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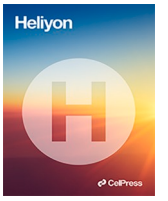

Research article

Relationship of changes in QRS duration with left ventricular ejection fraction in patients with acute ST segment elevation myocardial infarction treated with primary percutaneous coronary intervention

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A R T I C L E I N F O

Keywords:
Changes in QRS duration
Left ventricular ejection fraction
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A B S T R A C T

Objective: To assess the changes in QRS duration (△QRSd) before and after primary percutaneous coronary intervention(PPCI) regarding the relation of left ventricular ejection fraction (LVEF) in patients after a first acute ST segment elevation myocardial infarction (STEMI) treated with primary percutaneous coronary intervention (PPCI).

Methods: A total of 244 patients with STEMI were enrolled, and clinical, biochemical, and angiographic parameters were compared between two groups based on LVEF at 6 months post-discharge. QRS duration (QRSd) was analyzed in relation to LVEF, and feature selection using least absolute shrinkage and selection operator(LASSO) regression was performed. Logistic regression analysis and receiver operating characteristic (ROC) curve evaluation were conducted to identify predictors and assess model efficacy.

Results: Significant differences were observed between the two groups in terms of various parameters, including age, time from symptom onset to balloon dilation (STB), N-terminal pro B-type natriuretic peptide (NT-proBNP) levels, Left ventricular end-diastolic volume(LVEDV) at baseline, left ventricular end-systolic volume(LVESV)at baseline, left ventricular end-diastolic diameter (LVDD)at baseline and six months, hospital length of stay(days), ST-segment resolution (STR), the left anterior descending artery as the infarction-related artery (IRA-LAD), frequency of TIMI 3 flow post PPCI, thrombus aspiration and/or intracoronary thrombolysis, the use of tirofiban, and the number of implanted stents(stents).In addition, postoperative QRSd and △QRSd were significantly higher in patients with left ventricular systolic dysfunction(LVSD). LASSO regression selected six variables as predictors of postoperative LVEF. Logistic regression analysis identified age, STB, NT-proBNP, LVESV at baseline,△QRSd, and stents, as independent factors associated with LVSD within six months for patients with a first occurrence of STEMI. The models achieved AUC values of 0.906 (using ΔQRSd),0.922(using 6 variables excluding ΔQRSd) and 0.962 (using 6 variables).

Conclusion: This study identified ΔQRSd as a potential predictor of LVSD in patients with STEMI. The developed models showed good efficacy in predicting postoperative LVEF changes. These

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findings may contribute to risk stratification and individualized management strategies for STEMI patients.

1. Introduction

As a simple, convenient, and effective diagnostic tool, the electrocardiogram (ECG) holds significant clinical value in the diagnosis, treatment, and prognosis of patients with acute ST-segment elevation myocardial infarction (STEMI). Numerous studies have investigated the predictive value of ECG parameters concerning the outcomes of patients with STEMI. These parameters include the baseline number of pathological Q-waves, QRS duration (QRSd) post-percutaneous coronary intervention (PCI), the number of leads exhibiting ST-segment elevation, the sum of ST-segment elevations across all leads, and the maximal ST-segment elevation observed in a single lead [1–3].

The left ventricular ejection fraction (LVEF), assessed via transthoracic echocardiography, stands as a widely recognized metric for identifying left ventricular systolic dysfunction (LVSD) and predicting adverse outcomes in individuals following acute myocardial infarction (AMI) [4]. While numerous studies have assessed the prognostic significance of ECG in predicting the development of LVSD in patients post-AMI [3,5,6], many of these studies originate from the era of thrombolytic therapy for STEMI. They often involve heterogeneous cohorts in terms of reperfusion strategies, types of AMI, and pharmacotherapy. In contemporary practice, with primary percutaneous coronary intervention (PPCI) established as an effective and standard reperfusion strategy, alongside current STEMI management guidelines, there has been a remarkable reduction in major adverse cardiovascular events (MACE), including cardiac death, recurrent myocardial infarction, and stroke.

While ST segment elevation resolution is commonly employed to assess reperfusion efficacy in patients with STEMI,its value in predicting prognosis remains uncertain.Thus, some studies have explored the association between QRSd at admission and post-PCI with LVEF in STEMI patients [1,7,8]. However, there is limited literature addressing the relationship between the changes in QRSd (△QRSd) before and after primary percutaneous coronary intervention(PPCI) and LVEF in such patients currently. Consequently,our study seeks to assess the correlation between alterations in QRS duration (△QRSd) and LVEF among individuals diagnosed with STEMI who underwent PPCI.

2. Methods

2.1. Study design

Our retrospective cohort study comprised patients undergoing primary percutaneous coronary intervention (PPCI) with either stent implantation or balloon dilatation (depending on operator discretion) for a first occurrence of ST-elevation myocardial infarction (STEMI) at the Department of Cardiology, Second Affiliated Hospital of Anhui Medical University, from January 2020 to January 2023. STEMI was identified by International Classification of Diseases (ICD) codes from our electronic medical record system and validated by medical record review. Inclusion criteria for the study were as follows: diagnosis of first STEMI in accordance with the guidelines of the European Society of Cardiology [9] and presentation within 12 h of symptom onset. Exclusion criteria encompassed prior myocardial infarction or coronary revascularization, cardiogenic shock, infection, age below 18 years, complete left or right bundle branch block, patients requiring temporary pacemaker implantation due to atrioventricular block, non-sinus rhythm, incomplete medical records, and in-hospital mortality. The study was conducted in accordance with the Helsinki Declaration and the principles of Good Clinical Practice, and approval for the study was obtained from the Ethics Committee of the Second Affiliated Hospital of Anhui Medical University (Approval No: YX2023-071).

