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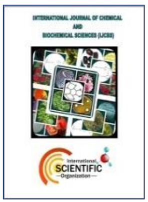

The Frontal QRS-T Angle Following Primary Percutaneous Coronary Intervention in Patients with ST Elevation Myocardial Infarction: Prognostic Significance and Functional Consequences

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Abstract

Employing the frontal QRS-T angle on 12-lead surface electrocardiogram as a non-invasive and easily accessible measure to assess the functional consequences following primary percutaneous coronary intervention. A cohort prospective study included 76 unselected patients with acute ST elevation myocardial infarction underwent primary percutaneous coronary intervention excluding those with bundle branch block, pacemaker rhythm, and electrocardiographic criteria of left ventricular hypertrophy. Patients were subjected to routine medical history, clinical examination, risk stratification, basal/post-reperfusion electrocardiogram, echocardiography, coronary angiography evaluation and observation of the hospital course. The optimal cut-off value of frontal QRS-T angle for predicting in-hospital mortality and/or a high GRACE score for in-hospital death was > 91°. Patients were divided into 2 groups according to this cut-off value; group (A): included 51patients with angle= (0°-91°) and group (B): included 25 patients with angle= (92°- 180°). Patients in the wide-angle group showed significant older age (P-value= 0.012), a higher GRACE risk score (P-value=0.003), a higher TIMI risk index (P-value= 0.007), a lower ST-segment resolution percentage (P-value=0.018), more incidence of Killip III (P-value= 0.042), severe mitral regurgitation (P-value=0.034), cardiogenic shock (P-value= 0.033) and in-hospital death (P-value= 0.042). Moreover, frontal QRS-T angle correlated directly to age, serum creatinine, GRACE risk score, TIMI risk index, and length of stay and indirectly to percentage of ST-segment resolution. A good predictive value exists for the frontal QRS-T angle on a 12-lead surface electrocardiogram after primary percutaneous coronary intervention. An angle greater than 91° is substantially linked to unfavorable outcomes.

Keywords:

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1. Introduction

Over the past three decades, primary percutaneous coronary intervention (pPCI) has been the standard of care for the treatment of ST-segment elevation myocardial infarction (STEMI) [1]. In spite of this, among patients receiving primary PCI, cardiac death has been rather high in the first month [2]. A number of novel criteria have been applied to the electrocardiogram (ECG) to identify high-risk patients with acute STEMI. Among these new ECG variables is the frontal plane QRS-T [f (QRS-T)] angle [3]. In a seminal 1934 paper, Wilson and colleagues suggested that by measuring the ventricular deflection areas of the ECG, it was possible to determine the mean electrical axis of the QRS complex, which resembles the direction of ventricular depolarization, and the mean electrical axis of the T wave, which resembles the direction of ventricular repolarization [4].

The vector deviation between the depolarization and repolarization is found by the spatial QRS-T angle by calculating the cosine values between the three-dimensional "R" and "T" wave loop vectors [5]. The spatial QRS and T vectors are projected onto the frontal plane in three dimensions to obtain the frontal QRS and T vectors. The angle formed by the two vectors is known as the frontal QRS-T angle [6]. According to a study with 13,973 participants from the atherosclerosis risk in communities (ARIC), the frontal plane QRS-T angle is a clinically useful stand-in for the spatial QRS-T angle for risk prediction because it is a readily calculated measure [7]. A broad spatial or frontal QRS-T angle showed a significant association with a greater occurrence of cardiac and all-cause mortality in all populations, according to a meta-analysis of 22 studies on QRS-T angle that included 164,171 participants [8].

Frontal QRS-T angle could provide encouraging data with a good predictive value on all-cause mortality. Our aim was to research the functional consequences and the prognostic significance of calculating the frontal QRS-T angle in patients with STEMI underwent primary PCI.

