Original Research Article

SCIENCE PROGRESS

Science Progress
2024, Vol. 108(1) 1–14

DOI: 10.1177/00368504241309454
journals.sagepub.com/home/sci

Noninvasive prediction of coronary artery disease severity: Comparative analysis of electrocardiographic findings and risk factors with SYNTAX and Gensini score

Farzaneh-Sadat Mirjalili[1], Tahere Baghiani[1], Faezeh Badkoubeh[2], Abbas Andishmand[1], Mohammadtaghi Sarebanhassanabadi[1], Hamidreza Mohammadi[1], Amin Salehi-Abargouei[1,3,4], Maryam Motallaei[1,3,4] and Seyed Mostafa Seyedhosseini[1]

[1]Yazd Cardiovascular Research Center, Non-communicable Diseases Research Institute, Shahid Sadoughi University of Medical Sciences, Yazd, Iran
[2]School of Medicine, Arak University of Medical Sciences, Arak, Iran
[3]Research Center for Food Hygiene and Safety, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran
[4]Department of Nutrition, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

Abstract

Objective: Coronary artery disease (CAD) remains a significant global health burden, characterized by the narrowing or blockage of coronary arteries. Treatment decisions are often guided by angiography-based scoring systems, such as the Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery (SYNTAX) and Gensini scores, although these require invasive procedures. This study explores the potential of electrocardiography (ECG) as a noninvasive diagnostic tool for predicting CAD severity, alongside traditional risk factors.

Corresponding author:
Seyed Mostafa Seyedhosseini, Yazd Cardiovascular Research Center, Non-communicable Diseases Research Institute, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.
Email: m.seyedhossaini@gmail.com

Methods: This retrospective cross-sectional study was conducted on 348 CAD patients who underwent coronary angiography. Demographic data, ECG findings, SYNTAX, and Gensini scores were collected. The association between ECG findings and demographic information with the severity of coronary artery stenosis, as assessed by SYNTAX and Gensini scores, was investigated using SPSS software, version 23.
Results: Significant associations were observed between CAD severity and risk factors such as male gender, diabetes mellitus (DM), and smoking. Additionally, certain ECG indicators, including Q waves and ST depression (STD), showed significant correlations with CAD severity, particularly according to the Gensini score.
Conclusion: This study underscores the utility of ECG and clinical factors in identifying severe CAD, offering cost-effective diagnostic alternatives to angiography. Integrating various parameters into a single score is crucial in clinical practice, providing a stronger diagnostic and prognostic tool without increasing costs. Further comprehensive studies are warranted to refine risk prediction models and improve CAD management strategies.

Keywords
Coronary artery disease, electrocardiography, SYNTAX, Gensini, risk factors

Introduction

Coronary artery disease (CAD) is characterized by the narrowing or blockage of the coronary arteries and is still a major pathology associated with all-cause morbidity and mortality worldwide.[1,2] Due to obstructive coronary atherosclerosis, ischemia causes electrical heterogeneity in the vulnerable ventricular myocardium, resulting in ventricular arrhythmias. These abnormalities reflect surface electrocardiography (ECG).[1,3] The risk factors associated with CAD include smoking, diabetes mellitus (DM), hyperlipidemia (HLP), and hypertension (HTN). The basis of CAD treatment is to prevent complete blockage of the coronary arteries by helping to reduce the size of the clot and atherosclerotic plaque, reduce ischemia, and modify risk factors for stroke.[4] Various scoring systems and laboratory parameters have been used in clinical practice to select the appropriate treatment method. Angiographically based scoring systems such as Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery (SYNTAX) and Gensini scores are used to determine the extent and severity of CAD and to determine the course of treatment.[5] Angiography is associated with certain risks, the need for hospitalization, and related in-hospital complications. Despite the benefits of using SYNTAX and Gensini scores, these two criteria can only be calculated based on coronary angiography.[6,7] Therefore, the investigation of noninvasive diagnostic tools for predicting the severity of CAD has recently been considered mainly because they offer an alternative, cost-effective, and noninvasive method.[8]

Recent studies have focused on utilizing simpler, more accurate, and cost-effective tools, such as the ECG, to predict the severity of CAD. Leasure et al. utilized a combination of ECG findings and angiographic results to preliminarily predict the presence, localization, and severity of coronary lesions.[9] In addition, Alizadeh et al. used demographics, clinical, and paraclinical variables to predict the stenosis of coronary arteries.[10] Furthermore, a novel ECG scoring system based on various measured ECG parameters

has been developed. This scoring system has demonstrated the ability to predict sudden or arrhythmic death in patients with CAD.[11]

ECG is commonly used for diagnosing CAD due to its low-cost and noninvasive characteristics; however, early coronary stenosis may have minimal impact on the ECG signal waveform, making it susceptible to being missed or misidentified.[12] Combining multiple ECG findings could enhance the identification of high-risk individuals prior to coronary angiography. In the present study, we aim to assess the relationship between SYNTAX and Gensini scores with ECG findings and CAD risk factors in patients undergoing coronary angiography.