2.2. Study population

A total of 244 patients diagnosed with STEMI met the inclusion and exclusion criteria of our study. Among them, 142 patients presented with acute anterior wall myocardial infarction, 79 patients with acute inferior wall and/or right ventricular myocardial infarction, and 23 patients with acute lateral wall myocardial infarction. Comprehensive medical and family histories, physical examinations, standard laboratory tests, 12-lead electrocardiograms, and transthoracic echocardiography were conducted for each patient during hospitalization. Follow-up transthoracic echocardiography was scheduled six months after discharge, during which patients were categorized into two groups based on their measured LVEF: the LVEF normal group (EF $\geq$ 50 %, n = 157) and the LVEF impaired group (EF $<$ 50 %, n = 87), in accordance with the recommendations of the European Society of Cardiology [10].

2.3. ECG analysis

All patients underwent ECG examination immediately upon their initial medical contact and within 30 min following PPCI, serving as the admission ECG and post-PPCI surgical ECG, respectively. ECG recordings were conducted at a paper speed of 25 mm/s and a gain of 0.1 mV/mm, utilizing 12 standard leads or 18 leads (if necessary). Two investigators independently measured the QRS duration at admission and post-PPCI, as well as assessed ST segment resolution. Changes in QRS duration were defined as the post-PPCI QRS duration minus the admission QRS duration. In instances of disagreement during analysis, a third cardiologist was consulted to provide

adjudication through consensus.

2.4. Echocardiographic parameters

Two-dimensional transthoracic echocardiography was conducted to assess LVEF using a Philips iE33 device (Philips, USA) at baseline(before discharge)and 6 months after discharge by two echocardiographers. Image acquisitions and measurements were performed in accordance with the guidelines of the European Association of Echocardiography and the American Society of Echocardiography [11]. Left ventricular end-diastolic volume(LVEDV) and left ventricular end-systolic volume(LVESV) estimations were carried out using the biplane method of discs based on apical 4-chamber and 2-chamber views, meanwhile LVEF was calculated by (LVEDV minus LVESV)/LVEDV×100 %. The echocardiographers were blinded to the ECG analysis, and refined their averages as the final results.

2.5. Primary percutaneous coronary intervention

PPCI was uniformly performed in each patient using standard technique, primarily via the radial artery approach. Assessment of coronary artery lesions was conducted utilizing the Gensini Score [12]. The primary objective of PPCI was to reinstate normal blood flow in the infarct-related artery (IRA), achieved through either stent implantation or balloon dilatation alone, contingent upon the operator's discretion. Evaluation of IRA blood flow was based on the Thrombolysis in Myocardial Infarction (TIMI) score. Other significant non-culprit lesions of $\geq$70 % severity was addressed during the index hospitalization or selectively managed in consultation with the attending physician and the patient.

2.6. Pharmacotherapy

All patients received an oral loading dose of aspirin (300 mg) and either clopidogrel (600 mg) or ticagrelor (180 mg) at their initial medical contact. Subsequently, aspirin (100 mg, once daily) and clopidogrel (75 mg, once daily) or ticagrelor (90 mg, twice daily) were continued for one year. Concomitant medications for all patients included beta-blockers and either an angiotensin-converting enzyme inhibitor (ACEI) or an angiotensin II receptor blocker (ARB) or angiotensin receptor-neprilysin inhibitor(ARNI), with doses adjusted according to heart rate and blood pressure, as well as statins. The decision to utilize thrombus aspiration and/or intracoronary thrombolysis, as well as tirofiban during the perioperative period, was at the discretion of the treating physician.

2.7. Objective

The primary aim of this study was to examine the correlation between changes in QRS duration ($\triangle$QRSd) and the occurrence of left ventricular systolic dysfunction (LVSD), defined as a LVEF $<$50 %, six months following STEMI. Additionally, we sought to assess whether the onset of LVSD is linked to QRSd measurements at admission and post-PPCI.

2.8. Statistical analysis

Data analysis was conducted using R software(version 4.22). Categorical variables were expressed as numbers or percentages (%), and between-group differences were assessed using the chi-square test. The Shapiro–Wilk test was employed to evaluate the normality of distribution. Continuous variables with a normal distribution were presented as means $\pm$ one standard deviation (SD) and compared using Student's t-test, whereas non-normally distributed data were reported as medians and interquartile ranges or represented as median (P25, P75) and compared using the Wilcoxon Rank Sum test. Interclass correlation coefficient (ICC) was used to assess the reliability of ECG measurements between different doctors. Least absolute shrinkage and selection operator(LASSO) regression was used to screen parameters. The screened variables included age, STB, NT-proBNP, LVESV at baseline,$\triangle$QRSd, and the number of implanted stents. Subsequently, multivariate logistic regression was used to analyze the predictive value of non-zero coefficient variables. The receiver operator characteristic (ROC) curve was used to determine the best cutoff value and validity of certain variables. ROC curve analysis results were presented as area under the ROC curve (AUC),95 % confidence interval (CI). A significance level of $P < 0.05$ was considered statistically significant.