2. Patients and methods

A prospective cohort research was carried out over a 16-month period (August 2021–December 2022) on 76 unselected patients who received primary PCI for STEMI. 65 men and 11 women between the ages of 29 and 75 made up the study's patient population. Patients who met the ECG criteria for left ventricular hypertrophy (LVH), pacemaker rhythm, left bundle branch block (LBBB), or right bundle branch block (RBBB) were not included. In compliance with the ethical committee's guidelines, all participants or their legal relations have provided written consent in an informed manner. In order to assess the risk factors of coronary artery disease (CAD), determine Killip class, qtd.in, and calculate GRACE risk score and TIMI risk index using the MDCalc application for medical professionals, the patients underwent routine medical history, clinical examination, and biochemical analyses. Every patient had a 12-lead surface ECG performed at a paper speed of 25 mm/s upon admission and after primary PCI to: (1) Diagnose STEMI in accordance with the fourth universal definition of MI (myocardial infarction) [9-13]. (2) Find the criterion for exclusion. (3) Measure ST-segment resolution (STR), which determined single-lead ST resolution by utilizing the ECG lead with the largest ST-segment deviation both upon admission and during reperfusion. A STR of ≥70% was regarded complete resolution in cases of anterior and inferior infarction, whereas a STR of <50% in anterior STEMI cases and <20% in inferior STEMI cases indicated no ST resolution [14]. (4) Calculate the frontal QRS-T angle, which is the absolute value of the difference between the frontal plane QRS axis and T axis. When the difference was greater than 180°, the angle is calculated as (360° - the absolute value of the difference) [6]. Frontal QRS-T angle was computed manually or automatically using the ECG machine. The net amplitude and polarity of the QRS complex and T wave in any limb lead were measured, and the results were applied to the corresponding leads of Einthoven's triangle to determine the QRS and T axes (Fig. 1 & 2) or by an online ECG axis calculator using leads (I) and (III). Left ventricular end-diastolic dimension (LVEDD), left ventricular ejection fraction (LVEF), wall motion score index (WMSI), and the degree of mitral regurgitation were all measured using trans-thoracic echocardiography [15]. Using the Gensini score, qtd.in, and the number of diseased arteries, the severity and degree of CAD were assessed in all patient's coronary angiography data. Every patient's length of stay (LOS) in the hospital was recorded, and during the hospital stay, significant advanced cardiac events (MACE) such as cardiogenic shock, arrhythmia, and mortality were noted [16-17]. For quantitative data, the statistical data was expressed as mean ± standard deviation (SD), while for qualitative data, the words number and % were used. In analytical statistics, two groups with quantitative variables that had a normal distribution were compared using the student t-test (for parametric data), two groups with non-normal distribution quantitative variables were compared using the Mann-Whitney U Test (for non-parametric data), and two groups with normal distribution quantitative variables were compared using the chi-square test ($\chi 2$). To evaluate the parameter's clinical performance, a receiver operating characteristic (ROC) curve was built. The Spearman's coefficient was used to perform correlations. A statistically significant P-value of less than 0.05 was deemed to be the probability value.

3. Results and discussion

Of 76 unselected patients received primary PCI for STEMI, the ROC curve showed that the optimal cut-off value of the f (QRS-T) angle for predicting in-hospital mortality and/or a high GRACE score for in-hospital death was > 91° with 85.7% sensitivity and 72.5% specificity. Area under the curve (AUC) = 0.758, P-value = 0.014 (Fig. 3). Patients were divided according to this cut-off value into two groups; group (A) included 51 patients (67.1%) with f (QRS-T) ≤ 91° and group (B) included 25 patients (32.9%) with f(QRS-T) ranging between 92°-180°. As regards general demographic characteristics and major risk factors of CAD including hypertension, diabetes mellitus (DM), dyslipidemia, current smoking, and impaired renal function at admission, the study revealed no significant difference between both groups, however, patients with wider f (QRS-T) angle were significantly older, P-value =0.012. GRACE risk score and TIMI risk index were significantly higher in group (B) than group (A) (116.28 ± 32.01 vs 96.33 ± 26.04, P-value = 0.003 and 27.64 ± 18.06 vs 19.20 ± 11.99, P-value = 0.007, respectively) (Table 1). Additionally, f (QRS-T) angle was directly and significantly correlated to the age of the participants, GRACE risk score and TIMI risk index; P-value = 0.001, 0.000 and 0.002, respectively (Fig. 4, 5 & Table 3). Clinical risk assessment using Killip classification showed a significantly higher incidence of Killip III in group (B), P-value =0.042 (Table 1). The percentage of STR among the both groups was significantly higher in patients with narrow frontal QRS-T angle, P-value = 0.018. Patients with wide f (QRS-T) angle had more significant incidence of STR failure (P-value = 0.006) whilst those with narrow angle had more significant incidence of complete STR (P-value = 0.037) (Table 2). Moreover, an indirect strong correlation existed between the f (QRS-T) angle and the percentage of STR, P-value = 0.002 (Table 3). The presence of severe mitral regurgitation (MR) was more significant in group (B) (P-value = 0.034), whereas absence of MR found to be significantly more in group (A) (P-value = 0.049), other echocardiographic measurements including LVEDD, LVEF, and WMSI were not significantly comparable between both groups. Although Gensini score was higher in patients with wide f (QRS-T), it, as well as number of diseased vessels, did not demonstrate any significant differentiation between the two groups. Occurrence of arrhythmia did not differ between both groups, nevertheless, the incidence of cardiogenic shock and in-hospital death was significantly more in patients who had wider f (QRS-T) angle (P-value = 0.033 and 0.042, respectively) (Table 2). Furthermore, the hospital length of stay was positively and significantly correlated with the f (QRS-T) angle (P-value = 0.032) (Table 3).

