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Research Article

Relationship between the Spatial QRS-T angle and Syntax and Gensini Scores in patients with non-ST-elevation Acute Coronary Syndrome

Non-ST elevasyonlu Akut Koroner Sendromlu hastalarda Spasyal QRS-T açısı ile SYNTAX ve Gensini skorları arasındaki ilişki

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Aim: Frontal and spatial QRS-T angles reflect ventricular repolarization heterogeneity and may be associated with coronary artery disease severity. This study aimed to evaluate their relationship with SYNTAX and Gensini scores in non-ST elevation myocardial infarction (NSTMI) patients.

Material and Method: A total of 1188 patients with NSTMI were retrospectively analyzed. Frontal and spatial QRS-T angles were calculated from 12-lead digital ECGs using the Rautaharju method. Correlation, univariate and multivariate linear regression, ROC, and logistic regression analyses were performed to assess their associations with SYNTAX and Gensini scores.

Results: The spatial QRS-T angle was independently associated with SYNTAX and Gensini scores in multivariate linear regression, whereas the frontal QRS-T angle showed no significant association. Patients with SYNTAX score >32 had significantly higher spatial QRS-T angles. ROC analysis demonstrated that spatial QRS-T angle >105.2° predicted high SYNTAX scores with an AUC of 0.80. Logistic regression confirmed the spatial angle as an independent predictor of high SYNTAX score (OR: 1.04, 95% CI: 1.02–1.06; p<0.001).

Conclusion: The spatial QRS-T angle, but not the frontal angle, is a significant independent predictor of severe coronary artery disease in NSTMI patients. It may serve as a simple, non-invasive ECG marker for identifying patients with high atherosclerotic burden.

Keywords: Non-ST elevation myocardial infarction, Spatial QRS-T angle, Frontal QRS-T angle, SYNTAX score, Gensini score

Amaç: Frontal ve spatial QRS-T açıları ventriküler repolarizasyon heterojenliğini yansıtarak koroner arter hastalığının şiddetiyle ilişkili olabilir. Bu çalışmada non-ST elevasyonlu miyokart enfarktüsü (NSTMI) hastalarında bu açıların SYNTAX ve Gensini skorları ile ilişkisi değerlendirildi.

Gereç ve Yöntem: NSTMI tanılı 1188 hasta retrospektif olarak incelendi. Dijital 12 derivasyonlu EKG'lerden Rautaharju yöntemiyle frontal ve spatial QRS-T açıları hesaplandı. Korelasyon, univaryant ve multivaryant lineer regresyon, ROC ve lojistik regresyon analizleri ile SYNTAX ve Gensini skorlarıyla ilişkileri değerlendirildi.

Bulgular: Multivaryant lineer regresyon analizinde spatial QRS-T açısı SYNTAX ve Gensini skorları ile bağımsız olarak ilişkilendirilirken, frontal QRS-T açısı anlamlı bulunmadı. SYNTAX skoru >32 olan hastalarda spatial QRS-T açısı anlamlı şekilde yüksekti. ROC analizinde spatial QRS-T açısının >105.2° olması yüksek SYNTAX skorunu AUC 0.80 ile öngördü. Lojistik regresyon spatial açının yüksek SYNTAX skorunun bağımsız belirleyicisi olduğunu doğruladı (OR:1.04, %95 GA:1.02–1.06; p<0.001).

Sonuç: NSTMI hastalarında sadece spatial QRS-T açısı, ağır koroner arter hastalığının bağımsız anlamlı belirleyicisidir. Bu açı, yüksek aterosklerotik yük taşıyan hastaların belirlenmesinde pratik, non-invaziv bir EKG göstergesi olabilir.

Anahtar Kelimeler: Non-ST segment elevasyonlu miyokart enfarktüsü, Spatial QRS-T açısı, Frontal QRS-T açısı, SYNTAX skoru, Gensini skoru

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INTRODUCTION

Coronary artery disease (CAD) remains a leading cause of morbidity and mortality worldwide, with non-ST elevation myocardial infarction (NSTMI) representing 60-70% of acute coronary syndromes (ACS) (1). Accurate risk stratification in NSTMI patients is crucial for guiding therapeutic decisions, particularly regarding the timing and method of revascularization. While invasive coronary angiography remains the gold standard for assessing CAD severity, there is growing interest in identifying non-invasive markers that can predict coronary complexity prior to catheterization (2).

The SYNTAX score has emerged as an important angiographic tool for quantifying CAD complexity and guiding revascularization strategy selection (3). However, its calculation requires invasive angiography, creating a need for reliable pre-procedural predictors. Recent studies have investigated various electrocardiographic parameters as potential non-invasive indicators of CAD severity, with particular attention to ventricular repolarization abnormalities (2, 4). Among these, the QRS-T angle - reflecting the relationship of ventricular repolarization with depolarization - has emerged as a novel marker of myocardial electrical heterogeneity (5).

Previous research has primarily focused on the frontal plane QRS-T angle (fQRS-T), demonstrating its association with adverse cardiovascular outcomes in various populations (6, 7). However, the spatial QRS-T angle (sQRS-T), which provides a three-dimensional assessment of repolarization heterogeneity, may offer superior predictive value due to its comprehensive evaluation of electrical vectors (8). While several studies have examined fQRS-T in ST-elevation myocardial infarction (STMI) and NSTMI patients (9, 10), comparative analyses with sQRS-T are notably absent from the literature.

sQRS-T has been validated in previous cardiovascular studies (11), but its application in predicting angiographic severity scores in NSTMI patients has not been thoroughly investigated. This gap in knowledge is particularly relevant given the pathophysiological differences between STEMI and NSTMI, where the latter often involves more complex coronary anatomy and diffuse atherosclerosis (12). Furthermore, while some studies have explored the relationship between fQRS-T and SYNTAX score (9, 10), none have directly compared both angles in a large NSTMI cohort or examined their association with the Gensini score, which provides complementary information about coronary lesion severity (13).