3. Results

3.1. The course of study

During the period spanning from January 2020 to January 2023, our hospital admitted a total of 544 patients diagnosed with ST-elevation myocardial infarction (STEMI). Of them,126 patients with secondary STEMI or prior coronary revascularization,8 patients with cardiogenic shock,1 patient below 18 years,32 patients with complete left or right bundle branch block,24 patients needed temporary pacemaker implantation,78 patients with non-sinus rhythm,28 patients with incomplete medical records and 3 patients died. Therefore, we identified a study cohort comprising 244 patients. This cohort was subsequently stratified into two groups based on left ventricular ejection fraction (LVEF) measurements taken six months post-discharge following the index STEMI event: those with LVEF $\geq$50 % (Normal EF group) and those with LVEF $<$50 % (Reduced EF group). Among these groups, 87 patients (35.65 %) exhibited

an LVEF <50 % (refer to Fig. 1).

3.2. Clinical, biochemical and angiographic parameters

. A comparison of clinical, biochemical, and angiographic parameters between the two groups is presented in Table 1.At baseline, significant differences were observed between the two groups in terms of age, time from symptom onset to balloon dilation (STB), N-terminal pro B-type natriuretic peptide (NT-proBNP) levels, left ventricular end-diastolic diameter (LVDD), hospital length of stay, post-PPCI QRS duration (QRSd), changes in QRS duration(△QRSd), ST-segment resolution (STR), the left anterior descending artery as the infarction-related artery (IRA-LAD), frequency of TIMI 3 flow post PPCI, thrombus aspiration and/or intracoronary thrombolysis, the use of tirofiban, and the number of implanted stents. These detailed characteristics are presented in Table 1.

3.3. Comparison of QRSd in patients with STEMI

According to the LVEF at 6 months post-discharge, patients were divided into normal EF Group(LVEF ≥50 %) and reduce EF Group (LVEF <50 %). A comparison was made between the two groups regarding pre-operative QRS duration(preQRSd), post-operative QRS duration(postQRSd), and the changes in QRS duration(△QRSd). The results indicated that there was no statistically significant difference in preQRSd between the two groups. However, postQRSd and △QRSd exhibited significant differences, with both being significantly higher in reduce EF Group compared to normal EF Group(Fig. 2).

3.4. Refinement and analysis of feature selection using LASSO regression in STEMI patients' EF variation Prediction

LASSO regression was used to screen parameters. The 5-fold cross-validation method was applied to the iterative analysis, and a model with excellent performance but minimum number of variables was obtained when λ was 0.036 of the minimum criteria (showed in Fig. 3). The screened variables included age, STB, NT-proBNP, LVESV at baseline,△QRSd, and the number of implanted stents.

3.5. Predictors of the development of LVSD

Using LVEF as the dependent variable and predictive variables selected by LASSO regression as independent variables, multivariate logistic regression analysis was employed to explore the influencing factors of postoperative EF in STEMI patients. The results revealed six independent predictors including age, STB, NT-proBNP, LVESV at baseline,△QRSd, and the number of implanted stents, as β coefficient, odds ratio (OR), confidence interval (CI) and P value summarized in Fig. 4.

3.6. Evaluation of the models by receiver operating characteristic (ROC) curve

Model 1 using △QRSd as the independent variable and postoperative LVEF as the dependent variable, and the area under the ROC curve (AUC) was 0.906,with95 % CI(0.663–0.793). The cutoff value was 0.486 indicated an increased probability of LVSD when QRSd was wider after PPCI.Model 2 using the 6 variables selected by multivariate logistic analysis except △QRSd as independent variables and postoperative LVEF as the dependent variable, and the area under the ROC curve (AUC) was 0.922,with 95 % CI(0.712–0.827). Model 3 using all the 6 variables selected by multivariate logistic analysis as independent variables and postoperative LVEF as the dependent variable, and the area under the ROC curve (AUC) was 0.951,with 95 % CI(0.712–0.827) as showed in Fig. 5.

4. Discussion

To our knowledge, our study represents the inaugural investigation elucidating the correlation between changes in QRS duration

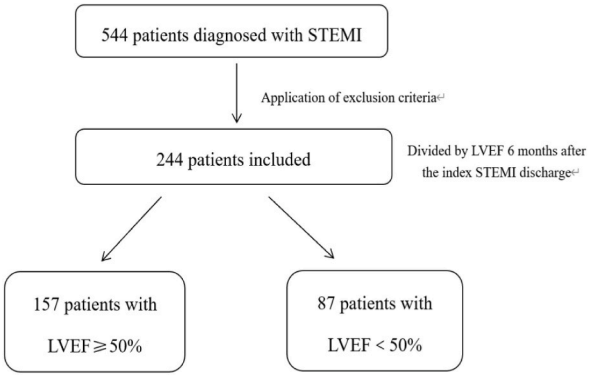

Fig. 1. Diagram of patients' inclusion/exclusion criterion.

Table 1
Clinical, biochemical and angiographic parameters of the study population in two groups.