Repolarization of the left ventricular free wall normally happens in the opposite order from depolarization; however, the process is not a perfect mirror image. An atypically broad spatial QRS-T angle signifies a pathological alteration in the ions channel within certain cardiac areas, impacting the ventricular repolarization processes [7]. In this investigation, we examined the functional implications and prognostic relevance of the f(QRS-T) angle in patients who had undergone primary PCI finding that poor outcomes were associated with a broad f(QRS-T) angle following pPCI. Our ROC curve, which was used to determine the ideal f(QRS-T) angle cut-off value to predict in-hospital mortality and/or a high GRACE score for in-hospital death, showed that the cut off value was > 91°. Our findings were in line with a 2018 study, which found that an independent predictor of in-hospital death in patients with acute STEMI was f(QRS-T) angle 89.6° after coronary reperfusion [3]. Although there was no discernible difference in the baseline features and primary risk factors of CAD between the two study groups, group (B) patients had a significantly higher average age than group (A) patients. Similar to this, additional investigations revealed no significant differences with regard to sex, smoking, dyslipidemia, hypertension, DM, and serum creatinine; however, in a 2020 research, age tended to be substantially older in the group with wider QRS-T angle (P-value = 0.019) [3,18-19]. Additionally, the age of the patients who took part in our investigation had a direct and substantial correlation with the f (QRS-T) angle (P-value = 0.001), supporting the finding that ageing was a major contributing factor to the increasing QRS-T angle [20]. Additionally, there was a substantial and direct link between the f (QRS-T) angle and GRACE risk score. The GRACE risk score showed a statistically significant higher value in the group with f(QRS-T) angle more than 91° (P-Value = 0.003). The discriminating power of the frontal QRS-T angle-age risk score (FAAR) was favorably compared to the GRACE risk score [21]. To the extent of our knowledge, this was the first study to examine the frontal QRS-T angle in relation to the TIMI risk index; it was shown that patients with broader QRS-T angles (>91°) had significantly greater frontal QRS-T angles (P-value = 0.007). Additionally, we observed a significant positive correlation (P-value = 0.002) between the TIMI risk score and the f(QRS-T) angle. Killip class III showed a statistically significant higher incidence among the wider frontal QRS-T angle group (P-value =0.042), in the other classes, however, f (QRS-T) angle was unable to represent any significant difference between both groups. According to the STR grades (no, partial, or complete resolution), patients with wider f(QRS-T) angles had a substantially greater incidence of failed STR after primary PCI (P-Value = 0.006), whereas patients with narrower angles had a significantly higher incidence of complete STR (P-Value = 0.037). Group (A) had a greater and statistically significant STR proportion than group (B), with a P-Value of 0.018. Colluoglu and colleagues in 2018 were also successful in identifying a noteworthy distinction between the two study groups. Furthermore, our results agreed well with their findings as f(QRS-T) angle was negatively and highly connected with ST resolution (P-Value = 0.033, 0.008 in our study and their study, respectively) [3]. Significant differences were seen in the degree of mitral regurgitation between the two groups. While there were significantly more patients in group (A) without mitral regurgitation, patients in group (B) had a significantly higher incidence of severe MR (P-Value= 0.034). To the best of our knowledge, this is the first study to look into the connection between mitral regurgitation and the frontal QRS-T angle. There was no discernible difference in LVEF, WMSI, or LVEDD between the patients in the two groups based on other echocardiographic results. However, after reperfusion therapy, patients with f(QRS-T) angle ≥89.6° had a poorer LVEF, according to the previously reported study [3]. This discrepancy may have returned to the relatively small population in our study. In 2021, Akın and Bilge's study revealed a noteworthy correlation between the f(QRS-T) angle and the severity of CAD using the Gensini score [22]. In contrast to this study, we were unable to find any differences in the Gensini scores between the two groups. This is understandable as our study included patients with STEMI while theirs included patients with stable CAD. Our findings were consistent with Colluoglu et al., since there was no statistically significant difference in the number of diseased arteries between groups (A) and (B) [3]. Patients with f(QRS-T) angle > 91° had a higher and statistically significant incidence of cardiogenic shock (P-Value = 0.033). Relevantly, Kaya et al. (2015) discovered that following off-pump coronary artery bypass graft (CABG) surgery, a preoperative broad f(QRS-T) angle > 90° was linked to a greater need for circulatory assistance with vasoactive drugs or IABP (intra-aortic balloon pump) [23-24]. However, there was no significant difference in the development of arrhythmias (atrial, ventricular, or conduction abnormalities) between the two groups during the hospital stay. Sawant et al.'s findings, in contrast to ours, showed that patients with the highest f (QRS-T) angles had a greater incidence of atrial fibrillation (AF) [19]. The study's distinct design could be the cause of the discrepancy in the results, where included also patients post CABG and did not study rather forms of arrhythmia than AF. Our study found that patients in Group (B) who had a wider frontal QRS-T angle experienced a significant hospital mortality (P-Value = 0.042). Wide QRS-T angles have been linked to higher fatality rates in myocardial infarction patients, according to several prior research [3,19,21,24]. In addition, the hospital length of stay, and the f(QRS-T) angle were positively and significantly associated (P= 0.032). The relatively small sample size is one of the study's limitations. Larger studies are needed to better understand the areas in which the results differ from those of other studies. Additionally, the long-term follow-up was not assessed; it would be valuable to investigate the prognostic significance of the frontal QRS-T angle in the long run after STEMI.

