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ORIGINAL ARTICLE

Evaluation of Frontal QRS-T Angle in Patients with Coronary Artery Ectasia

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Abstract

Background: Coronary artery ectasia (CAE) is defined by focal enlargement of the coronary artery exceeding 1.5 times the adjacent normal segment. CAE can often cause arrhythmias, heart failure, sudden death, and myocardial ischemia. Ischemia due to microvascular dysfunction may be responsible for the ventricular heterogeneity in CAE.

Objectives: The aim of our study was to evaluate the frontal QRS-T angle in patients with CAE.

Methods: Our study included 55 patients with CAE and 50 individuals in the control group. Demographic characteristics and electrocardiographic parameters were compared between the two groups. Categorical variables were compared using the chi-square test. Continuous variables were compared using unpaired Student's t-test. P values < 0.05 were considered statistically significant. The frontal QRS-T angle was calculated from 12-lead electrocardiograms (ECGs) using the automatic report from the electrocardiography machine.

Results: The average age of patients with CAE was 63.2 ± 3.4 years, with 18 women among them. The control group had an average age of 61.1 ± 3.2 years, with 28 women included. There was no significant difference in demographic parameters between the two groups. Compared to the control group, patients with CAE had significantly wider frontal QRS-T angle ($p < 0.001$), as well as longer QTmax duration, $p = 0.002$; Tp-Te interval, $p = 0.02$; and QT dispersion (QTd), $p = 0.04$.

Conclusion: The frontal QRS-T angle can be calculated easily and time-efficiently using surface electrocardiography. In this study, we showed for the first time that the frontal QRS-T angle was significantly increased in patients with CAE.

Keywords: Coronary Artery Disease; Dilatation, Pathologic; Electrocardiography.

Introduction

Coronary artery ectasia (CAE) is defined by focal enlargement of the coronary artery exceeding 1.5 times the adjacent normal segment.[1,2] CAE is a silent disease that is usually detected incidentally by coronary angiography or computed tomography angiography. There is a wide range of complications ranging from chest pain to sudden cardiac death. It is sometimes detected together with coronary artery disease.[3,4] The etiology of CAE includes atherosclerosis, congenital abnormalities, and/or inflammatory and connective tissue diseases.[5,6]

Myocardial repolarization and depolarization have been evaluated using various methods such as QT interval (QT), QT dispersion (QTd), transmural dispersion of repolarization, and QRS duration. On the electrocardiogram (ECG), the Tpeak-to-Tend interval (Tp-Te) between the peak and end of the T wave is considered as the transmural dispersion index of ventricular repolarization.[7] Recently, a new parameter has been defined to predict malignant ventricular arrhythmias. The spatial QRS-T angle is a new marker of myocardial repolarization and is defined as the angle difference between the direction of ventricular depolarization (QRS wave) and the direction of ventricular repolarization (T wave).[8] In contrast, QRS-T angle in the

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Central Illustration: Evaluation of Frontal QRS-T Angle in Patients with Coronary Artery Ectasia

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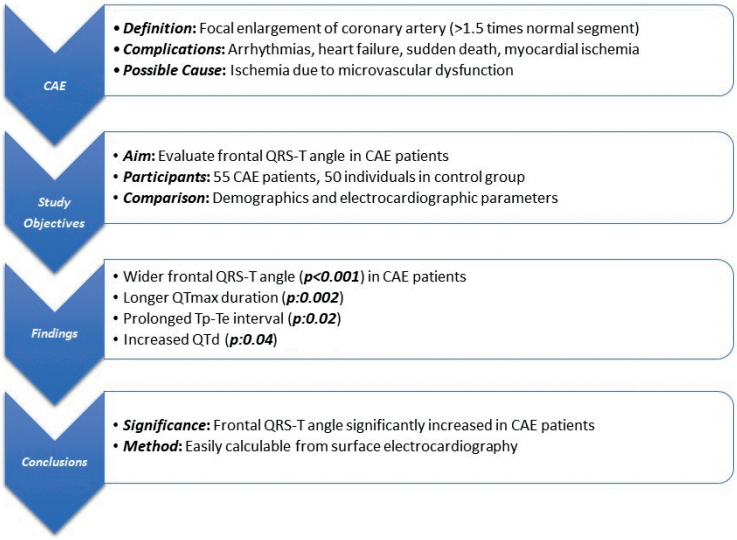

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Tp-Te: Tpeak-to-Tend interval; CAE: coronary artery ectasia; QTd: QT dispersion

frontal plane can be easily measured from the automatic report of ECG devices, and it correlates well with spatial QRS-T angle in risk estimation.[9] Therefore, the frontal QRS-T angle has received greater attention than the spatial QRS-T angle, and an increased frontal QRS-T angle is associated with worse cardiac outcomes.[10]

Ischemia due to microvascular dysfunction may be responsible for the ventricular heterogeneity in CAE and may lead to arrhythmic complications. The aim of our study was to evaluate the frontal QRS-T angle in patients with CAE.