Variable	Normal EF group(n = 157)	Reduced EF group(n = 87)	t/W/χ [2]	P
Follow time(month)	6.132 ± 1.241	6.367 ± 0.986	−1.520	0.130
Male/n(%)	111 (70.701)	70 (80.460)	2.297	0.095
Age(years)	59.000 [53.000, 69.000]	67.000 [57.500, 73.500]	5362.5	0.005
Positive family history of IHD/n(%)	40 (25.478)	21 (24.138)	0.054	0.817
Hypertension/n(%)	64 (40.764)	36 (41.379)	0.009	0.925
Heart rate (BPM)	75.000 [70.000, 85.000]	77.000 [70.000, 81.000]	6855.5	0.961
Diabetes Mellitus/n (%)	58 (36.943)	32 (36.782)	0.001	0.980
BMI/(kg/m^2)	27.32 ± 6.21	26.72 ± 7.18	0.683	0.495
Smoker/n(%)	68 (43.312)	42 (48.276)	0.557	0.445
Drinker/n(%)	56 (35.669)	29 (33.333)	0.135	0.714
Dual antiplatelet drugs/n(%)	157(100)	87(100)	–	–
ACEI/ARB/ARNI/n(%)	65(41.401)	47(54.023)	3.591	0.058
Stains/n(%)	157(100.0)	87(100.0)	–	–
β-blockers/n(%)	134(85.35)	72(82.76)	0.286	0.593
STB(min)	82.000 [68.000, 110.000]	165.000 [124.500, 211.500]	1743.5	<0.001
Gensini score	63.82 ± 20.24	58.36 ± 21.57	1.971	0.050
Glucose(mmol/L)	7.310 [6.080, 9.820]	7.560 [5.910, 9.455]	6740.5	0.866
Creatinine (umol/L)	79.000 [63.000, 97.000]	76.000 [62.000, 100.500]	7004.0	0.741
White blood cell(× 10^9/L)	8.000 [6.480, 10.050]	8.450 [6.505, 10.410]	6572.0	0.626
Total cholesterol (mmol/L)	4.466 ± 1.267	4.305 ± 1.169	0.999	0.330
Triglycerides (mmol/L)	1.540 [1.040, 2.330]	1.370 [1.010, 1.930]	7314.5	0.358
LDL (mmol/L)	2.783 ± 0.950	2.727 ± 0.959	0.440	0.661
Alanine aminotransferase (u/L)	33.000 [23.000, 47.000]	35.000 [24.000, 49.000]	5467.3	0.613
Cardiac troponin I(ng/dl)	1.460 [0.300, 4.170]	2.210 [0.315, 6.325]	6484.0	0.513
N terminal pro B-type natriuretic peptide (pg/ml)	368.000 [124.000, 909.000]	1466.000 [568.500,3595.000]	3227.5	<0.001
LVEDV at baseline(ml)	112.000 [98.000, 129.000]	136.000 [89.000, 162.000]	3456.4	<0.001
LVESV at baseline(ml)	50.000 [40.000, 59.000]	77.000 [51.000, 94.500]	3756.3	<0.001
LVDD at baseline(mm)	49.000 [45.000, 53.000]	56.000 [52.000, 60.000]	2876.5	<0.001
LVDD at 6months (mm)	49.000 [45.000, 53.000]	56.000 [52.000, 60.000]	3436.0	<0.001
hospital length of stay(days)	6.000 [6.000, 7.000]	10.000 [8.000, 11.000]	1183.0	<0.001
QRS duration at admission(ms)	96.000 [92.000, 104.000]	98.000 [93.000, 106.000]	6460.0	0.482
Post-PPCI QRS duration(ms)	90.000 [82.000, 96.000]	106.000 [96.000, 110.000]	2289.5	<0.001
Changes in QRS duration(ms)	−6.000 [-10.000, −2.000]	6.000 [2.000, 8.000]	12400.5	<0.001
ST segment resolution(mv)	0.300 [0.200, 0.400]	0.100 [0.000, 0.100]	11310.0	<0.001
IRA-LAD/n(%)	80 (50.955)	62 (71.264)	9.491	0.002
Frequency of TIMI 3 flow post PPCI/n(%)	153 (97.452)	57 (65.517)	47.604	<0.001
thrombus aspiration and/or intracoronary thrombolysis/n(%)	21 (13.376)	31 (35.632)	16.535	<0.001
GP IIb/IIIa inhibitor usage/n(%)	35 (22.293)	37 (42.529)	11.020	0.001
Stent implantation/n	1.000 [1.000, 1.000]	2.000 [1.000, 2.000]	3019.0	<0.01
Patients addressing other significant non-culprit lesions selectively/n (%)	36(22.93)	25(28.74)	1.006	0.316

IHD, ischemic heart disease; BMI, body mass index; Drinker, individuals who drank alcohol at least once a week in the year prior to the baseline survey are defined as drinkers; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; ARNI, angiotensin receptor-neprilysin inhibitor; STB, time from symptom onset to balloon dilation; LDL, low-density-lipoprotein cholesterol; LVDD, left ventricular end diastolic diameter; IRA-LAD, left anterior descending artery as the infarction related artery.

(△QRSd) and left ventricular ejection fraction (LVEF) in patients with ST-segment elevation myocardial infarction (STEMI) undergoing primary percutaneous coronary intervention (PPCI). A pivotal finding of our research is the identification of age, STB, NT-proBNP, hospital length of stay,△QRSd, cTnI, and the number of implanted stents as independent predictors of LVEF at 6 months post-STEMI, when considering the clinical, biochemical, and angiographic parameters encompassed in our study through multivariate analysis.

QRSd prolongation has been construed as a dynamic phenomenon instigated by ischemia and potentially ameliorated by successful reperfusion in patients with STEMI [13]. Previously, Kacmaz et al. reported that the degree of QRSd reduction on the 90th-minute electrocardiogram (ECG) following fibrinolysis independently predicted adequate reperfusion in STEMI patients [14], harkening back to the era of thrombolytic treatment. Nonetheless, scant literature exists evaluating the relationship between changes in QRSd and the onset of left ventricular systolic dysfunction (LVSD) within contemporary standards of STEMI management. Consequently, our investigation stands as the inaugural study to substantiate the independent association between post-PPCI changes in QRSd and LVSD. Consistent with our findings, several studies have documented significantly shorter QRSd in individuals achieving successful reperfusion compared to those with impaired reperfusion when ECG were performed immediately post-PPCI [15–17]. This association is presumed to stem from extensive microvascular injury, which has been identified as a prominent predictor of adverse outcomes in STEMI patients [18,19].Our study confirmed that STEMI patients with a wider QRSd compared with QRSd at admission are at an increased risk of developing LVSD. Therefore, it is important to closely monitor such patients for potential complications and provide them with additional attention.