Table 1: General demographic characteristic, major risk factors of coronary artery disease, and risk stratifications.

	Frontal QRS-T angle ≤ 91° (Group A)	Frontal QRS-T angle ≥ 92° (Group B)	P-value
Age (years) Min - Max Mean ± SD	29-73 54.10 ± 10.20	34-75 60.64 ± 10.64	*0.012*
Sex (male/female)	43/8	22/3	*0.668*
Hypertension	22/51	10/25	*0.795*
Diabetes Mellitus	25/51	13/25	*0.807*
Dyslipidemia	37/50	20/25	*0.566*
Current smoking	27/51	10/25	*0.289*
Serum creatinine (mg/dL) Mean ± SD	1.12 ± 0.88	1.23 ± 0.61	*0.125*
GRACE risk score Mean ± SD	96.33 ± 26.04	116.28 ± 32.01	*0.003*
TIMI risk index Mean ± SD	19.20 ± 11.99	27.64 ± 18.06	*0.007*
Killip Class			
I	38/51	17/25	*0.343*
II	11/51	7/25	*0.536*
III	0/51	2/25	*0.042*
IV	2/51	0/25	*0.319*

GRACE: Global Registry of Acute Coronary Events, **mg/dL:** Milligram/Deciliter, **SD:** standard deviation, **TIMI**: Thrombolysis in Myocardial Infarction.