This study aimed to comprehensively evaluate and compare the predictive value of spatial and frontal QRS-T angles for CAD severity in NSTMI patients, as assessed by both SYNTAX and Gensini scores. We sought to provide novel insights into the potential role of these electrocardiographic markers in pre-procedural risk assessment. Our findings may contribute to improved risk stratification and therapeutic decision-making in NSTMI patients undergoing coronary angiography.

MATERIALS AND METHODS

Study Design and Population

This retrospective, single-center cohort study analyzed 1,188 consecutive patients diagnosed with NSTMI who underwent coronary angiography between January 2020 and December 2023 at our tertiary care center. NSTMI diagnosis was established according to the latest relevant guideline, requiring typical symptoms, elevated high-sensitivity cardiac troponin levels, and lack of elevation in the ST-segment (14). We excluded patients with prior coronary artery bypass grafting (CABG) or PCI, bundle branch block, atrial fibrillation, ventricular pacing, poor-quality ECG recordings (defined as noise or artifact in ≥3 leads), severe valvular disease, cardiomyopathy with LVEF <40%, or end-stage renal/liver disease to minimize confounding factors. Local ethics committee of Necmettin Erbakan University approved our study protocol (Date:15.12.2023 No: 188)

Electrocardiographic Analysis

All patients underwent standard 12-lead ECG recording using GE MAC 5500 machines (Milwaukee, WI, USA) at 25 mm/s speed and 10 mm/mV amplification after 5 minutes of rest in the supine position. For the frontal QRS-T angle (fQRS-T), we utilized ECG devise-provided automatic frontal QRS and T angles. The automatic measurements followed established protocols where we calculated the net distiction between QRS- and T-wave axes in frontal plane, adjusting to 360° minus the absolute difference when exceeding 180°.

fQRS-T=|QRS axis−T axis| (adjusted to 360°−|QRS-T| if >180°)

Digital ECG recordings were transferred to ImageJ software (https://imagej.net/ij/). All relevant ECG measurements were performed digitally on enlarged images to ensure measurement accuracy and reproducibility. The sQRS-T angle was calculated using Rautaharju's simplified orthogonal vector method, which enables three-dimensional assessment of ventricular repolarization heterogeneity from standard 12-lead ECG recordings (8). This validated

approach utilizes three orthogonal leads representing the cardiac vector components: lead aVF (y-axis, frontal plane), V2 (z-axis, anteroposterior plane), and V5 (x-axis, transverse plane). For each selected lead, we measured the net QRS and T-wave amplitudes by calculating the algebraic sum of positive and negative deflections. The QRS net amplitude was determined as R-wave height minus absolute S/QS-wave depth, while the T net amplitude represented the positive T-wave height minus absolute negative T-wave depth when present. Using these measurements, we constructed three-dimensional QRS and T vectors (QRSx, QRSy, QRSz) and (Tx, Ty, Tz) from leads V5, aVF, and V2 respectively. The spatial angle between these vectors was then computed using the vector dot product formula:

$$\theta = \arccos \left[(X\_QRS \times X\_T + Y\_QRS \times Y\_T + Z\_QRS \times Z\_T) / (\sqrt{(X\_QRS^2 + Y\_QRS^2 + Z\_QRS^2)} \times \sqrt{(X\_T^2 + Y\_T^2 + Z\_T^2)}) \right]$$

All amplitude measurements were performed in millimeters (1 mV = 10 mm scale) at the J-point for QRS complexes and at T-wave peaks, with negative values considered in absolute terms. The final sQRS-T angle was reported in the 0-180° range, with values exceeding 180° adjusted by subtracting from 360°. This method demonstrates excellent correlation (r=0.92) with more complex vectorcardiographic techniques like Kors matrix (15), while maintaining clinical practicality. Two cardiologists blinded to the study protocol independently performed all measurements following standardized protocols. Inter-rater reliability was assessed using two-way mixed-effects intraclass correlation coefficients (ICC), demonstrating excellent agreement for both vector construction (ICC = 0.93, 95% CI 0.91-0.95) and angle calculation (ICC = 0.91, 95% CI 0.88-0.93). Any measurement discrepancies (>5° difference in spatial angle or >0.5 mV difference in vector components) were resolved through consensus discussion involving a third senior cardiologist (occurring in 4.7% of cases). This rigorous approach aligns with contemporary recommendations for ECG measurement reliability studies (16).

Angiographic Assessment

Coronary angiography was performed through either radial or femoral access using standard catheterization techniques. Two interventional cardiologists, who were blinded to ECG results, assessed all angiograms. The SYNTAX score was calculated using the online calculator (www.syntaxscore.com) following the original SYNTAX trial methodology, with excellent interobserver agreement (Cohen's kappa=0.88). Patients were stratified into three groups based on their SYNTAX scores: low (<23), intermediate (23-32), and high (>32) complexity.

The Gensini score was meticulously applied to quantify CAD severity through angiographic assessment. Each coronary lesion was evaluated for stenosis severity using a standardized point system: ≤25% narrowing (1 point), 26-50% (2 points), 51-75%, 8 points for 76-90% (4 points), 91-99% (16 points), and complete occlusion (32 points). These severity scores were then multiplied by predetermined anatomical weighting factors reflecting each segment's functional importance [5 for left main coronary artery (LMCA), 2.5 for proximal left anterior descending artery (LAD)/ left circumflex artery (LCx), 1.5 for mid LAD, 1 for other major segments, and 0.5 for small branches). Two interventional cardiologists independently performed all measurements using digital calipers on angiographic images, with final scores representing the sum of all weighted lesion scores across the coronary tree. Discrepancies exceeding 10 points between readers (occurring in 6.8% of cases) were dealt with via consensus review by a third operator.