Methods

Study population

This is a retrospective study with the aim of identifying patients with CAE who underwent coronary angiography between January 2017 and January 2022. Coronary angiography was performed in both groups, as noninvasive screening tests were positive for myocardial ischemia or typical angina. According to the angiographic definition by Hartnell et al.,[11] CAE was defined as the lumen enlargement of non-obstructive lesions of the coronary arteries 1.5 times or more than the adjacent normal coronary segment (Central Illustration). The exclusion criteria of the study were low ejection fraction, critical coronary stenosis, valvular heart disease, atrioventricular block and bundle branch block, atrial fibrillation, kidney disease, and thyroid disease.

Blood samples were tested using a standard Beckman Coulter LH 780 analyzer. Echocardiographic evaluation was performed using a Hewlett Packard SONOS 4500 and 2.5 to 3.5 mHz transducer according to the recommended criteria of the American Society of Echocardiography. Transthoracic echocardiographic examination was performed in all patients to evaluate heart size and functions and to exclude valvular disorders. Left ventricular ejection fraction was measured using the modified Simpson method.

Electrocardiography

Electrocardiograms were taken at a rate of 25 mm/s and gain of 10 mm/mV while the patients were in the resting position, using a Nihon Kohden (Japan) device. They were saved to a computer to reduce error measurements. Adobe Photoshop software was used for 400% magnification. Electrocardiographic depolarization and repolarization parameters were measured manually.

Electrocardiographic measurements of QRS duration, QT, corrected QT interval (QTc), QTd, Tp-Te, and the frontal QRS-T angle were performed by a cardiologist

blinded to this study. The QT was measured from the beginning of the QRS complex to the end of the T wave. The longest QT in leads V5 and V6 was defined as the QT maximum, and the shortest QT in any lead was defined as the minimum QT. QTcs were calculated according to the Bazett formula (QTc = QT / $\sqrt{}$RR). The Tp-Te was defined as Tp-Te measured at V5 and V6. The Tp-Te/QT ratio was calculated separately in V5 and V6. The frontal QRS-T angle was calculated as the difference between the QRS axis and the T axis. When the frontal QRS-T angle difference exceeded 180 degrees, this angle was calculated as 360 degrees minus the absolute value of the difference between the frontal plane QRS axis and T axis.[8] The frontal QRS-T angle was calculated and used based on the automatic report of the ECG machine (Figure 1).

Coronary angiography

Coronary angiograms were recorded using a Philips AlluraXper FD 10/10 device. The contrast injector was set at 3 mL/sec for the right coronary artery (6 mL bolus) and 4 mL/sec for the left coronary artery (8 mL bolus). Coronary arteries were visualized in standard positions. According to the angiographic definition by Hartnell et al.,[11] CAE was defined as the lumen enlargement of non-obstructive lesions of the coronary arteries 1.5 times or more than the adjacent normal coronary segment.

Statistical analysis

Statistical analyses were performed using SPSS 18.0 (SPSS, Inc, Chicago, Illinois, United States). Normality of the distribution was analyzed using the Kolmogorov–Smirnov test. Categorical variables were expressed as absolute values (n) and percentages (%) and were compared using the chi-square test. Continuous variables with normal distribution were expressed as mean ± standard deviation and were compared using unpaired Student's t-test. P values of <0.05 were considered statistically significant.

Results

The mean age of patients with CAE was 63.2 ± 3.4 years, and there were 37 male patients in this group. The mean age of the participants in the control group was 61.1 ± 3.2 years, and there were 22 male patients in this group. Although there was no statistically significant difference between the two groups in terms of sex, the proportion of male patients was higher in the CAE group compared to the control group ($p = 0.07$). Other demographic parameters between groups are shown in Table 1. When the patients with CAE were compared with the control group, there was no statistically significant difference in demographic parameters.

The results of the ECG features between patients with CAE and the control group are summarized in Table 2, which shows that patients with CAE had significantly longer QT duration, QTd, Tp-Te interval, and a wider frontal QRS-T angle compared to the control group.