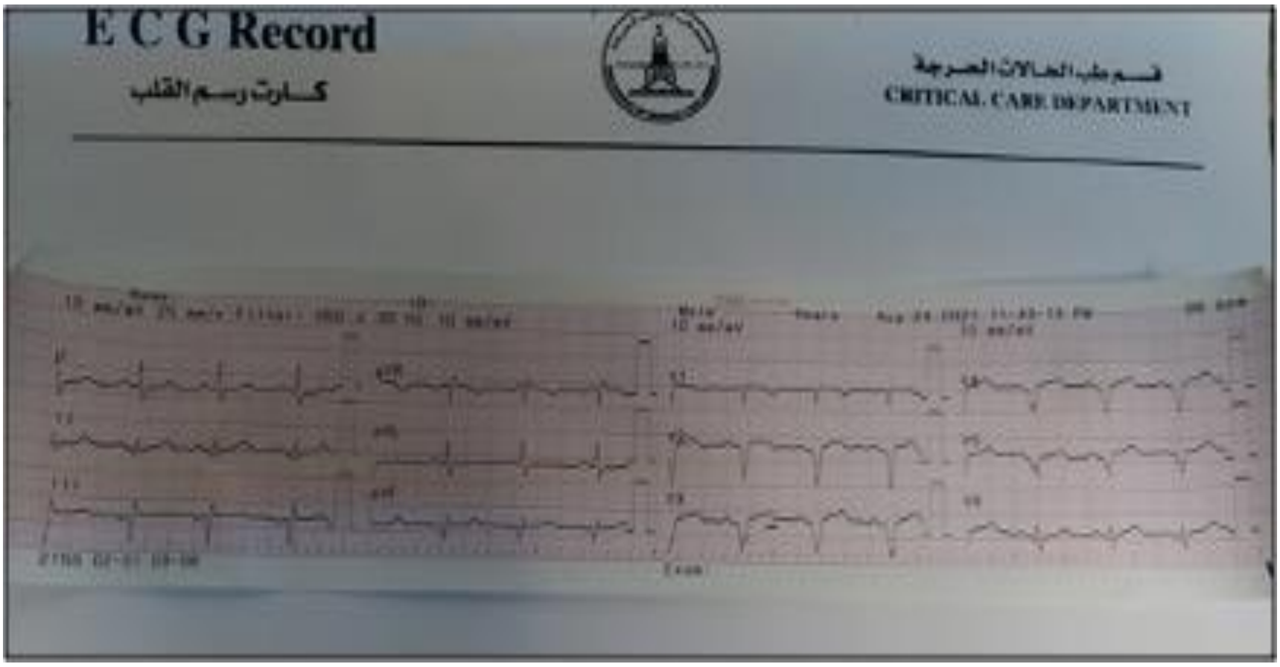

Figure 1: Electrocardiogram of a participant showing QRS complex amplitudes in leads I and aVF = +3 and -1.1 millimeter, respectively and T-wave amplitudes in the same leads = +1.2 and +1.4 millimeter respectively.

Table 2: ST-segment resolution, echocardiographic measurements, Gensini score and in-hospital major advanced cardiac events.

	Frontal QRS-T angle ≤ 91° (Group A)	**Frontal QRS-T angle ≥ 92° (Group B)**	**P-value**
ST-segment resolution (%) Mean ± SD	64.75 ± 27.03	48.00 ± 34.85	*0.018*
Grade of ST resolution			
No	5/51	9/25	*0.006*
Partial	21/51	10/25	*0.922*
Complete	25/51	6/25	*0.037*
Degree of mitral regurgitation			
No	18/51	3/23	*0.049*
Mild	25/51	13/23	*0.550*
Moderate	8/51	5/23	*0.527*
Severe	0/51	2/23	*0.034*
LVEDD (mm) Mean ± SD	52.06 ± 6.97	53.30 ± 5.91	*0.312*
LVEF (%) Mean ± SD	49.88 ± 13.35	44.88 ± 10.46	*0.181*
WMSI Mean ± SD	1.44 ± 0.325	1.46 ± 0.345	*0.783*
Gensini score Mean ± SD	66.19 ± 42.70	77.68 ± 37.80	*0.101*
Number of diseased vessels			
Single vessel	19/51	8/25	*0.653*
Two-vessel	20/51	6/25	*0.189*
Three-vessel	12/51	11/25	*0.680*
MACE			
Arrhythmia	19/51	12/25	*0.370*
Cardiogenic shock	6/51	8/25	*0.033*
In-hospital death	0/51	2/25	*0.042*

LVEDD: left ventricular end-diastolic dimension, **LVEF:** left ventricular ejection fraction, **MACE:** major advanced cardiac events, **mm:** millimeter, **SD:** standard deviation, **WMSI:** wall motion score index.

Table 3: Correlation between the frontal QRS-T angle and some variables.

	Frontal QRS-T angle	
	Correlation coefficient	**P**
Age	0.361	*0.001*
Serum creatinine	0.257	*0.025*
GRACE risk score	0.403	0.000
TIMI risk index	0.342	0.002
ST-segment resolution (%)	-0.349	0.002
LVEF (%)	-0.179	0.125
WMSI	0.077	0.512
Gensini score	0.169	0.145
Length of stay	0.246	0.032

GRACE: Global Registry of Acute Coronary Events, **LVEF:** left ventricular ejection fraction, **TIMI**: Thrombolysis In Myocardial Infarction, **WMSI:** wall motion score index.