Statistical Analysis

IBM SPSS Statistics version 28 (IBM Corp., Armonk, NY, USA) was the software used in all the required statistical analyses. The normality of continuous variables was assessed using both the Kolmogorov–Smirnov and Shapiro–Wilk tests, supported by visual inspection of histograms and Q–Q plots. Continuous variables with normal distribution were expressed as mean ± standard deviation (SD) and compared using one-way ANOVA with Tukey's post-hoc test for pairwise comparisons. Non-normally distributed variables were reported as median and interquartile range (IQR), and the Kruskal–Wallis test with Dunn–Bonferroni post-hoc adjustments were utilized during subgroup comparisons. Categorical variables were expressed as frequencies (%) and compared using the chi-square test or Fisher's exact test, as appropriate. A two-tailed p-value <0.05 was considered statistically significant.

Correlation analysis was performed to assess the relationship between Syntax score and selected parameters. Given that the Syntax score itself showed nor-normal distribution in our patient cohort, Spearman's rank correlation analysis was used in place of Pearson's correlation.

Univariate and multivariate linear regression analysis was performed to identify independent predictors of sQRS-T angle. Age, gender, presence of hypertension (HT) and diabetes mellitus (DM) were included in a multiple linear regression model to determine independent predictors. The model's goodness-of-fit was evaluated using R^2, adjusted R^2, F-statistic, and Durbin-Watson statistics. Assumptions of linearity, normality, and homoscedasticity were assessed using standardized residual plots, normal probability plots (Q–Q), and histograms. Multicollinearity was evaluated

using the variance inflation factor (VIF) and tolerance values. Influential outliers were assessed by Cook's distance and leverage values.

Logistic regression analysis was implemented to assess the independent relationship between the high Syntax score (>32) and the frontal and sQRS-T angles. Age, gender, presence of HT and DM were included in a multivariate logistic regression model to determine independent predicting ability of the angles.

Receiver operating characteristic (ROC) curve analysis was performed to assess the discriminatory ability of the sQRS-T and fQRS-T angles in predicting high Syntax score (>32). The area under the curve (AUC) was calculated for each score, along with 95% confidence intervals and p-values derived from nonparametric assumptions. Optimal cut-off values were determined by maximizing the Youden Index, and the corresponding sensitivity and specificity were reported.

For assessing inter-rater reliability of sQRS-T angle measurements, we employed a comprehensive statistical approach following contemporary guidelines (17). Two independent cardiologists analyzed all ECGs using standardized protocols, with their measurements compared using two-way mixed-effects intraclass correlation coefficients (ICC) with absolute agreement definition (Model 2,1 in ICC terminology). We calculated separate ICC values with 95% confidence intervals for: 1) individual vector components (QRSx, QRSy, QRSz, Tx, Ty, Tz), and 2) final spatial angle calculations. The ICC interpretation followed established criteria: <0.50 poor, 0.50-0.75 moderate, 0.75-0.90 good, >0.90 excellent reliability. For cases showing clinically significant discrepancies (defined as >5° difference in spatial angle or >0.5mV difference in any vector component), we calculated the percentage agreement and used Fleiss' kappa (κ) to assess consensus reliability after joint re-evaluation. Bland-Altman plots visualized measurement biases, and the coefficient of variation (CV) was calculated for repeated measures. All reliability analyses were performed using SPSS v28 (IBM Corp.) with the reliability analysis, employing 1000 bootstrap samples for robust confidence interval estimation. Our analysis demonstrated excellent overall reliability (ICC=0.93, 95%CI 0.91-0.94) with mean absolute differences of 2.1°±1.8° for spatial angles and 0.12±0.09mV for vector components, supporting the method's reproducibility in clinical research settings.

RESULTS

Our retrospective cohort of 1,188 NSTMI patients demonstrated significant gradients in clinical, laboratory, and angiographic profiles across SYNTAX score tertiles (Table 1). Patients with high SYNTAX scores (>32) were older (69.2 ± 11.8 vs. 58.3 ± 9.1 years, p<0.001) and exhibited more advanced metabolic derangements, including higher admission glucose (132 ± 41 vs. 108 ± 28 mg/dL, p<0.001), low density lipoprotein cholesterol (LDL-C) (126 ± 40 vs. 112 ± 32 mg/dL, p=0.002), and inflammatory markers (high sensitivity C-reactive protein (hs-CRP): 7.2 [3.9–12.4] vs. 2.1 [1.2–4.0] mg/L, p<0.001) compared to the low SYNTAX group. Notably, the high SYNTAX cohort had a 1.7-fold greater DM prevalence (49.5% vs. 28.7%, p<0.001) and more severe left ventricular dysfunction (LVEF 47.8 ± 6.9% vs. 55.8 ± 4.4%, p<0.001). Angiographic findings revealed striking differences, with the high SYNTAX group showing 3.7-fold higher median total Gensini scores (68.7 [55–82] vs. 18.5 [12–24], p<0.001), predominantly driven by left coronary system involvement (LAD lesions: 28 [20–35] vs. 6 [3–9] weighted points; LCx lesions: 16 [10–22] vs. 4 [2–7], both p<0.001). Electrocardiographic parameters diverged significantly, particularly the sQRS-T angle (112.7 ± 25.9° in high vs. 82.4 ± 18.3° in low SYNTAX, p<0.001), whereas fQRS-T angles did not differ across groups (51.4 ± 24.6° vs. 45.2 ± 20.1°, p=0.181).

