 21.2	.080
Total CPB time, min	114.0 ± 46.05	117.06 ± 47.25	107.04 ± 42.86	.210
Drainage amount, mL	503.76 ± 199.07	509.91 ± 200.98	489.79 ± 196.04	.561
Inotrope necessity, n (%)	58 (36.9)	30 (27.5)	28 (58.3)	<.001
Intubation time, min	464.96 ± 352.34	413.57 ± 219.26	581.66 ± 530.61	.006
IABP, n (%)	14 (8.9)	9 (8.3)	5 (10.4)	.434
ICU stay time, d (median, IQR)	1 (0.50)	1 (0.50)	1 (0.75)	.710*
Hospitalization time, d, median (IQR)	8 (3)	7 (2)	8 (3)	.154*
Death, n (%)	2 (1.3)	0 (0)	2 (4.2)	.092
Postoperative AF, n (%)	28 (17.8)	13 (11.9)	15 (31.2)	.004

CPB indicates cardiopulmonary bypass; ICU, intensive care unit; IABP, intraaortic balloon pump; AF, atrial fibrillation; IQR, interquartile range.
* Mann-Whitney test was used.

Table 3. Preoperative Electrocardiographic Data of Patients

	All patients (n = 157)	Group 1 (QRS/T angle <90) (n = 109)	Group 2 (QRS/T angle ≥90) (n = 48)	*P*
QTc	422.0 ± 26.67	422.52 ± 25.91	420.81 ± 28.57	.713
P axis	47.11 ± 25.96	47.04 ± 28.03	47.20 ± 20.77	.960
QRS axis	16.05 ± 47.22	25.96 ± 44.34	-6.45 ± 46.25	<.001
T axis	49.42 ± 58.08	36.76 ± 53.70	78.16 ± 57.91	<.001
Planar QRS/T angle	61.26 ± 44.78	36.30 ± 22.92	117.95 ± 26.86	<.001

58.3% for group 2, $P < .001$). Mean length of stay in the ICU was 1 day (0.5 IQR) for all patients. Moreover, the length of stay in the ICU and hospital did not significantly differ statistically between the two groups. The prevalence of postoperative atrial fibrillation (AF) was higher in group 2 compared with group 1. Two patients died in group 2, whereas no patients died in group 1. The difference was not statistically significant, probably due to the small volume of the study population (Table 2). Preoperative electrocardiographic data of patients is shown in Table 3.

We performed univariate correlation analysis with frontal planar QRS/T angle and found significant correlations for inotropic agent usage ($r = -0.303$, $P < .001$), postoperative AF prevalence ($r = -0.235$, $P = .003$), EuroSCORE ($r = 0.283$, $P < .001$), QRS axis ($r = - 0.350$, $P < .001$) and T axis ($r = 0.346$, $P < .001$). Following univariate correlations, a multivariate logistic regression analysis with backward LR process including age, HT, diabetes mellitus, ejection fraction, total cardiopulmonary bypass time, cross-clamp time, postoperative AF prevalence, EuroSCORE, and frontal planar QRS/T angle variables was applied to identify independent predictors of positive inotropic agent usage in the postoperative period. In the regression analysis, only EuroSCORE (OR: 0.792, 95% CI: 0.646-0.971, $P = .025$) and frontal planar QRS/T angle (OR: 0.989, 95% CI: 0.981-0.997, $P = .008$) were found as independent predictors of the requirement for positive inotropic usage in the postoperative period (Table 4).

DISCUSSION

In this retrospective study, we found that EuroSCORE, inotropic agent requirement, total intubation time, and postoperative AF frequency were higher in patients with frontal planar QRS/T angle 90° compared to those with frontal planar QRS/T angle <90°. In addition, we found that EuroSCORE and frontal planar QRS/T angle were independent predictors of the inotropic agent requirement in the postoperative period.

Today, CABG is the most commonly performed cardiac surgery. The perioperative mortality in patients undergoing CABG increases with preoperative risk factors such as advanced age, reoperation, necessity of emergency coronary revascularization, female sex, lower body surface area, history of myocardial infarction, left ventricle EF <30%, dialysis

Table 4. Effect of Numerous Variables on Postoperative Inotropic Agent Usage in Multivariate Logistic Regression Analyses

Covariates	Adjusted OR	95% CI	*P*
Age	1.007	0.968-1.047	.723
Hypertension	0.893	0.408-1.952	.776
Diabetes	0.877	0.427-1.801	.721
Ejection fraction	1.002	0.969-1.036	.909
Total CPB time	0.998	0.991-1.006	.625
Cross-clamp time	1.015	0.989-1.041	.256
Postoperative AF	0.976	0.386-2.468	.960
EuroSCORE	0.792	0.646-0.971	.025
Planar QRS/T angle	0.989	0.981-0.997	.008

CPB indicates cardiopulmonary bypass; ICU, intensive care unit; IABP, intraaortic balloon pump; IQR, interquartile range; AF, atrial fibrillation.

dependency, and presence of other associated diseases. Different scoring systems have been established for defining the morbidity and mortality rates after cardiac surgery. EuroSCORE, Cleveland model, STS, Corradi, and Parsonnet scores are similar scoring methods that are used to predict morbidity and mortality rates for CABG surgery [Nilsson 2004]. EuroSCORE is routinely used to define the mortality and morbidity rates for patients undergoing open heart surgery in our clinic. Myers et al showed that the length of hospital stay was significantly longer in diabetic and hypertensive patients, but there was no statistically significant difference for in-hospital mortality [Myers 1999]. Rady et al reported that COPD was an important risk factor in addition to advanced age and left ventricular (LV) dysfunction [Rady 1999]. In our study, in terms of comorbidities, there was no statistically significant difference between the two groups.