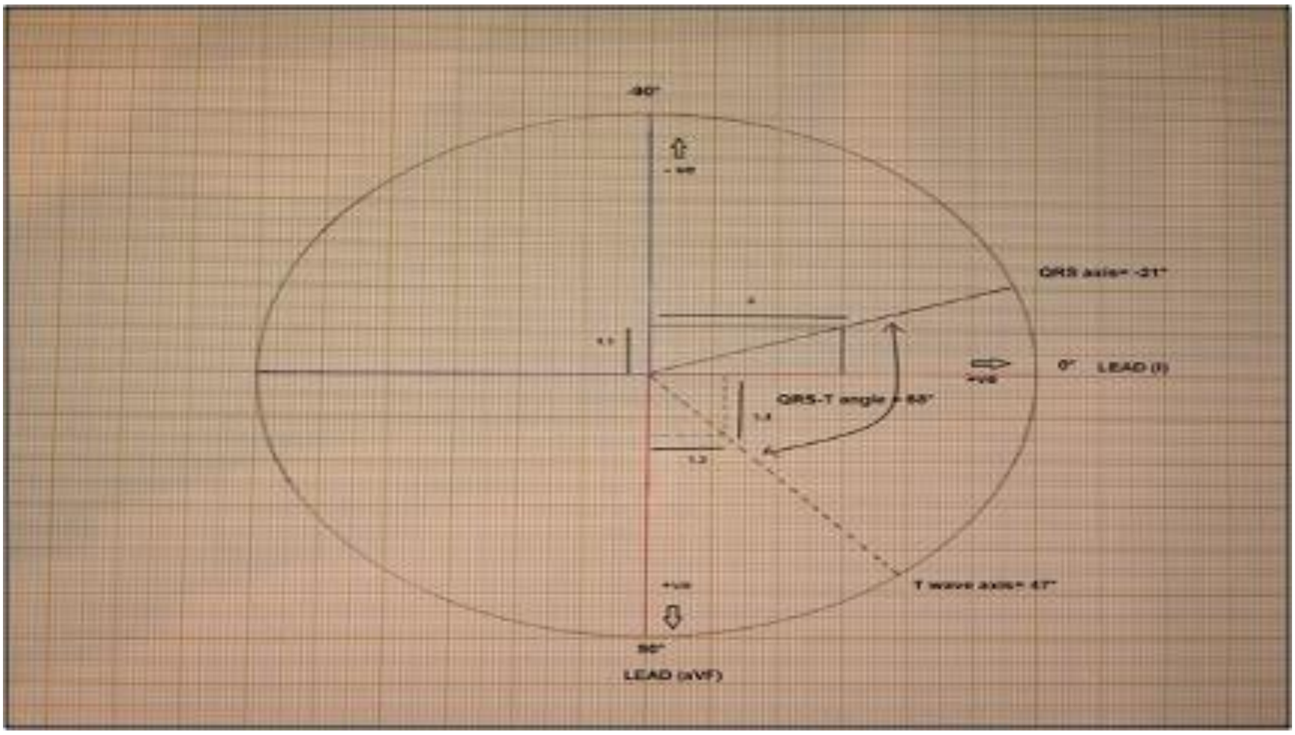

Figure 2: Calculation of QRS axis (black line) and T axis (dotted line) after applying amplitude and polarity of both QRS complex and T-wave in leads I and aVF of the previous ECG example. QRS axis = -21° and T axis = +47 °, so the frontal QRS-T angle= 68°. Note that the axis of lead I= 0° and of aVF = 90° as introduced in Einthoven’s triangle, red and blue lines represent positive and negative electrical polarity, respectively.