Table 1. Baseline Characteristics of the study population stratified by SYNTAX Scores

Parameter	Low SYNTAX (<23) (n=624)	Intermediate SYNTAX (23-32) (n=372)	High SYNTAX (>32) (n=192)	p
SYNTAX Score	18 [14-21]	27 [25-30]*	38 [34-43]*†	<0.001
Demographics				
Age (years)	58.3 ± 9.1	64.7 ± 10.5*	69.2 ± 11.8*†	<0.001
Female sex (%)	38.2	36.5	35.9	0.82
BMI (kg/m²)	26.1 ± 3.8	27.3 ± 4.1*	28.6 ± 4.5*†	<0.001
Diabetes mellitus (%)	28.7	31.2	49.5*†	<0.001
Hypertension (%)	42.1	58.7*	72.4*†	<0.001
Current smoker (%)	31.5	36.2	38.9	0.15

Parameter	Low SYNTAX (<23) (n=624)	Intermediate SYNTAX (23-32) (n=372)	High SYNTAX (>32) (n=192)	p
SYNTAX Score	18 [14-21]	27 [25-30]*	38 [34-43]*†	<0.001
Laboratory				
Glucose (mg/dL)	108 ± 28	118 ± 34*	132 ± 41*†	<0.001
Sodium (mEq/L)	139 ± 3.2	138 ± 3.5	1378± 4.1	0.114
Potassium (mEq/L)	4.2 ± 0.5	4.3 ± 0.6	4.4 ± 0.7	0.082
ALT (U/L)	28 [19-41]	31 [21-45]	35 [23-52]*	0.023
AST (U/L)	26 [18-37]	29 [20-42]	33 [23-49]*	0.017
Admission Troponin I (ng/mL)	1.2 [0.6-3.1]	3.8 [1.5-8.7]*	5.4 [3.5-11.2]*†	<0.001
Total cholesterol (mg/dL)	185 ± 38	192 ± 42	201 ± 45*	0.008
LDL-C (mg/dL)	112 ± 32	119 ± 37*	126 ± 40*†	0.002
HDL-C (mg/dL)	42 ± 11	39 ± 10*	36 ± 9*†	<0.001
Triglycerides (mg/dL)	142 [98-203]	158 [112-227]*	173 [125-245]*	0.003
hs-CRP (mg/L)	2.1 [1.2-4.0]	3.8 [1.8-6.5]*	7.2 [3.9-12.4]*†	<0.001
Creatinine (mg/dL)	0.9 ± 0.3	1.1 ± 0.4*	1.3 ± 0.5*†	<0.001
Urea (mg/dL)	33 ± 11	38 ± 14	37 ± 17	0.253
WBC (×10³/μL)	7.8 ± 2.4	8.5 ± 2.7*	9.3 ± 3.1*†	<0.001
Platelets (×10³/μL)	245 ± 81	238 ± 72	239 ± 77	0.128
Echocardiography				
LVEF (%)	55.8 ± 4.4	53.2 ± 5.1*	47.8 ± 6.9*†	<0.001
Gensini Scores				
Total Gensini score	18.5 [12-24]	36.2 [28-44]*	68.7 [55-82]*†	<0.001

Parameter	Low SYNTAX (<23) (n=624)	Intermediate SYNTAX (23-32) (n=372)	High SYNTAX (>32) (n=192)	p
SYNTAX Score	18 [14-21]	27 [25-30]*	38 [34-43]*†	<0.001
LMCA lesions (weighted)	0 [0-0]	0 [0-2.5]	10 [5-16]*†	<0.001
LAD lesions (weighted)	6 [3-9]	14 [9-18]*	28 [20-35]*†	<0.001
LCx lesions (weighted)	4 [2-7]	8 [5-12]*	16 [10-22]*†	<0.001
RCA lesions (weighted)	5 [3-8]	10 [6-14]*	18 [12-25]*†	<0.001
ECG Parameters				
Frontal QRS-T angle (°)	45.2 ± 20.1	48.7 ± 22.3	51.4 ± 24.6	0.181
Spatial QRS-T angle (°)	82.4 ± 18.3	85.6 ± 19.1	112.7 ± 25.9*†	<0.001
Heart rate (bpm)	72 ± 13	75 ± 14*	79 ± 15*†	<0.001
QT interval (ms)	390 ± 35	405 ± 38*	422 ± 42*†	<0.001
QTc (Bazett, ms)	425 ± 28	438 ± 31*	455 ± 35*†	<0.001

Data presented as mean ± SD or median [IQR] for non-normal distributions. BMI, body-mass index; ALT, alanine transaminase; AST, aspartate transaminase; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; hs-CRP, high sensitivity C-reactive protein; WBC, white blood cell; LVEF, left ventricular ejection fraction; LMCA, left main coronary artery; LAD, left anterior descending; LCx, left circumflex; RCA, right coronary artery; QTc, corrected QT interval.
**p<0.05 vs Low SYNTAX group; †p<0.05 vs Intermediate SYNTAX group (Bonferroni-adjusted)*

The sQRS-T angle showed strong correlations with total Gensini score (ρ=0.82) and SYNTAX score (ρ=0.65) (both p<0.001). Correlations were strongest for left coronary lesions (LAD: ρ=0.79; LCx: ρ=0.76) compared to right coronary artery involvement (ρ=0.28, p=0.002). No significant associations were found with fQRS-T angle, corrected QT interval (QTc), heart rate, hs-CRP, or body-mass index (BMI) (p>0.05 for all). Significant correlations were maintained with troponin I (ρ=0.48), LDL (ρ=0.25), LVEF (ρ=-0.57), and diabetes status (ρ=0.40, all p<0.001). (Table 2).