Method

Study design and participant selection

This retrospective cross-sectional was conducted on 700 patients examined in the Iranian-CARDIO study at Afshar hospitals (Yazd, Iran) between July 2020 and November 2021. A comprehensive protocol of the Iranian-CARDIO study has been previously published, providing detailed information.[13] The primary endpoint of this study was to determine the association between specific electrocardiographic findings and SYNTAX and Gensini scores in participants with CAD. Patients with confirmed CAD based on medical history, physical examination, and angiographic findings were included in the study.

Patients with a previous history of Structural heart disease, Acute Coronary Syndrome (ACS), heart failure, open-heart surgery, implanting electrical devices, electrolyte disorders, anemia, chronic kidney disease (CKD), a history of Digoxin consumption, and patients with incomplete medical records were excluded.

Finally, a total of 348 patients with CAD were consecutively enrolled in the present study. The required sample size was calculated using the following formula, based on data extracted from the study by Helmy et al.[14] Considering $\alpha = 5\%$, statistical power = 80%, mean = 1.83, standard deviation = 3.20, and margin of error = 2.5, and accounting for a potential 20% dropout rate, a sample size of 280 participants was determined. The sample size of the present study exceeded the calculated sample size.

$$N = \frac{z^2_{\frac{1-\alpha}{2}} * S^2}{d^2}$$

Coronary angiography was performed via the femoral artery by an interventional cardiologist, with the right femoral artery as the primary access site and the left as an alternative. The puncture site was located 2–3 cm below the inguinal ligament. After detecting arterial blood flow using an 18G introducer needle (SCW Meditech, China), a 0.035-inch J-tip guidewire was advanced into the lumen. Once confirmed, a 6F arterial sheath (Avanti Plus, Cordis, USA) was inserted. Following the procedure, patients received treatment and were hospitalized for a minimum of 24 h.

Subsequently, the angiographic reports of all patients were thoroughly reviewed to identify cases of CAD. Demographic variables including age, gender, BMI, smoking

status, HTN, DM, and HLP, were collected from the patients' medical records. Additionally, findings from emergency department ECG and angiographic reports were extracted for comprehensive analysis.

Ethical consideration

The present study was approved by the Research Ethics Committees of the School of Medicine, Shahid Sadoughi University of Medical Sciences, located in Yazd, Iran (approval number: IR.SSU.MEDICINE.REC.1401.067, date of approval: 2022-07-26) and conducted based on the Declaration of Helsinki on medical research. Informed consent was obtained from eligible individuals. The data collection process ensured complete anonymity, with no personally identifying information included in the individual data. This study was based on the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) declaration.[15]

ECG analyses

The findings of 12-lead ECG (filter range, 0.15–100 Hz; AC filter, 60 Hz, 25 mm/s, 10 mm/mV) were examined by A blinded cardiologist. The ECG parameters were standardized and interpreted according to the guidelines provided by the American Heart Association and the Heart Rhythm Society. ECG parameters such as Axis, Rhythm, fragment QRS, AVR fragment QRS, bundle branch block, Abnormal Q wave, STD, AVR STE, Poor R progression, T wave inverted heart rate (b.p.m.), the shortest and longest QT (ms), T peak-T end interval (ms), and TAaVR (mV) were analyzed.[16]

Assessment of SYNTAX and Gensini scores

Calculation of the SYNTAX as a measure of the severity of CAD assessed using the SYNTAX using the application at https://syntaxscore.org/calculator/start.htm. SYNTAX is grouped into three groups. SYNTAX is classified as low risk (SYNTAX $\leq$22), medium risk (SYNTAX 23-32), and high risk (SYNTAX $\geq$ 33).[17]

The Gensini score was determined by assigning severity scores to specific coronary stenoses, considering the extent of luminal narrowing and their anatomical relevance. The evaluation included assessing reductions in lumen diameter and the angiographic characteristics of concentric lesions and eccentric plaques. Specific reductions (25%, 50%, 75%, 90%, 99%, and complete occlusion) are assigned scores of 1, 2, 4, 8, 16, and 32, respectively. These scores are then adjusted by multiplying each lesion score by a factor reflecting its importance in the coronary circulation. Factors include 5 for the left main coronary artery, 2.5 for the proximal left anterior descending coronary artery, 2.5 for the proximal circumflex artery, 1.5 for the mid left anterior descending coronary artery, 1.0 for the right coronary artery, distal left anterior descending coronary artery, posterolateral artery, and obtuse marginal artery, and 0.5 for other segments. The Gensini score was categorized into low risk (GS <26), medium risk (GS 26–54), and high risk (GS >54).[18]

Statistical analyses

Statistical analysis was conducted utilizing SPSS software, version 23 (IBM Corp., Armonk, NY, USA). Categorical and continuous variables were expressed as number (%) and mean ± SD, respectively. Comparisons among multiple groups were analyzed using the one-way ANOVA test. Categorical variables were compared using the chi-square test. A general line model analysis was performed to assess the relationship between the number of risk factors with the SYNTAX and Gensini scores. A two-sided *P*-value of ≤.05 was considered statistically significant.