Reduced LV function has become the most important risk factor, with a high score in all of the models. Argenziano et al reported that patients with a low EF are 2.4 times more likely to stay in the intensive care unit [Argenziano 1999]. There was no statistically significant difference for LVEF between the 2 groups. However, it is well known that electrocardiographic depolarization and repolarization changes are not sufficiently taken into consideration in these risk stratification schemes due to lower sensitivity and specificity of presently used ECG parameters such as QT dispersion, QRS duration, and ST segment patterns. Hence the search for new ECG parameters to determine the ventricular depolarization and/or repolarization abnormalities. In this regard, there has been an increasing interest in the evaluation of the angle between the QRS and T vectors for almost 10 years [Pavri 2008].

The concept of the QRS-T angle has been known for a long time. The pathophysiological mechanisms underlying repolarization abnormalities and their relationship with myocardial performance are often ignored as inconsequential in former studies [Voulgari 2009]. The QRS axis reflects the main orientation of electrical heart activity during ventricular depolarization, whereas the T axis reflects it during ventricular repolarization. The frontal planar QRS/T angle characterizes the concordance/discordance of the ECG. Typically, the direction of the ventricular depolarization and repolarization axes is in a similar course, as a result of the balanced regulation of electric activation [Scherptong 2008]. Narrow frontal planar QRS/T angle is indicative of concordant ECG. When myocardial damage occurs, the spread of electrical forces through the myocardial wall is distorted [Rautaharju 2006]. Wider frontal planar QRS/T angle reflects the increased heterogeneity of ventricular repolarization, which can grow for damaged or inhomogeneous areas of myocardium and has been associated with fatal and non-fatal cardiovascular disease events.

The spatial QRS/T angle has better prognostic value for cardiac risk prediction than frontal planar QRS/T angle [Kannel 1987]. However, measurement of the spatial QRS/T angle is quite complex and requires availability of the orthogonal or at least quasi-orthogonal X, Y, and Z leads, thoughtful cardiac electrophysiological knowledge, and a dedicated computer program, which is not generally available in most centers. Conversely, most current ECG machines report automatic QRS and T axes and the frontal planar QRS/T angle can be readily derived as the absolute difference between the frontal QRS wave axes and T-wave axes from standard printed electrocardiographic reports. In addition, recent studies have demonstrated that the frontal planar QRS/T angle has the same predictive value and can be a convenient substitute for the spatial QRS/T angle for risk prediction [Yamazaki 2005]. We measured the frontal planar QRS/T angle, not the spatial QRS/T angle.

The QRS/T angle has been found to carry prognostic value for various study population groups. Kors et al concluded that QRS/T angle is a significant and important predictor of cardiac death and total mortality from the Rotterdam Study in the Netherlands [Kors 2003]. In another study, Rautaharju et al evaluated the predictive value of QRS/T angle in 38.283 women and concluded that wide QRS/T angle is one of the important predictors for ischemic heart diseases and their related mortality [Rautaharju 2006]. Despite many studies about this new parameter on several cardiac disorders, we cannot find any paper in the literature about the prognostic factor of QRS/T angle in patients who underwent cardiac surgery. To the best of our knowledge, our study is the first study in this era. In patients with frontal planar QRS/T angle 90, EuroSCORE was higher than those of <90. In terms of mortality, there was no statistically significant difference between the two groups. However, we believe that this is due to an insufficient number of patients. Also, in group 2, the requirement of positive inotropic drugs and frequency of postoperative AF were observed to be at a higher rate in the early postoperative period. Since it is not the main topic of this study, we did not focused on the etiology of the postoperative AF. Moreover, the higher frequency rate of postoperative AF in group 2 (frontal planar QRS/T angle 90) might be due to a higher incidence of positive inotropic drugs, which is mainly sympathomimetic.

In conclusion, we found that frontal planar QRS/T angle can be easily calculated from a standard 12-lead ECG by visual examination and can be regarded as a feasible index for predicting prognosis in patients undergoing CABG. In addition, we found that frontal planar QRS/T angle might be an important preoperative parameter for the prediction of a requirement for inotropic drugs in the early postoperative period in these patient groups. However, there is a need for larger sample-size studies for determining the exact prognostic value of frontal planar QRS/T angle in patients undergoing cardiac surgery.

Limitations

The present study has a number of limitations. The major limitation of the study is retrospective design from a single tertiary center and a relatively small number of patients, which may affect study generalizability. However, our study can give inspiration for further larger sample size prospective studies. Second, since comprehensive and computer-based assessment is required, we preferred to use the frontal planar QRS/T angle instead of the spatial QRS/T angle. However, previous studies demonstrated that the results with frontal planar QRS/T angle are similar to those derived with spatial QRS/T angle [Yamazaki 2005]. Finally, there is no reported cut-off value for QRS/T angle in the literature. In some studies, QRS/T angle below 45° is described as normal [Yan-Hong 2013; Wagner 2001; Malik 2004; Hingra 2005]. In a recent study, Raposeiras-Roubín et al defined the cut-off value of QRS/T angle as 90 [Raposeiras-Roubín 2014]. We accepted the value of >90 for abnormal QRS/T angle, which is clearly outside of the possible calculation errors.

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