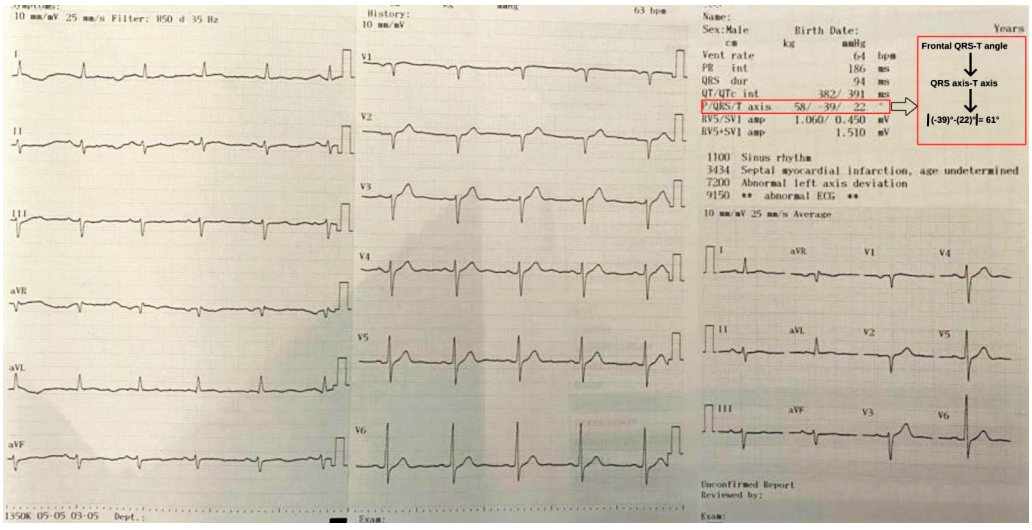

Figure 1 – Calculation of frontal QRS-T angle from ECG report.

Table 1 – Demographic characteristics of the patients

Characteristics	Patients with CAE n = 55	Control group n = 50	p value
Age (years)	63±3.4	61±3.2	0.51
Sex (female/ male), n	18/37	28/22	0.07
Systolic BP, mmHg	117±9	114±9	0.53
Diastolic BP, mmHg	74±4	73±5	0.65
Diabetes mellitus, n (%)	5(9)	4(8)	0.69
Hypertension, n (%)	9(16)	4(8)	0.06
Smoking, n (%)	16(29)	12(24)	0.20
Glucose (mg/dL)	130±45	110±30	0.18
Creatinine (mg/dL)	0.8±0.2	0.77±0.18	0.31
HDL cholesterol (mg/dL)	38.7±11	37.6±12	0.42
LDL cholesterol (mg/dL)	120±31.5	109±31.2	0.07
WBC	8.62±3.14	8.51±2.4	0.80
Hematocrit	42±3	41±3	0.42
LVEF (%)	64±3	64±2.5	0.25

BP: blood pressure; CAE: coronary artery ectasia; HDL: high-density lipoprotein: LDL: low-density lipoprotein; LVEF: left ventricle ejection fraction; WBC: white blood cells.

Table 2 – Electrocardiographic parameters of the patient

Parameters	Patients with CAE n = 55	Control group n = 50	p value
Heart rate (bpm)	82±13	87±12	0.82
PR interval, ms	152±24.2	149±27.7	0.62
QRS duration, ms	91±9	76±6	0.32
QT minimum, ms	364±18	322±16	0.21
QT maximum, ms	417±17	358±24	0.002
QTd, ms	52±13	22±10	0.04
Tp-Te, ms	85±3	66±4	0.02
Tp-Te/QT ratio	0.20±0.1	0.18±0.1	0.07
Frontal QRS-T angle	68±11	33±7	<0.001

Tp-Te: Tpeak-to-Tend interval; CAE: coronary artery ectasia; QTd: QT dispersion; PR : PR interval.

Discussion

To our knowledge, there is no study in which the frontal QRS-T angle was evaluated in patients with CAE. In this study, we examined for the first time the relationship between the frontal QRS-T angle and CAE. We found that patients with CAE had significantly wider frontal QRS-T angle.

CAE is a rare coronary anomaly characterized by inappropriate dilatation of coronary vessels. The pathophysiology and clinical significance of coronary ectasia are not fully understood. Atherosclerosis, congenital abnormalities, and inflammatory and connective tissue diseases are among the etiologies of CAE.[5,6] CAE can often occur in different clinical forms such as myocardial ischemia, arrhythmias, heart failure, and sudden death.[12-15]

Ischemia due to microvascular dysfunction may be responsible for the ventricular heterogeneity in CAE and may lead to arrhythmic complications. However, ischemia after microvascular dysfunction may be the cause of prolonged QT time and QTd leads to electrical instability and ventricular fibrillation.[15] We also found that patients with CAE had significantly longer QT duration, QTd, and Tp-Te interval.