Results

A total of 348 patients with CAD were included in the study based on the inclusion and exclusion criteria. The mean age was 52.20 ± 9.28 years (range: 30–76), and the mean BMI was 27.6 ± 4.4 kg/m². Approximately 200 patients (57.4%) had DM. The severity of CAD was assessed using the Gensini score, with 190 participants (54.6%) classified as having mild stenosis, 73 participants (21%) as moderate stenosis, and 85 participants (24.4%) as severe stenosis. According to the SYNTAX score, 286 participants (82.2%) were classified as having mild stenosis, 41 participants (11.8%) as moderate stenosis, and 21 participants (6%) as severe stenosis.

The severity of CAD, as measured by the SYNTAX score, was significantly associated with male gender ($P = .001$), DM ($P = .037$), and smoking ($P = .002$). The Gensini score was significantly associated with older age ($P = .004$), male gender ($P = .001$), DM ($P = .037$), smoking ($p = 0.001$), and HLP ($P = .043$). (Table 1)

Figures 1 and 2 show the relationship between the number of risk factors and the severity of CAD, as assessed by the SYNTAX and Gensini scores (Figure 1–2).

We found that the highest occurrence of abnormal Q wave was observed in the inferior leads in participants with severe Gensini scores. The abnormal Q wave significantly differed across the various leads among the Gensini score groups ($P = .013$). The highest occurrence of ST depression (STD) was observed in the lateral leads in participants with severe Gensini score. The frequency of STD showed a significant difference across the various leads among the Gensini score groups ($P = .049$) (Table 2). However, no significant association was found between CAD severity based on the SYNTAX score and ECG findings ($P > .05$) (Table 3).

Discussion

Despite significant advancements in diagnostic and therapeutic modalities over the past decade, ACS persists as a significant cause of global mortality and morbidity. The implementation of a risk-based approach, where individuals at high risk are directed towards early invasive management, has shown improvements in prognosis. A variety of clinical, laboratory, ECG, and imaging parameters have been utilized, which are commonly considered indicative of both the severity of CAD and the patency of the culpable artery.[19] ECG is a unique diagnostic tool for identifying high-risk acute coronary syndrome (ACS) patients who may potentially benefit from early revascularization. In the context of

Table 1. Baseline characteristics of the patients according to the Gensini and SYNTAX score.

		Gensini score			
Characteristic	Total ($N = 348$)	Low ($N = 190$)	Moderate ($N = 73$)	High ($N = 85$)	*P*-value
Age, years	56 ± 9.29	54.6 ± 9.2	58.6 ± 8.6	57.6 ± 9.3	.004
BMI, kg/m^2	27.7 ± 4.5	28 ± 4.7	27.5 ± 4.4	27.3 ± 4.1	.42
Sex (male)	202 (58)	85 (44.7)	48 (65.8)	69 (81.2)	<.001
DM	152 (43.7)	66 (34.7)	40 (54.8)	46 (54.1)	<.001
HTN	200 (57.5)	105 (55.3)	46 (63)	49 (57.6)	.52
HLP	196 (56.3)	104 (54.7)	50 (68.5)	42 (49.4)	.043
Smoking	105 (30.2)	44 (23.2)	20 (27.4)	41 (48.2)	<.001
		SYNTAX score			
		Low ($N = 286$)	Moderate ($N = 41$)	High ($N = 21$)	
Age, years	52.20 ± 9.28	55.5 ± 9.2	58.8 ± 8.7	57 ± 10	.09
BMI, kg/m^2	27.6 ± 4.4	27.6 ± 4.5	27.4 ± 4.3	28.8 ± 3.5	<.001
Sex (male)	202 (58)	152 (53.1)	32 (78)	18 (85.7)	.42
DM	152 (43.7)	116 (40.6)	23 (56.1)	13 (61.9)	.03
HTN	200 (57.5)	163 (57)	25 (61)	12 (57.1)	.9
HLP	196 (56.3)	161 (56.3)	24 (58.5)	11 (52.4)	.89
Smoking	105 (30.2)	74 (25.9)	19 (46.3)	12 (57.1)	<.001

Data presented as mean ± standard deviation or number (%). Abbreviations: BMI, Body Mass Index; DM, diabetes mellitus; HTN, hypertension; HLP, hyperlipidemia.

non-ST-elevation myocardial infarction (NSTEMI), the diagnostic and prognostic evaluation of ECG parameters poses a considerable challenge.[19–21] We surveyed the relationship between SYNTAX and Gensini scores with ECG changes and the risk factors of CAD in patients undergoing coronary angiography. The main discovery of our study was that the severity of CAD, according to the Gensini score, had a significant relationship with older age, male gender, DM, smoking, no previous history of heart disease, HLP, HTN, and BMI, and according to SYNTAX, there was a significant relationship with male gender, DM, smoking. Larifla et al., consistent with our findings, demonstrated DM and male gender significantly increase the risk of multivessel CAD. However, other conventional risk factors such as HTN, HLP, smoking, age, and family history of vascular disease did not demonstrate a significant correlation with CAD severity. Notably, for high-risk lesions, both DM and HTN emerged as independent predictors.[22] Another study suggested that according to the Gensini score, age, sex, DM, HLP, HTN, family history of CAD, and STEMI have significant effects on the severity of CAD.[23] Salimi et al. revealed that 65% of the patients were male and HTN was the primary risk factor, followed by DM and HLP. They found a significant association between HTN and SYNTAX score.[8] Additionally, Vianna-Cedro et al. reported a male predominance of 68.1% within their study population, with HTN (83.3%), DM (36.2%), and HLP (52.2%) being the prevalent