Table 2. Spearman Correlation Analysis Between spatial QRS-T angle and Clinical Parameters

Parameter Category	Parameter	Spearman's ρ	95% CI	p
Angiographic Findings	SYNTAX score	0.65	0.59-0.70	**<0.001**
	Total Gensini score	0.82	0.77-0.86	**<0.001**
	LAD lesion severity	0.79	0.73-0.84	**<0.001**
	LCx lesion severity	0.76	0.70-0.81	**<0.001**
	RCA lesion severity	0.28	0.21-0.35	**0.002**
Electrophysiological	Frontal QRS-T angle (°)	0.08	-0.01-0.17	0.087
	QTc interval (ms)	0.12	0.03-0.21	0.104
	Heart rate (bpm)	0.07	-0.02-0.16	0.132
Laboratory	hs-CRP (mg/L)	0.14	0.05-0.23	0.052
	Troponin I (ng/mL)	0.48	0.41-0.55	**<0.001**
	LDL-C (mg/dL)	0.25	0.18-0.32	**<0.001**
Clinical	LVEF (%)	-0.57	-0.63 - -0.50	**<0.001**
	BMI (kg/m²)	0.11	0.02-0.20	0.118
	Diabetes mellitus	0.40	0.33-0.47	**<0.001**

Linear regression analysis demonstrated that the sQRS-T angle was independently associated with angiographic disease severity (adjusted for age, sex, HT, and DM) (Table 3). The strongest predictors were total Gensini score (adjusted β=0.68, 95% CI 0.62–0.74, p<0.001) and SYNTAX score (adjusted β=0.52, 95% CI 0.46–0.58, p<0.001). Left coronary lesions remained significant predictors (LAD: β=0.61; LCx: β=0.58, both p<0.001), whereas right coronary artery (RCA) lesion severity lost significance after adjustment (β=0.09, p=0.112). Significant clinical predictors also included LVEF (β=-0.42, p<0.001), DM (β=0.31, p=0.002), troponin I (β=0.35, p=0.004), and LDL-C (β=0.18, p=0.025). Notably, several parameters failed to show independent predictive value in the adjusted model. fQRS-T angle (β=0.05, p=0.321), BMI (β=0.07, p=0.156), and hs-CRP (β=0.12, p=0.087) showed no significant independent associations. Heart rate (p=0.132) and QTc interval (p=0.104) also demonstrated no predictive value for sQRS-T angles.

Table 3. Predictors of Spatial QRS-T Angle: Linear Regression Analysis

Predictor	Univariate β (95% CI)	p-value	Multivariate* β (95% CI)	p-value
Angiographic				
SYNTAX score	0.65 (0.59-0.71)	<0.001	0.52 (0.46-0.58)	**<0.001**
Total Gensini score	0.82 (0.77-0.87)	<0.001	0.68 (0.62-0.74)	**<0.001**
LAD lesion severity	0.79 (0.73-0.85)	<0.001	0.61 (0.55-0.67)	**<0.001**
LCx lesion severity	0.76 (0.70-0.82)	<0.001	0.58 (0.52-0.64)	**<0.001**
RCA lesion severity	0.32 (0.25-0.39)	0.003	0.09 (-0.02-0.20)	0.112
Clinical				
LVEF (%)	-0.57 (-0.63--0.51)	<0.001	-0.42 (-0.48--0.36)	**<0.001**
Diabetes mellitus	0.40 (0.33-0.47)	<0.01	0.31 (0.24-0.38)	**0.002**
BMI	0.22 (0.15-0.29)	0.017	0.07 (-0.02-0.16)	0.156
LDL-C (mg/dL)	0.25 (0.18-0.32)	0.008	0.18 (0.11-0.25)	**0.025**
Troponin I (ng/mL)	0.48 (0.41-0.55)	<0.01	0.35 (0.28-0.42)	**0.004**
hs-CRP (mg/L)	0.28 (0.21-0.35)	0.011	0.12 (0.05-0.19)	0.087
Frontal QRS-T angle	0.15 (0.06-0.24)	0.042	0.05 (-0.04-0.14)	0.321

**Adjusted for age, sex, hypertension and diabetes mellitus*
Model statistics: $R^2 = 0.72$, Adjusted $R^2 = 0.70$, $F = 42.8$, $p < 0.001$, Durbin-Watson = 1.96

The linear regression model demonstrated good fit (R^2 = 0.72, adjusted $R^2 = 0.70$, $F = 42.8$, $p < 0.001$). Residuals were normally distributed (assessed via histogram and Q–Q plot) and showed no pattern of heteroscedasticity. Multicollinearity was not detected (all VIF values < 2.1). Cook's distance values were all below 0.42, indicating no influential outliers. Durbin–Watson statistic was 1.96, suggesting no autocorrelation.

Logistic regression analysis was performed to assess the predictive value of frontal and sQRS-T angles for identifying patients with a high SYNTAX score (>32). In the univariate analysis, only the sQRS-T angle was significantly associated with high SYNTAX scores (OR: 1.05, 95% CI: 1.03–1.07; p<0.001), whereas the fQRS-T angle did not reach statistical significance (p=0.276). This finding remained consistent in the multivariate model, where the sQRS-T angle remained an independent predictor (OR: 1.04, 95% CI: 1.02–1.06; p<0.001) (Table 4).

Table 4. Logistic Regression Analysis for Predicting High SYNTAX Score (>32) Based on QRS-T Angles

Variable	**Univariate OR (95% CI)**	**p**	**Multivariate OR (95% CI)***	**p**
Frontal QRS-T angle (°)	1.01 (0.99–1.03)	0.276	1.00 (0.98–1.02)	0.741
Spatial QRS-T angle (°)	1.05 (1.03–1.07)	**<0.001**	1.04 (1.02–1.06)	**<0.001**

***Adjusted for age, sex, hypertension and diabetes mellitus*

ROC analysis demonstrated quite well discriminatory capacity of the sQRS-T angle for identifying high SYNTAX scores (>32), with an AUC of 0.80 (95% CI 0.75–0.85, p<0.001). A cutoff value of >105.2° provided balanced sensitivity (70%) and specificity (75%), suggesting clinical utility for pre-procedural risk stratification (Figure). In contrast, no clinically meaningful and significant cutoff could be established for the fQRS-T angle.