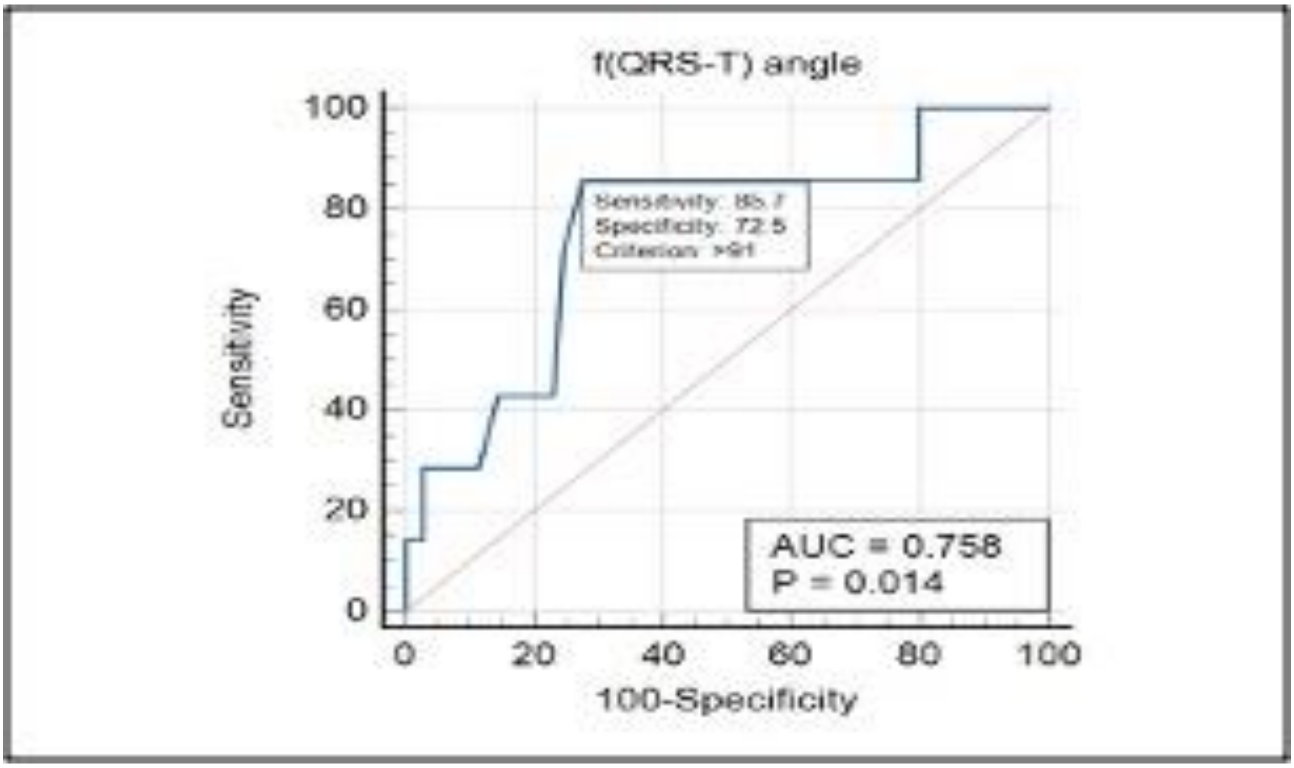

Figure 3: ROC (receiver operating characteristic) curve for the frontal QRS-T angle that predicted in-hospital mortality, and/or high GRACE score for in-hospital death.