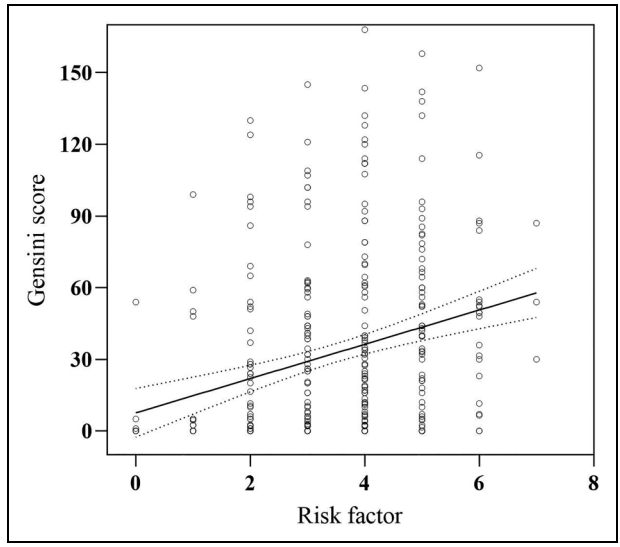

Figure 1. Linear graph between number of risk factor and Gensini score. The result of the equation obtained for risk factor is the Gensini score = 7.176* Risk factor + 7.585.

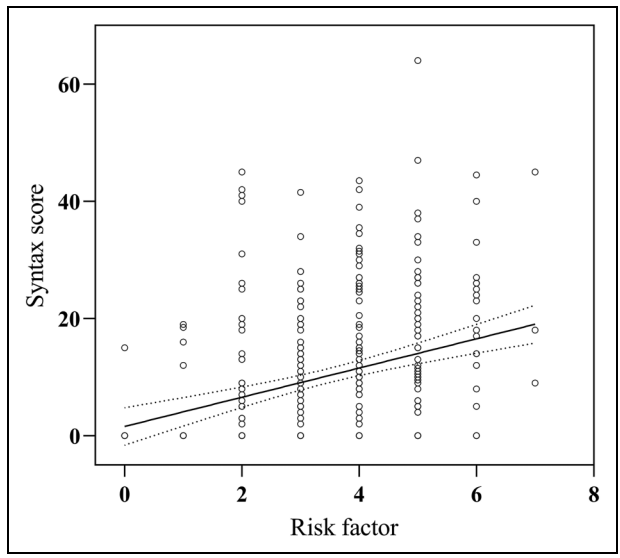

Figure 2. Linear graph between number of risk factor and SYNTAX score. The result of the equation obtained for risk factor is the SYNTAX score = 2.492* Risk factor + 1.580.

risk factors. Interestingly, they found no significant associations between patients' characteristics, except for age and SYNTAX.[24]

Table 2. Electrocardiographic findings according to Gensini score.

ECG parameters	Total ($N = 348$)	Gensini score			*P*-value
		Low ($N = 190$)	Moderate ($N = 73$)	High ($N = 85$)	
Axis					.15
Normal axis	298 (85.6)	170 (89.5)	60 (82.2)	68 (80)	
Right axis deviation	3 (0.9)	2 (1.1)	0	1 (1.2)	
Left axis deviation	47 (13.5)	18 (9.5)	13 (17.8)	16 (18.8)	
Rhythm					.2
Normal	311 (89.4)	164 (86.3)	65 (89)	82 (96.5)	
Tachycardia	18 (5.2)	11 (5.8)	5 (6.8)	2 (2.4)	
Bradycardia	16 (4.6)	12 (6.3)	3 (4.1)	1 (1.2)	
AF	3 (0.9)	3 (1)	0	0	
PVC	9 (2.5)	4 (2.1)	3 (4.1)	2 (2.4)	.64
Fragment QRS	19 (5.5)	11 (5.8)	5 (6.8)	3 (3.5)	.62
AVR Fragment QRS	3 (0.9)	3 (1.6)	0	0	.28
Bundle branch block					.16
LBBB	5 (1.4)	4 (2.1)	0	1 (1.2)	
RBBB	10 (2.8)	3 (1.6)	5 (6.9)	2 (2.3)	
Abnormal Q wave,					.013
Inferior leads	31 (8.9)	10 (5.2)	7(9.5)	14 (16.5)	
Anterior leads	17 (4.8)	6 (3.2)	5 (6.9)	6 (7)	
ST depression					.049
Anterior leads	33 (9.4)	20 (10.5)	9 (12.3)	4 (4.7)	
Inferior leads	23 (6.6)	14 (7.4)	4 (5.5)	5 (5.8)	
Lateral leads	24 (6.8)	6 (3.2)	7 (9.6)	11 (12.9)	
AVR ST Elevation	3 (0.8)	3 (1.6)	0	0	.42
Poor R progression	64 (18.3)	36 (18.9)	9 (12.3)	19 (22.3)	.26
T wave inverted					.11
Anterior leads	36 (10.3)	23 (12.1)	6 (8.2)	7 (8.2)	
Inferior leads	29 (8.3)	13 (6.8)	6 (8.2)	10 (11.8)	
Lateral leads	8 (2.3)	4 (2.1)	0	4 (4.7)	
Inferior + lateral leads	19 (5.5)	8 (4.2)	6 (8.2)	5 (5.9)	
Anterior + lateral leads	14 (4)	3(1.6)	5 (6.8)	6 (7.1)	
Heart rate, bpm	76 ± 14.15	76.76 ± 15.47	76.26 ± 12.69	74.09 ± 12.12	.34
QT shortest, ms	343.8 ± 34.2	345.2 ± 32.5	341 ± 31.5	344.3 ± 35.9	.71
QT longest, ms	378.1 ± 31.7	377.4 ± 34	374.1 ± 25.9	383 ± 30.5	.19
PR interval, ms	153.9 ± 25.3	152.3 ± 26.6	153.6 ± 23.2	157.5 ± 24.2	.28
T peak–T end interval, ms	73.3 ± 18.4	72.1 ± 19.1	74.3 ± 17.7	75.33 ± 17.4	.36
TAaVR, mV	-0.30 ± 1.3	-0.27 ± 1.4	-0.34 ± 1.4	-0.32 ± 1.1	.92