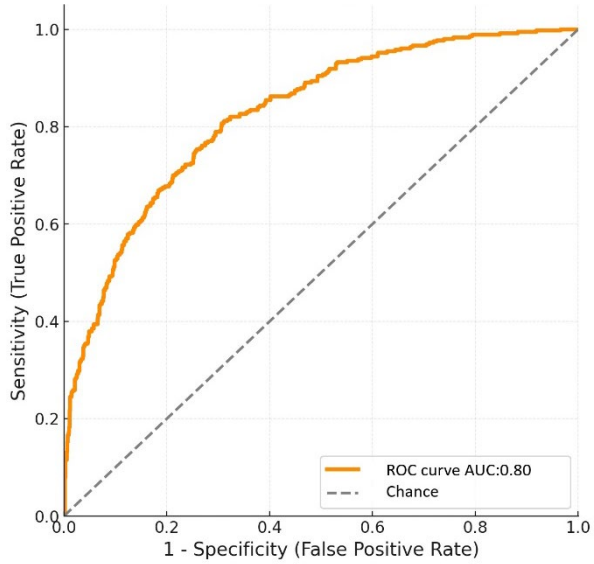

Figure: ROC curve for Spatial QRS-T Angle Predicting SYNTAX >32.

DISCUSSION

Our study demonstrates that the sQRS-T angle serves as a more robust, independent predictor of CAD complexity assessed by both Syntax and Gensini scores in NSTMI patients, compared with the fQRS-T angle.

Chronic myocardial ischemia leads to conduction delays in the local Purkinje network and contributes to partial disruption in both depolarization and repolarization processes within the ventricles. As a consequence, myocardial activation proceeds more slowly, which plays a key role in compromising the uniformity of ventricular electrical activity (18). Ultimately, the presence of ischemia-induced myocardial injury or heterogeneity gives rise to impaired repolarization patterns, often reflected by a widened frontal and sQRS-T angles (19).

The sQRS-T angle is a well-established electrocardiographic marker that reflects the spatial disparity between ventricular depolarization and repolarization vectors, thus serving as an indicator of myocardial electrical heterogeneity. Escalated QRS-T angle has been related to greater arrhythmic risk and adverse cardiovascular outcomes in various clinical settings. Kardys et al. (20) reported a significant relationship between sQRS-T angle and total and cardiac mortalities in general population. In standard 12-lead ECGs, the fQRS-T angle is easily accessible through automated algorithms; however, it is limited by its two-dimensional nature, as it only considers projections on the frontal plane.

In contrast, the sQRS-T angle, calculated via vectorcardiographic reconstruction methods such as the Kors transformation, inverse Dower transformation and Rautaharju's method, incorporates three orthogonal components (X, Y, Z) of cardiac electrical activity and therefore provides a more comprehensive assessment of ventricular heterogeneity (21). Previous studies have shown that the sQRS-T angle has superior prognostic significance compared to the fQRS-T angle, particularly in predicting ventricular arrhythmias, sudden cardiac death, and cardiovascular mortality (22, 23). Moreover, in patients with structural or ischemic heart disease, spatial angle widening has been linked to myocardial scarring, inflammation, conduction delay, and regional repolarization abnormalities, which may not be fully captured by the frontal angle alone (24, 25). Several studies have indicated that, compared to traditional ECG-based repolarization indices, the QRS-T angle demonstrates greater robustness, higher reproducibility, and reduced susceptibility to noise and measurement inconsistencies (26).

Although multiple vectorcardiographic transformation techniques have been developed to estimate sQRS-T angle

from standard 12-lead ECGs, the Kors matrix method remains the most widely adopted approach due to its high diagnostic accuracy and robust validation in clinical cohorts (27). This method utilizes a regression-based transformation matrix to reconstruct orthogonal X, Y, and Z leads from a combination of 8 to 10 standard ECG leads, offering a precise three-dimensional representation of cardiac electrical activity. However, alternative techniques such as the Rautaharju method have also been proposed, which use a simplified transformation requiring input from only four ECG leads. While this simplification reduces computational complexity and facilitates implementation in routine settings, recent studies have demonstrated that the Rautaharju-derived sQRS-T angle performs comparably to the Kors method in terms of diagnostic and prognostic power, particularly in predicting adverse cardiac outcomes and ischemic burden (21). In fact, some reports have shown that the Rautaharju method may yield area under the curve (AUC) values that rival or even exceed those obtained with the more complex Kors method, making it a practical alternative in settings where efficiency and ease of use are prioritized (8, 20, 22).

Both the SYNTAX and Gensini scores are established angiographic tools used to quantify the extent and severity of CAD, each offering complementary insights into the anatomical burden of atherosclerosis. The Syntax score, originally developed to guide revascularization strategy in left main and multivessel disease, provides a detailed anatomical assessment by assigning weighted values to lesion characteristics, such as bifurcation, tortuosity, calcification, and total occlusion (28). It has since evolved into a broadly accepted marker of coronary complexity and is strongly associated with adverse (29). In contrast, the Gensini score is based on a segmental weighting system that accounts for both segments (29). This scoring system allows for a more diffuse quantification of atherosclerotic burden, making it a sensitive index for total plaque load. While SYNTAX is more procedural and lesion-specific—primarily guiding revascularization decisions—Gensini may better reflect global ischemic burden, including the contribution of non-culprit or non-obstructive disease (30).