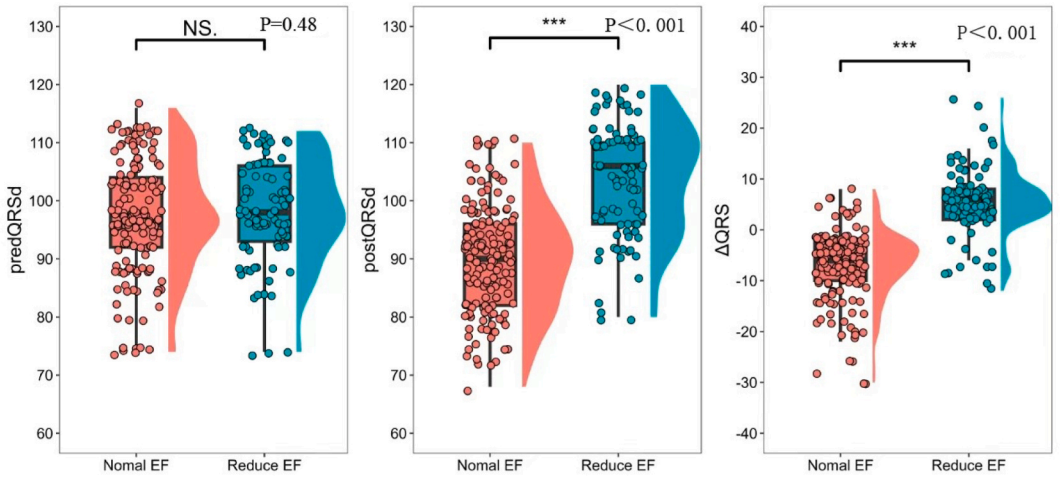

Fig. 2. Comparison of QRS duration and changes of QRS duration in patients with STEMI pre QRSd, QRSd at admission; post QRSd, QRSd post PPCI; △QRSd, changes in QRSd before and after PPCI.

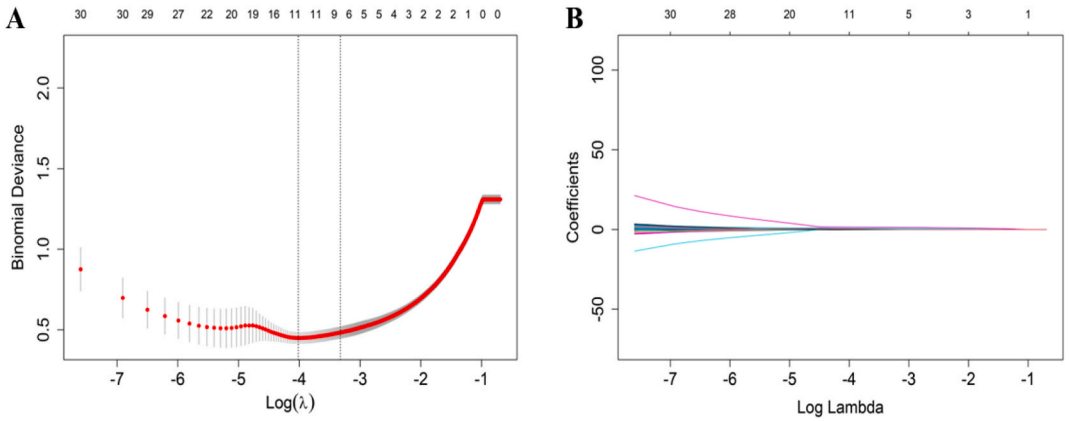

Fig. 3. Screening of variables based on LASSO regression

The tuning parameter (λ) is selected through 5-fold cross-validation using minimum criteria to optimize the model's performance in LASSO regression. The partial likelihood binomial deviance is plotted against log(λ). Optimal log(λ) values, indicating feature selection points, are marked by dotted vertical lines, with one standard error of the minimum criteria (Fig. 3A). A coefficient profile plot was generated against the log(lambda) sequence. Eight variables with nonzero coefficients were selected based on the optimal lambda (Fig. 3B).

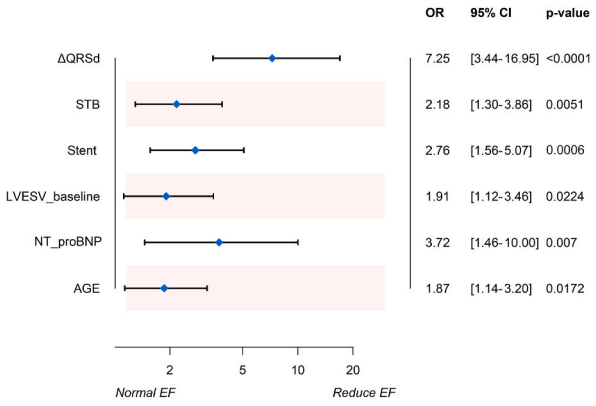

Fig. 4. Multivariate logistic analysis of predictors of LVSD in patients with STEMI STB, symptom to ballon; Stent,the number of implanted stents.