El Kresh et al. demonstrated that advanced age, DM, and cigarette smoking stand out as independent risk factors significantly contributing to the complexity of CAD.[25] The available data on the relationship between gender and SYNTAX appears to be somewhat conflicting.[8,26–28] In general, the results of these studies confirm the relationship between age, DM, and HLP with the severity of CAD. Notably, in our study, these risk factors exhibited a more pronounced correlation with the Gensini score. The difference in the

Table 3. Electrocardiographic findings according to SYNTAX score.

ECG parameters	Total ($N = 348$)	SYNTAX score			*P*-value
		Low ($N = 286$)	Moderate ($N = 41$)	High ($N = 21$)	
Axis					.13
Normal axis	298 (85.6)	249 (87.1)	32 (78)	17 (81)	
Right axis deviation	2 (0.5)	2 (0.7)	0	1 (4.8)	
Left axis deviation	47 (13.5)	35 (12.2)	9 (22)	3 (14.3)	
Rhythm					.78
Normal	311 (89.4)	253 (88.5)	37 (90.2)	21(100)	
Tachycardia	18 (5.2)	16 (5.6)	2 (4.9)	0	
Bradycardia	16 (4.6)	14 (4.9)	2 (4.9)	0	
AF	3 (0.9)	3 (1)	0	0	
PVC	9 (2.6)	7 (2.4)	0	2 (9.5)	.07
Fragment QRS	19 (5.5)	17 (5.9)	2 (4.9)	0	.5
AVR Fragment QRS	3 (0.9)	3 (1)	0	0	.72
Bundle branch block					.71
LBBB	5 (1.4)	5 (1.7)	0	0	
RBBB	10 (2.9)	7 (2.4)	2 (4.9)	1 (4.8)	
Abnormal Q wave					.44
Inferior leads	31 (8.9)	22 (7.7)	6 (14.6)	3 (14.3)	
Anterior leads	17 (4.9)	13 (4.5)	3 (7.3)	1 (4.8)	
ST depression					.73
Anterior leads	33 (9.5)	29 (10.1)	3 (7.3)	1 (4.8)	
Inferior leads	23 (6.6)	19 (6.6)	2 (4.9)	2 (9.5)	
Lateral leads	24 (6.9)	17 (5.9)	5 (12.2)	2 (9.5)	
AVR ST Elevation	3 (0.9)	3 (1)	0	0	.72
Poor R progression	64 (18.4)	51 (17.8)	9 (22)	4 (19)	.81
T wave inverted					.34
Anterior leads	29 (8.2)	22 (7.7)	4 (9.8)	3 (14.2)	
Inferior leads	8 (2.3)	6 (2.1)	1 (2.4)	1 (4.7)	
Lateral leads	19 (5.5)	13 (4.5)	5 (12.2)	1 (4.7)	
Inferior + lateral leads	36 (10.3)	32 (11.2)	3 (7.3)	1 (4.7)	
Anterior + lateral leads	14 (4)	10 (3.5)	3 (7.3)	1 (4.7)	
Heart rate, bpm	76 ± 14.15	76.18 ± 14.5	74.73 ± 12.1	76.14 ± 11.9	.83
QT shortest, ms	343.8 ± 34.2	343.1 ± 34.3	345.2 ± 32.2	350.4 ± 37.2	.61
QT longest, ms	378.1 ± 31.7	376.6 ± 32.2	382.6 ± 25.8	389.5 ± 33.3	.12
PR interval, ms	153.9 ± 25.3	154.6 ± 25.3	159.2 ± 22.7	153.9 ± 25.3	.58
T peak–T end interval, ms	73.3 ± 18.4	72.6 ± 18.5	78.4 ± 16.4	73.2 ± 19.2	.16
TAaVR, mV	-0.30 ± 1.3	-0.29 ± 1.4	-0.26 ± 1.3	-0.46 ± 1	.84