Problems with ventricular repolarization are associated with malignant arrhythmias and have prognostic significance for mortality and sudden cardiac death.[16] Currently, Tp-Te interval and Tp-Te/QT ratio are perceived as true markers of increased dispersion of ventricular repolarization. Prolonged Tp-Te interval has been associated with increased mortality in patients with acute myocardial infarction, long QT syndrome, and Brugada syndrome.[17] In our study, we detected that some myocardial repolarization parameters were longer in patients with CAE.

In a previous study, CAE ECGs were found to be associated with an increase in Tp-Te, Tp-Te/QT ratio, QTc intervals, and P-wave distributions. This may suggest that the presence of CAE has a pro-arrhythmogenic structure.[18] In addition, Antzelevitch et al. reported that

there is a relationship between ventricular arrhythmia and Tp-Te prolongation.[19] In our study, we found that the Tp-Te interval was longer in patients with CAE. Another parameter is the ratio of Tp-Te to QT, a new ventricular repolarization index that remains constant despite changes in heart rate. The Tp-Te/QT ratio is recommended as a more precise arrhythmogenesis index compared to the Tp-Te interval, as it provides an estimate of the repolarization distribution over total repolarization time.[20] In this study, we could not find any difference between Tp-Te/QT ratio in patients with CAE compared to the control group. Studies have shown that QTc dispersion, which is another parameter that indicates increased ventricular arrhythmia and cardiovascular mortality risk, is associated with patients with slow coronary artery flow.[21] In this study, we found that QTd is increased in patients with CAE. Consequently, studies are ongoing for better or complementary risk markers.

The spatial QRS-T angle is a new marker of myocardial repolarization and is defined as the angle difference between the direction of ventricular depolarization and the direction of ventricular repolarization.[8] In contrast, QRS-T angle in the frontal plane can be easily measured from the automatic report of ECG devices and correlates well with spatial QRS-T angle in risk estimation.[9] In a previous study, it was recognized as a strong and independent risk indicator for cardiac morbidity and mortality compared with other cardiovascular risk factors and electrocardiographic risk indicators, such as QT length in patients with a wide QRS-T angle.[22] Most ECG devices automatically report the QRS and T axes, and the frontal QRS-T angle is easily calculated on the surface ECG. Frontal QRS-T angle abnormalities reflect the heterogeneity of myocardial repolarization, which can lead to electrical instability. Therefore, the frontal QRS-T angle width is effective in detecting repolarization abnormalities.[23] In our study, we found the frontal QRS-T angle to be wider in patients with CAE. In addition, Güngör et al. studied the frontal QRS-T angle in patients without angiographically evident atherosclerosis. They found that the frontal QRS-T angle was significantly higher in patients with hypertension and large coronary artery diameters. It has been suggested that increased frontal QRS-T angle can be used to monitor arrhythmic events even before significant disease occurs.[24]

CAE may cause deterioration in ventricular repolarization parameters and may predispose to arrhythmia. In our study, we analyzed all repolarization parameters and found that most of them were affected. Among these parameters, the frontal QRS-T angle can be measured automatically by the ECG device and easily calculated on the surface ECG, and its reproducibility is high. This patient group can be easily followed with this parameter.

Limitations

This study had some limitations. First of all, ECG repolarization parameters were measured manually. Second, it was a single-center study, and the number of patients was small. Third, patients were not followed for long-term clinical events such as arrhythmias and ECG changes. Ventricular heterogeneity and ECG changes may be observed in patients with CAE due to microvascular dysfunction, potentially leading to arrhythmic complications. However, the causal role of ECG abnormalities remains uncertain since patients are not assessed using magnetic resonance imaging. More comprehensive studies incorporating cardiac magnetic resonance imaging are required to elucidate this relationship further.

Conclusion

In our study, we found that many of the ventricular repolarization parameters were adversely affected in patients with CAE. Among these parameters, the frontal QRS-T angle can be measured automatically by the ECG device and easily calculated on the surface ECG, and its reproducibility is high. Ischemia due to microvascular dysfunction may be responsible for the ventricular heterogeneity in CAE and may lead to arrhythmic events. However, long-term and large-scale studies are needed to confirm and clarify the results of our study.

Author Contributions

Conception and design of the research: Karahan MZ, Aktan A, Güzel T; acquisition of data, analysis and interpretation of the data and critical revision of the manuscript for intellectual content: Karahan MZ, Aktan A, Güzel T, Kayan F, Günlü S; statistical analysis: Karahan MZ, Aktan A, Kayan F, Günlü S; writing of the manuscript: Karahan MZ.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Gazi Yaşargil Training and Research Hospital under the protocol number 42. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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