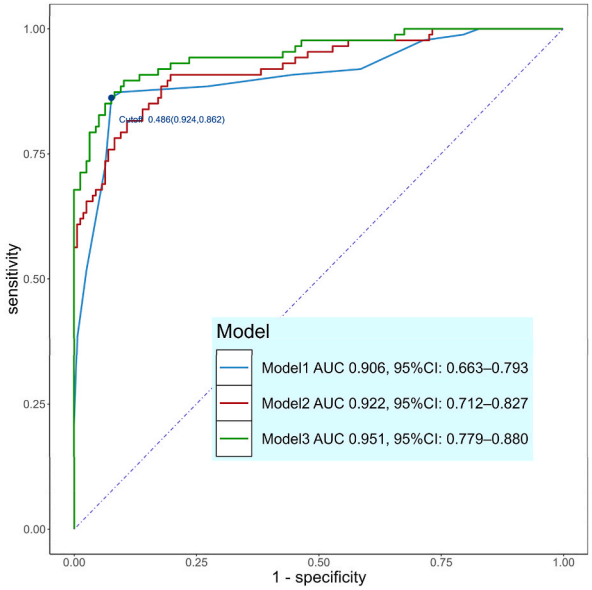

Fig. 5. The performance of models evaluated by ROC curve Model 1:using △QRSd as the independent variable and postoperative LVEF as the dependent variable; Model 2:using the 6 variables selected by LASSO(without △QRSd) as independent variables and postoperative LVEF as the dependent variable; Model 3:using the 6 variables selected by LASSO(with △QRSd) as independent variables and postoperative LVEF as the dependent variable.

Prolongation of QRS duration (QRSd) upon admission has been recognized as a significant predictor of increased mortality among patients with STEMI [7]. Various plausible mechanisms underlie this association. Firstly, myocardial ischemia can induce myocardial fibrosis and damage to the cardiac conduction system [20]. Additionally, the release of a substantial quantity of potassium ions from necrotic myocardial cells can result in reduced conduction velocity and prolonged depolarization time of myocardial cells. Consequently, this may lead to electrocardiographic excitation, disrupted conduction sequences, heightened risk of ventricular arrhythmias, diminished myocardial contractility, and a subsequent decrease in LVEF during STEMI [21]. However, certain studies have indicated that prolonged QRSd upon admission may not reliably predict left ventricular remodeling in STEMI patients within a six-month time-frame, nor does it serve as an indicator reflecting left ventricular injury measured by cardiac magnetic resonance imaging (CMR) [8,22]. Consistent with the latter findings, our observations similarly suggest that QRSd upon admission fails to predict the development of LVSD, possibly attributable to discrepancies in the characteristics of the enrolled population and variations in treatment modalities.

In contrast to prior findings associating a broader QRS duration (QRSd) post percutaneous coronary intervention (PPCI) with the presence of left ventricular systolic dysfunction (LVSD) in STEMI patients, defined as LVEF <40 % [1], our study did not reveal a significant association between QRSd post PPCI and LVSD. This discrepancy may stem from several factors, including the comparatively shorter duration of ischemia experienced by patients in our cohort and potential differences in the definition of LVEF utilized across studies.

In routine clinical assessment, analysis of ST segment changes serves as a common practice to evaluate myocardial reperfusion status following PPCI in patients presenting with STEMI. However, it has been observed that reciprocal ST segment changes do not exhibit a significant association with final infarct size or adverse clinical outcomes among STEMI patients undergoing PPCI [23]. In alignment with previous investigations, our study also indicates that ST-segment resolution (STR) fails to demonstrate independent association with LVEF six months post-STEMI when adjusting for other relevant variables.

The prolonged duration of QRS complexes, as assessed through ECG, has demonstrated a significant impact on cardiovascular outcomes across various clinical scenarios, including heart failure [24], diabetes [25], STEMI [1], and non-ST-segment elevation myocardial infarction (NSTEMI) [26]. Several plausible mechanisms underlie this association. Firstly, prolonged QRS duration may be indicative of advanced cardiovascular disease, such as the functional etiology of mitral regurgitation and impaired left ventricular (LV) function[27,28], both of which contribute to a poorer prognosis. This suggests a direct link between QRS prolongation and the severity of underlying cardiac pathology, thereby influencing clinical outcomes. Secondly, prolonged QRS duration may reflect underlying myocardial damage. Various factors, including ischemia and aging [20,29], can instigate myocardial fibrosis and disrupt the cardiac conduction system, culminating in prolonged QRS complexes. This myocardial damage not only alters the electrical properties of the heart but also serves as a marker for the extent of structural cardiac injury, thereby impacting cardiovascular prognosis. Overall, the association between prolonged QRS duration and adverse cardiovascular outcomes underscores its utility as a prognostic marker across a spectrum of cardiovascular conditions, highlighting its potential as a therapeutic target and indicating the importance of further elucidating its underlying pathophysiological mechanisms.

5. Conclusions

According to our study, the changes in QRS duration (△QRSd) possessed a strong relationship with LVSD within six months for patients with a first occurrence of STEMI.

6. Study limitations

This study is subject to certain limitations that warrant acknowledgment. Firstly, it is important to recognize that this was a retrospective, single-center study spanning a period of two years, introducing the potential for selection bias despite stringent adherence to predefined inclusion and exclusion criteria. Secondly, the analysis was confined to patients with available cardiac ultrasound data documented within our institution's electronic medical records six months post-discharge, thus introducing the possibility of missed follow-up and potential impact on the study outcomes. Lastly, the study cohort may not have been sufficiently large to draw definitive conclusions, and an extended duration of follow-up would be beneficial to comprehensively assess the outcomes of interest.

Data availability statement

The authors will supply the relevant data in response to reasonable requests.