In our study, both SYNTAX and Gensini scores were positively correlated with the sQRS-T angle, suggesting that this ECG-derived parameter reflects both the complexity and overall burden of CAD, whereas fQRS-T angle did not significantly differ across SYNTAX subgroups. This suggests that spatial angle better reflects the anatomical complexity and extent of CAD. The ROC analysis further confirmed the diagnostic superiority of spatial over frontal angle, with a high AUC and a clinically relevant cutoff of 105.2° for identifying patients with severe coronary disease. These results highlight the promising utilization of sQRS-T as a noninvasive, ECG-derived parameter for risk stratification in NSTMI patients, complementing traditional angiographic scoring systems.

A number of previous investigations reported that the fQRS-T angle be increased in NSTMI patients and that it independently predicts the SYNTAX score. However, sQRS-T angle was not exclusively investigated with regard to its diagnostic role in the complexity of CAD. In their study, Erdoğan et al. (10) evaluated the association of fQRS-T angle with SYNTAX score in subjects with NSTMI and found that a fQRS-T angle greater than 73.5° was associated with moderate-to-high SYNTAX scores. Similarly, Gül et al. (31) reported that a fQRS-T angle exceeding 61.5° was independently associated with a high Gensini score (>45). Akın et al. (32) also found that the fQRS-T angle was a significant predictor of the Gensini score in NSTMI patients. Planiswamy et al. (33) investigated the relationship of fQRS-T angle with CAD complexity and found that a fQRS-T angle >90° had been associated with presence of 3-vessel CAD in a composite patient cohort of acute and chronic coronary syndrome. In contrast to these findings, our study demonstrated no significant differences in fQRS-T angle across SYNTAX subgroups. However, the sQRS-T angle showed a significant stepwise increase across SYNTAX strata. Moreover, there was no significant correlation or linear relationship between the frontal and sQRS-T angles. Only the sQRS-T angle was found to have independently predicted both SYNTAX and Gensini scores, as confirmed by our multivariate linear regression analysis. This discrepancy may be attributed to the larger sample size in our cohort, which enhances statistical power. Additionally, the sQRS-T angle provides a more accurate representation of the terminal depolarization–repolarization axis by incorporating three-dimensional vector analysis, which is physiologically more comprehensive than the frontal plane angle alone. In this regard, our study is unique in comparative evaluation of the diagnostic performances of the frontal and sQRS-T angles in a relatively larger patient cohort of NSTMI.

This study has several limitations that warrant consideration. First, it was conducted at a single tertiary center, and although the sample size was larger than in previous studies, the findings might not be completely generalizable to NSTMI populations as a whole. Second, the sQRS-T angle was calculated using the Rautaharju transformation method, which—while more practical and easier to implement than the Kors matrix—relies on a reduced number of ECG leads and may not capture the full complexity of ventricular vector dynamics. Thirdly, establishment of causal relationships between QRS-T angles and angiographic scores might have been hindered by the cross-sectional nature of the study. Lastly, angiographic scoring systems such as SYNTAX and Gensini, despite being well-validated, have known limitations, including operator dependency and their inability to assess microvascular or functional ischemia.

CONCLUSION

sQRS-T angle, but not fQRS-T angle, predicts CAD complexity assessed by Syntax and Gensini scores in patients with NSTMI. Future multicenter investigations with larger cohorts are warranted to validate our results.

Declarations

Ethics Committee Approval: Ethics committee approval was obtained from the Human Research Ethics Committee of a university (Date: February 22, 2021, Decision No: 01/16). This study was conducted according to the principles of the Declaration of Helsinki.

Authors' Contributions

ES: Conceptualization, data collection, statistical analysis, manuscript writing.

AY: Data verification, data collection, critical manuscript review.

Both authors have read and approved the final version of the manuscript. Each author meets the ICMJE authorship criteria and accepts responsibility for the integrity and accuracy of the work.

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REFERENCES

1. Collet JP, Thiele H, Barbato E, Barthélémy O, Bauersachs J, Bhatt DL, et al. 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. Eur Heart J. 2021;42(14):1289-1367.
2. Sökmen E, Ateş MS, Kök Z, Bingöl B. Relationship between ECG-derived T-wave amplitude and T/R ratio and Syntax score in patients with acute non-st segment elevation myocardial infarction. J Electrocardiol. 2025;88:153829.
3. Serruys PW, Morice MC, Kappetein AP, Colombo A, Holmes DR, Mack MJ, et al. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. N Engl J Med. 2009;360(10):961-972.
4. Ateş MS, Sökmen E. Electrocardiographic P-Wave Indices in Metabolic Dysfunction-Associated Fatty Liver Disease and Their Relationship to Hepatic Fibrosis Risk. J Clin Med. 2025;14(13): 4650.
5. Zhang ZM, Prineas RJ, Case D, Soliman EZ, Rautaharju PM. Comparison of the prognostic significance of the electrocardiographic QRS/T angles in predicting incident coronary heart disease and total mortality (from the atherosclerosis risk in communities study). Am J Cardiol. 2007;100(5):844-849.
6. Aro AL, Huikuri HV, Tikkanen JT, Junttila MJ, Rissanen HA, Reunanen A, et al. QRS-T angle as a predictor of sudden cardiac death in a middle-aged general population. Europace. 2012;14(6):872-876.
7. Gotsman I, Keren A, Hellman Y, Banker J, Lotan C, Zwas DR. Usefulness of electrocardiographic frontal QRS-T angle to predict increased morbidity and mortality in patients with chronic heart failure. Am J Cardiol. 2013;111(10):1452-1459.
8. Rautaharju PM, Zhang ZM, Prineas R, Heiss G. Assessment of prolonged QT and JT intervals in ventricular conduction defects. Am J Cardiol. 2004;93(8):1017-1021.
9. Dogan A, Kahraman S. Frontal QRS-T angle predicts coronary atherosclerotic burden in patients with ST segment elevation myocardial infarction. J Electrocardiol. 2020;58:155-159.
10. Erdogan G, Yontar OC, Yenercag M, Gul S, Arslan U. Frontal QRS-T angle predicts syntax score in patients with non-ST elevation myocardial infarction. J Electrocardiol. 2020;61:86-91.
11. Scherptong RW, Henkens IR, Man SC, Le Cessie S, Vliegen HW, Draisma HH, et al. Normal limits of the spatial QRS-T angle and ventricular gradient in 12-lead electrocardiograms of young adults: dependence on sex and heart rate. J Electrocardiol. 2008;41(6):648-655.
12. Sardella G, Lucisano L, Garbo R, Pennacchi M, Cavallo E, Stio RE, et al. Single-Staged Compared With Multi-Staged PCI in Multivessel NSTEMI Patients: The SMILE Trial. J Am Coll Cardiol. 2016;67(3):264-272.
13. Gensini GG. A more meaningful scoring system for determining the severity of coronary heart disease. Am J Cardiol. 1983;51(3):606.
14. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth Universal Definition of Myocardial Infarction (2018). Circulation. 2018;138(20):e618-e51.