Data presented as mean ± standard deviation or number (%). Abbreviations: AF, atrial fibrillation; PVC, premature ventricular contractions; AVR Fragment QRS, atrial ventricular refractory fragmentation of QRS; LBBB, left bundle branch block; RBBB, right bundle branch block; AVR ST Elevation, atrial ventricular refractory S-T elevation; TAaVR, amplitude of the T wave in lead aVR.

results in these studies is due to the use of various statistical methods and different sample sizes. Also, in our study, there was no significant relationship between SYNTAX and ECG findings. However, according to Gensini score, there was a significant relationship

between the severity of CAD and Q wave and the presence of STD. Despite the demonstrated myocardial ischemia associated with prolonged conduction in experimental studies, our finding did not demonstrate any significant relationship. Bekler et al. and Rahma et al. showed that the higher frequency of (f-QRS) was correlated with the extent and severity of coronary lesions according to SYNTAX and Gensini scores.[29,30] However, in our study, there was no significant relationship between f-QRS, aVR, and the severity of CAD. In our study, we observed that patients with more severe CAD have longer QT; however, this association is not significant. Conversely, Helmy et al. reported a significant correlation between QTc dispersion and SYNTAX in non-diabetic STEMI patients, indicating the severity of CAD.[14] Additionally, Alshlbh et al. demonstrated a significant positive relationship between QRS size, QTc dispersion, and Gensini score (>20) in patients with NSTEMI.[31] The presence of Q waves classically signifies myocardial mass loss, with larger Q waves being linked to a worse prognosis compared to smaller Q waves. Godsk et al. demonstrated that the size of Q waves is associated with the degree of myocardial damage and loss of cardiac function, ultimately contributing to a poorer prognosis.[32] Cosgun et al. evaluated ECG ventricular repolarization parameters in stable CAD, and they observed that the length of QRS, HR, QTd, JT, Tp-e values, and Tp-e/JT and Tp-e/QT ratios showed no significant variation between high SYNTAX and low SYNTAX groups as well as normal group. These results are in line with our study.[33] Additionally, Celik et al. observed a higher prevalence of abnormal Q waves in the severe CAD group, although this difference did not achieve statistical significance.[19]

ST-segment changes, such as STD and STE in the aVR lead, are recognized as predictive indicators of high SYNTAX or the presence of three-vessel disease in patients with ACS.[34–36] In Celik et al.'s study, the presence of STE in aVR and STD were identified as being associated with severe CAD. However, no statistically significant association was observed between T-wave inversion and the severity of CAD.[19] Hatamnejad et al. evaluated the utility of SYNTAX predictability by ECG finding in patients with unstable angina. STE in right leads (aVR, III, V1) and STD in other leads were associated with high SYNTAX; meanwhile, diffuse STD without STE is a marker for moderate SYNTAX and can be applied for early risk stratification.[37] These findings are consistent with our study, which emphasizes the significance of STD in predicting CAD severity. Two separate studies by Mirvis et al. and Nikus et al. demonstrated that the presence of ST-T-wave abnormalities was associated with severe coronary stenosis, and a higher number of vessels with lesions.[38,39]

We had several limitations in our study. First, due to its retrospective design, prognostic information could not be incorporated into the investigation. Second, the single-center nature of the study may limit its external validity. Third, factors such as the use of medications, including antiarrhythmic drugs or treatments for electrolyte imbalances that may influence ST-segment and T-wave changes, were not accounted for in our analysis. Fourth, previous studies have demonstrated that traditional ECG has relatively low specificity and sensitivity for the early detection of CAD.[40,41] This limitation could reduce the accuracy of diagnosing CAD, particularly in the early stages. Therefore, relying solely on ECG may not suffice for identifying mild or ambiguous cases of CAD. Finally, due to the failure to meet the necessary assumptions of multivariable logistic regression analysis, we were unable to perform this method. We acknowledge these

limitations and recommend that future studies address these concerns with larger sample sizes, multicenter designs, and rigorous data preprocessing to enhance the reliability and generalizability of the findings.

Conclusion

Our findings indicate a correlation between the severity of CAD and male gender, DM, and smoking. This association was observed based on both criteria, as well as considering the presence of Q waves and STD in the ECG. Identifying patients with severe CAD using noninvasive tools is particularly valuable, especially in centers without advanced facilities. Both electrocardiography (ECG) and clinical risk factors serve as valuable tools for this purpose. The integration of various parameters into a single score is crucial in clinical practice, offering a stronger diagnostic and prognostic tool without increasing in costs. To accomplish this objective, further comprehensive studies are required.

Acknowledgment

We would like to express our sincere gratitude to all medical staff and researchers of Afshar Hospital in Yazd who contributed to this study.