Source of funding

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CRediT authorship contribution statement

Kai Wang: Writing – original draft, Validation, Investigation, Formal analysis, Data curation, Conceptualization. **Lin Wang:** Software, Methodology, Data curation. **Fei He:** Writing – review & editing. **Haoliang Li:** Methodology, Investigation, Data curation. **Yu Fang:** Software, Resources. **Guangquan Hu:** Project administration, Methodology, Investigation, Formal analysis. **Xiaocheng Wang:** Writing – review & editing, Software, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] T. Fabiszak, M. Kasprzak, M. Koziński, et al., Assessment of selected baseline and post-PCI electrocardiographic parameters as predictors of left ventricular systolic dysfunction after a first ST-segment elevation myocardial infarction, J. Clin. Med. 10 (22) (2021 Nov 22) 5445, doi: 10.3390.
[2] J.F. Rodríguez-Palomares, J. Figueras-Bellot, M. Descalzo, et al., Relation of ST-segment elevation before and after percutaneous transluminal coronary angioplasty to left ventricular area at risk, myocardial infarct size, and systolic function, Am. J. Cardiol. 113 (2014) 593–600, doi: 10.1016.
[3] C. Manes, M.A. Pfeffer, J.D. Rutherford, et al., Value of the electrocardiogram in predicting left ventricular enlargement and dysfunction after myocardial infarction, Am. J. Med. 114 (2003) 99–105, doi: 10.1016.
[4] J.N. Cohn, R. Ferrari, N. Sharpe, Cardiac remodeling—concepts and clinical implications: a consensus paper from an international forum on cardiac remodeling. Behalf of an International Forum on Cardiac Remodeling, J. Am. Coll. Cardiol. 35 (2000) 569–582, doi: 10.1016.
[5] P. Kaul, Y. Fu, C.M. Westerhout, C.B. Granger, P.W. Armstrong, Relative prognostic value of baseline Q wave and time from symptom onset among men and women with ST-elevation myocardial infarction undergoing percutaneous coronary intervention, Am. J. Cardiol. 110 (2012) 1555–1560, doi: 10.1016.
[6] R.L. Murkofsky, G. Dangas, J.A. Diamond, D. Mehta, A. Schaffer, J.A. Ambrose, A prolonged QRS duration on surface electrocardiogram is a specific indicator of left ventricular dysfunction, J. Am. Coll. Cardiol. 32 (1998) 476–482, doi: 10.1016.
[7] M. López-Castillo, Á. Aceña, A.M. Pello-Lázaro, V. Viegas, B. Merchán Muñoz, R. Carda, J. Franco-Peláez, M.L. Martín-Mariscal, S. Briongos-Figuero, J. Tuñón, Prognostic value of initial QRS analysis in anterior STEMI: correlation with left ventricular systolic dysfunction, serum biomarkers, and cardiac outcomes, Ann. Noninvasive Electrocardiol. 26 (1) (2021 Jan) e12791 doi: 10.1111.
[8] M. Kasprzak, T. Fabiszak, M. Koziński, J. Kubica, Diagnostic performance of selected baseline electrocardiographic parameters for prediction of left ventricular remodeling in patients with ST-segment elevation myocardial infarction, J. Clin. Med. 10 (11) (2021 May 29) 2405, doi: 10.3390.
[9] R.A. Byrne, X. Rossello, J.J. Coughlan, et al., ESC Scientific Document Group, 2023 ESC Guidelines for the management of acute coronary syndromes, Eur. Heart J. 44 (38) (2023 Oct 12) 3720–3826, doi: 10.1093.
[10] T.A. McDonagh, M. Metra, M. Adamo, R.S. Gardner, et al., ESC Scientific Document Group, 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure, Eur. Heart J. 42 (36) (2021 Sep 21) 3599–3726, doi: 10.1093.
[11] R.M. Lang, L.P. Badano, V. Mor-Avi, et al., Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging, J. Am. Soc. Echocardiogr. 28 (1) (2015 Jan) 1–39, e14. doi: 10.1016.
[12] G.G. Gensini, A more meaningful scoring system for determining the severity of coronary heart diseases, Am. J. Cardiol. 51 (3) (1983) 606, doi: 10.1016.
[13] K. Tsukahara, K. Kimura, M. Kosuge, T. Shimizu, T. Sugano, K. Hibi, M. Kanna, N. Toda, T. Takamura, J. Okuda, N. Nozawa, E. Furukawa, S. Umemura, Clinical implications of intermediate QRS prolongation in the absence of bundle-branch block in patients with ST-segment-elevation acute myocardial infarction, Circ. J. 69 (1) (2005 Jan) 29–34, doi: 10.1253.
[14] F. Kacmaz, O. Maden, S. Aksuyek, C. Ureyen, O. Alyan, A.R. Erbay, H. Selcuk, V. Ulusoy, Y. Balbay, E. Ilkay, Relationship of admission QRS duration and changes in QRS duration with myocardial reperfusion in patients with acute ST segment elevation myocardial infarction (STEMI) treated with fibrinolytic therapy, Circ. J. 72 (6) (2008 Jun) 873–879, doi: 10.1253.