15. Kors JA, Kardys I, van der Meer IM, van Herpen G, Hofman A, van der Kuip DA, et al. Spatial QRS-T angle as a risk indicator of cardiac death in an elderly population. J Electrocardiol. 2003;36 Suppl:113-114.
16. Mason JW, Hancock EW, Gettes LS, Bailey JJ, Childers R, Deal BJ, et al. Recommendations for the standardization and interpretation of the electrocardiogram: part II: electrocardiography diagnostic statement list a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society Endorsed by the International Society for Computerized Electrocardiology. J Am Coll Cardiol. 2007;49(10):1128-1135.
17. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med. 2016;15(2):155-163.
18. Birnbaum Y, Sclarovsky S. The grades of ischemia on the presenting electrocardiogram of patients with ST elevation acute myocardial infarction. J Electrocardiol. 2001;34 Suppl:17-26.
19. Gardner PI, Ursell PC, Fenoglio JJ, Jr., Wit AL. Electrophysiologic and anatomic basis for fractionated electrograms recorded from healed myocardial infarcts. Circulation. 1985;72(3):596-611.
20. Kardys I, Kors JA, van der Meer IM, Hofman A, van der Kuip DA, Witteman JC. Spatial QRS-T angle predicts cardiac death in a general population. Eur Heart J. 2003;24(14):1357-1364.
21. Rautaharju PM, Prineas RJ, Zhang ZM. A simple procedure for estimation of the spatial QRS/T angle from the standard 12-lead electrocardiogram. J Electrocardiol. 2007;40(3):300-304.
22. Oehler A, Feldman T, Henrikson CA, Tereshchenko LG. QRS-T angle: a review. Ann Noninvasive Electrocardiol. 2014;19(6):534-542.
23. Brown RA, Schlegel TT. Diagnostic utility of the spatial versus individual planar QRS-T angles in cardiac disease detection. J Electrocardiol. 2011;44(4):404-409.
24. Ateş MS, Yıldırım A, Sökmen E. Association Between Pan-Immune-Inflammation Value and Dipper/Non-Dipper Status in Newly Diagnosed Hypertensive Patients. J Inflamm Res. 2025;18:6217-28.
25. Sökmen E, Ateş MS, Celik M, Kaleli MF. Utility of pan-immune-inflammation index in the diagnosis of masked hypertension in patients with type 2 diabetes mellitus. Hormones (Athens). 2025.
26. Dilaveris P, Antoniou CK, Gatzoulis K, Tousoulis D. T wave axis deviation and QRS-T angle - Controversial indicators of incident coronary heart events. J Electrocardiol. 2017;50(4):466-475.
27. Kors JA, van Herpen G, Sittig AC, van Bemmel JH. Reconstruction of the Frank vectorcardiogram from standard electrocardiographic leads: diagnostic comparison of different methods. Eur Heart J. 1990;11(12):1083-1092.
28. Sianos G, Morel MA, Kappetein AP, Morice MC, Colombo A, Dawkins K, et al. The SYNTAX Score: an angiographic tool grading the complexity of coronary artery disease. EuroIntervention. 2005;1(2):219-227.
29. Neeland IJ, Patel RS, Eshtehardi P, Dhawan S, McDaniel MC, Rab ST, et al. Coronary angiographic scoring systems: an evaluation of their equivalence and validity. Am Heart J. 2012;164(4):547-52.e1.
30. Bittencourt MS, Hulten E, Ghoshhajra B, O'Leary D, Christman MP, Montana P, et al. Prognostic value of nonobstructive and obstructive coronary artery disease detected by coronary computed tomography angiography to identify cardiovascular events. Circ Cardiovasc Imaging. 2014;7(2):282-291.
31. Gül S, Erdoğan G, Yontar OC, Arslan U. The Relationship Between Electrocardiographic Frontal QRS-T Angle and Gencini Score in Non-ST Segment Elevated Myocardial Infarction. Kafkas Journal of Medical Sciences. 2021;11(2):268-274.
32. Akın H, Bilge Ö. Relationship between frontal QRS-T duration and the severity of coronary artery disease in who were non-diabetic and had stable angina pectoris. Anatol J Cardiol. 2021;25(8):572-578.
33. Palaniswamy C, Singh T, Aronow WS, Ahn C, Kalapatapu K, Weiss MB, et al. A planar QRS-T angle >90 degrees is associated with multivessel coronary artery disease in patients undergoing coronary angiography. Med Sci Monit. 2009;15(12):Ms31-4.

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