Authors' contributions

The original manuscript writing was carried out by Farzaneh-Sadat Mirjalili, Seyed Mostafa Seyedhosseini, Hamidreza Mohammadi, and Mohammadtaghi Sarebahassanabadi, with Hamidreza Mohammadi also responsible for the statistical analysis. Seyed Mostafa Seyedhosseini, Amin Salehi-Abargouei, and Maryam Motallaei were assigned to validate the statistical analysis results. Tahere Baghiani, Abbas Andishmand, and Faezeh Badkoubeh played crucial roles in the study design and manuscript revision. All authors participated in the final manuscript review and approval.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

This study was conducted after the approval of the local ethics committee of Shahid Sadoughi University of medical sciences (IR.SSU.MEDICINE.REC.1401.067) and conducted based on the Declaration of Helsinki on medical research. Written informed consent was obtained from all eligible participants.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Hamidreza Mohammadi https://orcid.org/0000-0002-7104-5295

References

1. Karadeniz FÖ and Altuntaş E. Correlation between frontal QRS-T angle, Tp-e interval, and Tp-e/QT ratio to coronary artery severity assessed with SYNTAX score in stable coronary artery disease patients. *J Arrhythm* 2022; 38: 783–789.
2. Khan MA, Hashim MJ, Mustafa H, et al. Global epidemiology of ischemic heart disease: results from the global burden of disease study. *Cureus* 2020; 12: e9349.
3. Tse G and Yan BP. Traditional and novel electrocardiographic conduction and repolarization markers of sudden cardiac death. *Europace* 2017; 19: 712–721.
4. Andishmand A, Emami Meybodi M, Namayandeh SM, et al. Comparison between myocardial infarction with non obstructive coronaries (MINOCA) and myocardial infarct patients with coronary artery disease (MI-CAD): a single-center retrospective cohort study. *Original Article. Caspian Journal of Internal Medicine* 2024; 15: 109–114.
5. Boyraz B and Peker T. Comparison of SYNTAX and gensini scores in the decision of surgery or percutaneous revascularization in patients with multivessel coronary artery disease. *Cureus* 2022; 14: e22482.
6. Ikeda N, Kogame N, Iijima R, et al. Carotid artery intima-media thickness and plaque score can predict the SYNTAX score. *Eur Heart J* 2012; 33: 113–119.
7. Karadeniz M, Duran M, Akyel A, et al. High sensitive CRP level is associated with intermediate and high syntax score in patients with acute coronary syndrome. *Int Heart J* 2015; 56: 377–380.
8. Salimi A, Zolghadrasli A, Jahangiri S, et al. The potential of HEART score to detect the severity of coronary artery disease according to SYNTAX score. *Sci Rep* 2023; 13: 7228.
9. Leasure M, Jain U, Butchy A, et al. Deep learning algorithm predicts angiographic coronary artery disease in stable patients using only a standard 12-lead electrocardiogram. *Can J Cardiol* 2021; 37: 1715–1724.
10. Alizadehsani R, Zangooei MH, Hosseini MJ, et al. Coronary artery disease detection using computational intelligence methods. *Knowl Based Syst* 2016; 109: 187–197.
11. Chatterjee NA, Tikkanen JT, Panicker GK, et al. Simple electrocardiographic measures improve sudden arrhythmic death prediction in coronary disease. *Eur Heart J* 2020; 41: 1988–1999.
12. Mahmoodzadeh S, Moazenzadeh M, Rashidinejad H, et al. Diagnostic performance of electrocardiography in the assessment of significant coronary artery disease and its anatomical size in comparison with coronary angiography. *J Res Med Sci. Jun* 2011; 16: 750–755.
13. Motallaei M, Darand M, Taftian M, et al. A cross-sectional study on the association between lifestyle factors and coronary artery stenosis severity among adults living in central Iran: A protocol for the Iranian- CARDIO study. *ARYA Ather J* 2023; 20: 51–61.
14. Helmy H, Abdel-Galeel A, Kishk YT, et al. Correlation of corrected QT dispersion with the severity of coronary artery disease detected by SYNTAX score in non-diabetic patients with STEMI. *The Egyptian Heart Journal* 2017; 69: 111–117.
15. Erik von Elm M, Altman DG, Egger M, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann Intern Med* 2007; 147: 573.
16. Sadeghi S, Jokar M, Tezerjani SMSH, et al. Electrocardiography changes and different stages of heart failure in central Iran: a cross-sectional study from Yazd health study. *Health Sci Rep* 2024; 7: e2011.