[15] J. Yusuf, D. Das, S. Mukhopadhyay, S. Tyagi, Correlation of QRS duration with myocardial blush grade as a marker of myocardial reperfusion in primary percutaneous coronary intervention, Indian Heart J. 70 (3) (2018) S359–S364, doi: 10.1016.
[16] E. Ilkay, F. Kacmaz, O. Maden, et al., A new electrocardiographic marker of myocardial reperfusion in patients with acute ST-segment elevation myocardial infarction treated with primary percutaneous intervention: the value of QRS duration, EuroIntervention 7 (12) (2012) 1406–1412, doi: 10.4244.
[17] Z. Karahan, B. Yaylak, M. Uğurlu, İ. Kaya, B. Uçaman, Ö. Öztürk, QRS duration: a novel marker of microvascular reperfusion as assessed by myocardial blush grade in ST elevation myocardial infarction patients undergoing a primary percutaneous intervention, Coron. Artery Dis. 26 (7) (2015) 583–586, doi: 10.1097.
[18] H. Ito, A. Maruyama, K. Iwakura, S. Takiuchi, T. Masuyama, M. Hori, Y. Higashino, K. Fujii, T. Minamino, Clinical implications of the 'no reflow' phenomenon. A predictor of complications and left ventricular remodeling in reperfused anterior wall myocardial infarction, Circulation 93 (2) (1996 Jan 15) 223–228, doi: 10.1161.
[19] F. Bellandi, M. Leoncini, M. Maioli, A. Toso, M. Gallopin, R. Piero Dabizzi, Markers of myocardial reperfusion as predictors of left ventricular function recovery in acute myocardial infarction treated with primary angioplasty, Clin. Cardiol. 27 (12) (2004 Dec) 683–688, doi: 10.1002.
[20] H. Watanabe, T. Morimoto, H. Shiomi, Y. Yoshikawa, T. Kato, N. Saito, S. Shizuta, K. Ono, K. Yamaji, K. Ando, S. Kaji, Y. Furukawa, M. Akao, T. Ishikawa, T. Tamura, Y. Yamamoto, T. Muramatsu, S. Suwa, Y. Nakagawa, K. Kadota, Y. Takatsu, H. Nishikawa, Y. Hiasa, Y. Hayashi, S. Miyazaki, T. Kimura, Mortality impact of post-discharge myocardial infarction size after percutaneous coronary intervention: a patient-level pooled analysis from the 4 large-scale Japanese studies, Cardiovasc Interv Ther 34 (1) (2019 Jan) 47–58, doi: 10.1007.
[21] R.P. Grant, H.T. Dodge, Mechanisms of QRS complex prolongation in man; left ventricular conduction disturbances, Am. J. Med. 20 (6) (1956 Jun) 834–852, https://doi.org/10.1016/0002-9343(56)90204-2.
[22] J. Almer, V. Elmberg, J. Bränsvik, et al., Ischemic QRS prolongation as a biomarker of myocardial injury in STEMI patients, Ann. Noninvasive Electrocardiol. 24 (1) (2019 Jan) e12601, https://doi.org/10.1111/anec.12601.
[23] J.W. Hwang, J.H. Yang, Y.B. Song, T.K. Park, J.M. Lee, J.H. Kim, W.J. Jang, S.H. Choi, J.Y. Hahn, J.H. Choi, J. Ahn, K. Carriere, S.H. Lee, H.C. Gwon, Clinical significance of reciprocal ST-segment changes in patients with STEMI: a cardiac magnetic resonance imaging study, Rev. Esp. Cardiol. 72 (2) (2019 Feb) 120–129. English, Spanish. doi: 10.1016.
[24] R. Dhingra, M.J. Pencina, T.J. Wang, B.H. Nam, E.J. Benjamin, D. Levy, M.G. Larson, W.B. Kannel, RB Sr D'Agostino, R.S. Vasan, Electrocardiographic QRS duration and the risk of congestive heart failure: the Framingham Heart Study, Hypertension 47 (5) (2006 May) 861–867, doi: 10.1161.
[25] M.J. Singleton, C. German, K.J. Hari, G. Saylor, D.M. Herrington, E.Z. Soliman, B.I. Freedman, D.W. Bowden, P.D. Bhave, J. Yeboah, QRS duration is associated with all-cause mortality in type 2 diabetes: the diabetes heart study, J. Electrocardiol. 58 (2020 Jan-Feb) 150–154, doi: 10.1016.
[26] E.S. Brilakis, N.C. Mavrogiorgos, S.L. Kopecky, C.C. Rihal, B.J. Gersh, B.A. Williams, I.P. Clements, Usefulness of QRS duration in the absence of bundle branch block as an early predictor of survival in non-ST elevation acute myocardial infarction, Am. J. Cardiol. 89 (9) (2002 May 1) 1013–1018, doi: 10.1016.
[27] N. Shiode, K. Kozuma, J. Aoki, M. Awata, M. Nanasato, K. Tanabe, J. Yamaguchi, H. Kusano, H. Nie, T. Kimura, V. Xievce, PMS Investigators Promus, The impact of coronary calcification on angiographic and 3-year clinical outcomes of everolimus-eluting stents: results of a XIENCE V/PROMUS post-marketing surveillance study, Cardiovasc Interv Ther 33 (4) (2018 Oct) 313–320, doi: 10.1007.
[28] A. Sugiura, M. Weber, N. Tabata, T. Goto, C. Öztürk, M. Lin, S. Zimmer, G. Nickenig, J.M. Sinning, QRS duration is a risk indicator of adverse outcomes after MitraClip, Cathet. Cardiovasc. Interv. 98 (4) (2021 Oct) E594–E601, doi: 10.1002.
[29] I. Shiraishi, T. Takamatsu, T. Minamikawa, Z. Onouchi, S. Fujita, Quantitative histological analysis of the human sinoatrial node during growth and aging, Circulation 85 (6) (1992 Jun) 2176–2184, doi: 10.1161.