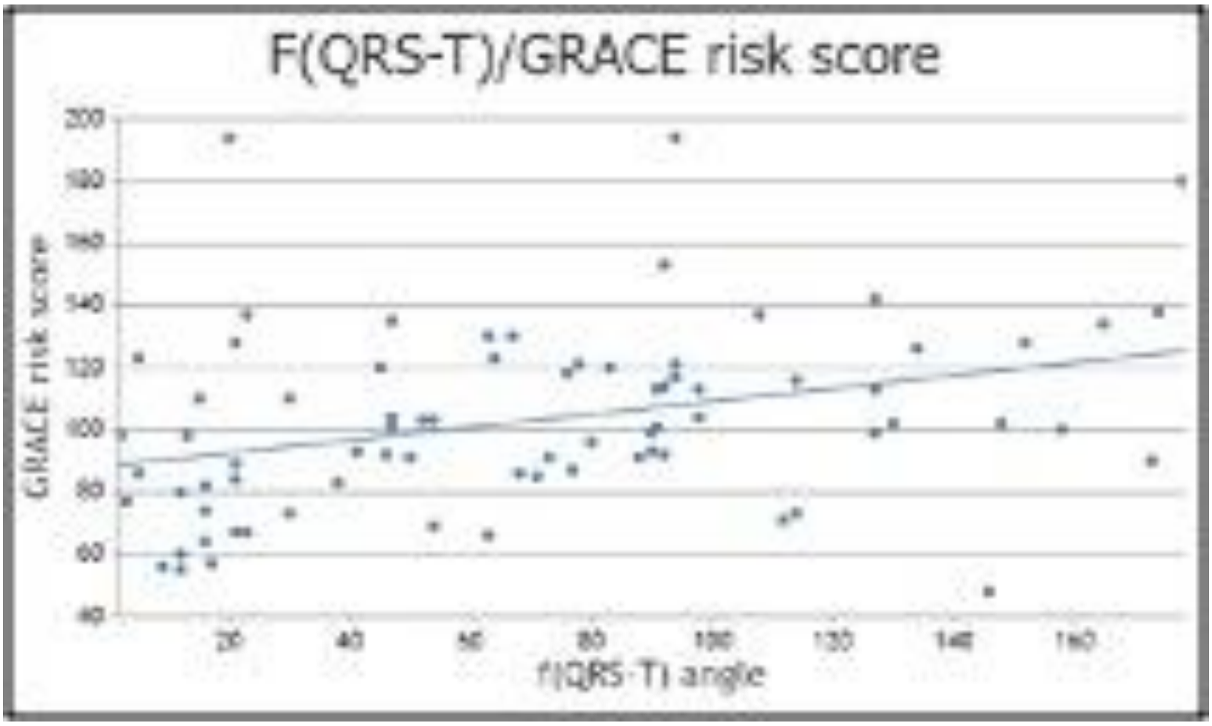

Figure 4: Correlation between the frontal QRS-T angle and GRACE (Global Registry of Acute Coronary Events) risk score, P-value is 0.000.

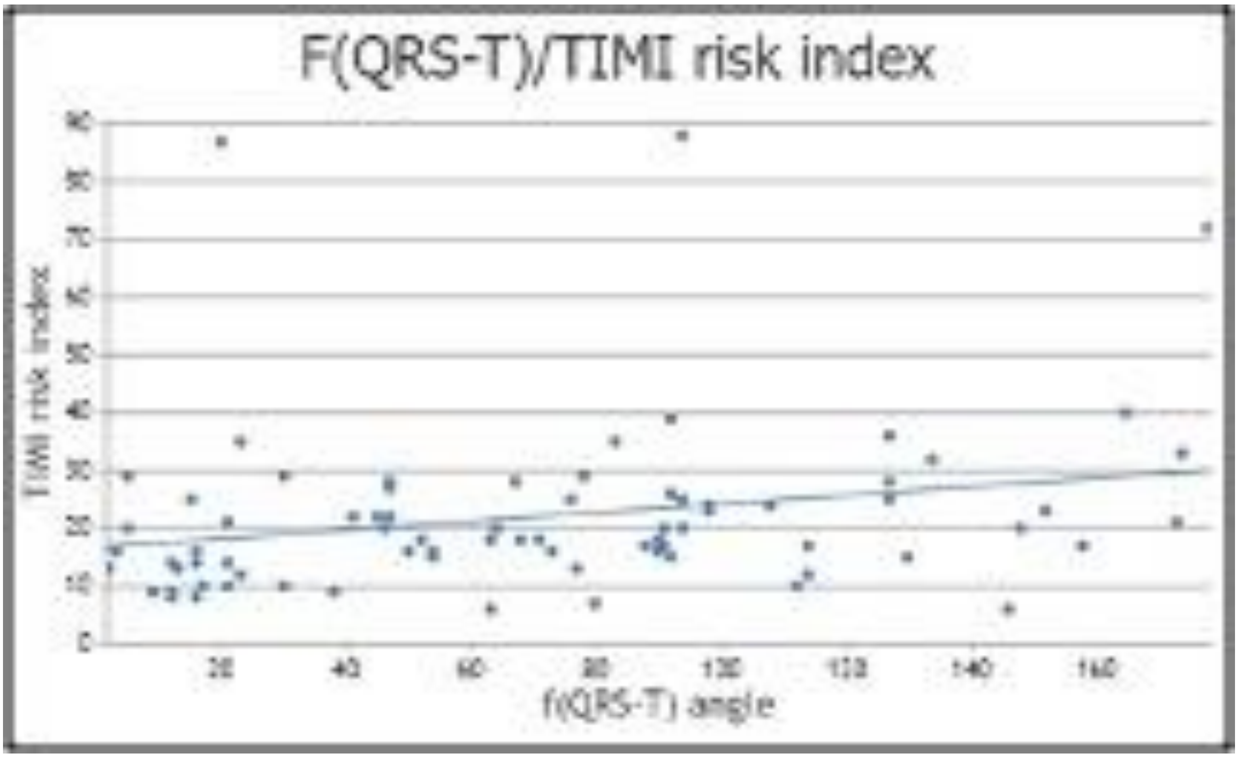

Figure 5: Correlation between the frontal QRS-T angle and TIMI (Thrombolysis in Myocardial Infarction) risk index, P-value is 0.002.

4. Conclusions

A good predictive value exists for the frontal QRS-T angle on a 12-lead surface electrocardiogram after primary percutaneous coronary intervention. An angle greater than 91° is substantially linked to unfavorable outcomes.

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