17. Head SJ, Davierwala PM, Serruys PW, et al. Coronary artery bypass grafting vs. Percutaneous coronary intervention for patients with three-vessel disease: final five-year follow-up of the SYNTAX trial. *Eur Heart J* 2014; 35: 2821–2830.
18. Avci A, Fidan S, Tabakçı MM, et al. Association between the gensini score and carotid artery stenosis. *Korean Circ J* 2016; 46: 639–645.
19. Celik AI, Bezgin T, Cagdas M, et al. A novel electrocardiographic score predicts the severity of coronary artery disease and clinical outcomes in patients with non-ST segment elevation myocardial infarction. *Acta Cardiol Sin* May 2022; 38: 326–333.
20. Elfahham AF, El Etriby SA, Abdelsalam AM, et al. The added value of ST-elevation in lead aVR to clinical TIMI score in predicting the angiographic severity of coronary artery disease in patients with non ST-elevation myocardial infarction. *QJM: An International Journal of Medicine* 2021; 114: hcab090. 001.
21. Hiltner E, Al Akshar A, Thanawala P, et al. Is isolated ST segment elevation in lead aVR associated with high grade coronary artery disease? *J Electrocardiol* 2020; 62: 170–177.
22. Larifla L, Armand C, Velayoudom-Cephise F-L, et al. Distribution of coronary artery disease severity and risk factors in afro-caribbeans. *Arch Cardiovasc Dis* 2014; 107: 212–218.
23. Omidi N, Sadeghian S, Salarifar M, et al. Relationship between the severity of coronary artery disease and cardiovascular risk factors in acute coronary syndrome: based on Tehran heart center's data registry. *J Tehran Heart Cent* 2021; 15: 165–170.
24. Cedro AV, Mota DM, Ohe LN, et al. Association between clinical risk score (heart, grace and TIMI) and angiographic complexity in acute coronary syndrome without ST segment elevation. *Arq Bras Cardiol* 2021; 117: 281–287.
25. El Kersh AM, Reda AA, Hadad E, et al. Correlation between SYNTAX score and pattern of risk factors in patients referred for coronary angiography in cardiology department, menoufia university. *World J Cardiovasc Dis* 2018; 8: 431–439.
26. Brzozowski P, Bulak L, Rakotoarison O, et al. Utility of the SYNTAX score in the risk stratification of patients undergoing rotational atherectomy. *Archives of Medical Science-Atherosclerotic Diseases* 2020; 5: 313–319.
27. Huang Z, Wang K, Yang D, et al. The predictive value of the HEART and GRACE scores for major adverse cardiac events in patients with acute chest pain. *Intern Emerg Med* 2021; 16: 193–200.
28. Hammami R, Jdidi J, Mroua F, et al. Accuracy of the TIMI and GRACE scores in predicting coronary disease in patients with non-ST-elevation acute coronary syndrome. *Rev Port Cardiol* 2018; 37: 41–49.
29. Bekler A, Barutçu A, Tenekecioglu E, et al. The relationship between fragmented QRS complexes and SYNTAX and gensini scores in patients with acute coronary syndrome. *Kardiologia Polska (Polish Heart Journal)* 2015; 73: 246–254.
30. Rahman HA, Ghany MA and Youssef AAA. Correlation of fragmented QRS complexes with the severity of CAD (using syntax score) in patients with non-ST elevation acute coronary syndromes. *The Egyptian Heart J* 2016; 68: 125–129.
31. Alshlbh RA, Mohamed AF, Alcekelly MM, et al. Correlation between QRS dispersion and severity of coronary artery disease detected by GENSINI score in patients with non ST elevation myocardial infraction. *Zagazig Univ Med J* 2020; 26: 814–822.
32. Godsk P, Jensen JS, Abildstrøm SZ, et al. Prognostic significance of electrocardiographic Q-waves in a low-risk population. *Europace* 2012; 14: 1012–1017.
33. Cosgun M, Erdal E, Gunes Y, et al. Evaluation of electrocardiographic ventricular repolarization parameters in stable coronary artery disease. *Exp Biom Res* 2021; 4: 141–147.
34. Rencüzoğulları İ, Çağdaş M, Karakoyun S, et al. The association between electrocardiographic R wave peak time and coronary artery disease severity in patients with non-ST

segment elevation myocardial infarction and unstable angina pectoris. *J Electrocardiol* 2018; 51: 230–235.
35. Kosuge M, Ebina T, Hibi K, et al. Early, accurate, non-invasive predictors of left main or 3-vessel disease in patients with non-ST-segment elevation acute coronary syndrome. *Circ J* 2009; 73: 1105–1110.
36. Misumida N, Kobayashi A, Fox JT, et al. Predictive value of ST-segment elevation in lead aVR for left main and/or three-vessel disease in non–ST-segment elevation myocardial infarction. *Ann Noninvasive Electrocardiol* 2016; 21: 91–97.
37. Hatamnejad MR, Heydari AA, Salimi M, et al. The utility of SYNTAX score predictability by electrocardiogram parameters in patients with unstable angina. *BMC Cardiovasc Disord* 2022; 22: 1–11.
38. Mirvis DM, El-Zeky F, Vander Zwaag R, et al. Clinical and pathophysiologic correlates of ST-T-wave abnormalities in coronary artery disease. *Am J Cardiol* 1990; 66: 699–704.
39. Nikus KC, Eskola MJ and Sclarovsky S. Electrocardiographic presentations of left main or severe triple vessel disease in acute coronary syndromes—an overview. *J Electrocardiol* 2006; 39: S68–S72.
40. Anthony D. Diagnosis and screening of coronary artery disease. *Primary Care: Clinics in Office Practice* 2005; 32: 931–946.
41. Fakhri Y, Andersson H, Gregg RE, et al. Diagnostic performance of a new ECG algorithm for reducing false positive cases in patients suspected acute coronary syndrome. *J Electrocardiol* 2021; 69: 60–64.