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ORIGINAL ARTICLE

QRS Configuration and ST Segment Shift as Determinants of Coronary Slow Flow and No reflow in Acute Coronary Syndrome Post Primary Percutaneous Intervention

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ABSTRACT

Background: Acute coronary syndrome (ACS) patients undergoing primary percutaneous coronary intervention (PCI) may experience coronary slow flow (CSF) or the no-reflow (NR) phenomenon, where myocardial perfusion remains insufficient despite restored epicardial artery patency. This study aimed to study the role of QRS complex configurations and ST segment shifts on ECG as predictors for coronary slow flow (CSF) and no-reflow (NR) phenomena in patients undergoing primary percutaneous coronary intervention (PCI) for acute coronary syndrome (ACS). **Methods**: This observational cohort study included 66 ACS patients were divided into two groups: 33 with ST-segment elevation (STEMI) and 33 without (NSTE-ACS). Coronary flow was assessed using TIMI flow grade and myocardial blush grade (MBG) pre- and post-PCI.**Results**: Among STEMI patients, 92% of those with fragmented or distorted QRS (QRS+) had TIMI flow <3, indicating no-reflow or slow-flow, compared to 50% of patients with normal QRS (P=0.020). A statistically significant correlation was observed between QRS+ and suboptimal coronary flow post-PCI (P=0.002). In NSTE-ACS patients, an ST segment shift >3 mm was significantly associated with no-reflow (P=0.05). **Conclusions**: QRS configuration and ST segment shifts on ECG are valuable predictors of coronary slow flow and no-reflow phenomena in ACS patients after primary PCI, aiding in risk stratification and clinical decision-making.

Keywords: QRS Configuration; ST Segment;TIMI flow grades ;myocardial blush grade

INTRODUCTION

Acute coronary syndrome is characterized by decreased blood flow to the coronary myocardium, it may present as ST-segment elevation myocardial infarction, unstable anginaor non-ST-segment elevation myocardial infarction. Common risk factors include having a body mass index of greater than 25 kg/m2, hypertension, diabetes mellitus, hyperlipidemia, current smoking, being at least 65 years old, or having a family history of early coronary artery disease [1]. The majority of ischemic heart disease (IHD)-related deaths, which account for 1.8 million deaths annually, are caused by ACS and sudden cardiac death. Although it usually happens 7–10 years earlier in men than in women, the incidence of IHD rises with age. While women make up the bulk of patients over 75, men are considerably more likely than women to have ACS before the age of 60[2].

When a STEMI patient presents within 12 hours of the onset of symptoms, primary percutaneous coronary intervention (PCI) is a tried-and-true standard for rapid reperfusion; however, it must be carried out within 120 minutes after the STEMI

diagnosis. The treatment of acute ST-elevation myocardial infarction (STEMI) requires prompt and sufficient revascularization of an IRA. In addition to rapidly restoring coronary flow, reopening the offending artery offers a conclusive diagnostic method for a comprehensive evaluation of coronary morphology, hemodynamic data, and the necessity of coronary artery bypass surgery (CABG). Additionally, through the determination of the thrombolysis in myocardial infarction flow grade or TIMI frame count, it offers predictive information on both short-term and long-term mortality. Patients with symptoms that have lasted longer than 12 hours and who show clinical indications of hemodynamic instability, ongoing ischemia, malignant arrhythmias, or heart failure should also be evaluated for PCI [3].Negative clinical outcomes have been associated with 5–23% of patients' infarct-related coronary arteries failing to regain optimal blood flow (i.e less than TIMI-3 flow), even though the success rate for reopening the thrombotic blockage can reach up to 95%. This phenomenon has been explained by a variety of theories, such as disturbances at the level of the vascular endothelium and coronary microcirculation, or obstruction of the epicardial coronary channels (residual stenosis, thrombus, or dissection). (distal embolization of plaque debris and thrombotic materials, leukocyte infiltration, and reperfusion injury). Effective management techniques are still lacking, though, as is up-to-date information on the causes and effects of inadequate TIMI flow [4].

The effect of CSF on patient prognosis is among its most notable features. Research has indicated that CSF is linked to worse long-term outcomes, such as increased mortality and recurrent MI, as well as greater rates of in-hospital sequelae, such as heart failure and recurrent ischemia. This emphasizes how crucial it is to detect and treat CSF early in order to enhance therapeutic results [5].

Two popular angiographic techniques for evaluating myocardial perfusion after PCI are thrombolysis in MBG and myocardial infarction (TIMI) flow grade. TIMI flow or MBG less than three is considered suboptimal coronary flow following primary PCI. MBG, in particular, has been shown to provide valuable insights into the extent of microvascular perfusion and is predictive of long-term outcomes [6]. The surface electrocardiogram (ECG) shows that ischemia, reperfusion, and the presence of necrosis or scarring all have an impact on the heart's electrical activity. Therefore, the ECG has remained the most widely utilized auxiliary tool for the initial evaluation of patients, in addition to a thorough history taking and physical examination exhibiting symptoms consistent with acute coronary syndromes [7].

ECG alterations have been shown to have prognostic significance in ACS patients in addition to being diagnostic (e.g., ST elevation in STEMI). Patients who arrive late (>2–3 hours after the beginning of symptoms) are more likely to exhibit changes in the terminal component of the QRS in leads with ST elevation. (Sclarovsky-Birnbaum grade 3 ischemia) forecast a larger infarct, less myocardial salvage, and a worse prognosis. All the data, though, came from research that were analyzed after the fact. When determining whether to transfer patients who arrive at facilities lacking 24-hour catheterization laboratory access for primary PCI versus thrombolytic therapy, there are no prospective studies assessing the Sclarovsky-Birnbaum score [8]. It has been suggested that the negative consequences could be explained by a mechanistic connection between severe ischemia and inadequate cardiac tissue perfusion. It is hypothesized that widespread ischemia disrupts the QRS pattern on the ECG by disrupting the conduction system's Purkinje fibers, which normally withstand ischemia better than the heart tissue as a whole [9].

In patients receiving primary PCI for ACS, this study examines the function of QRS complex topologies and ST segment changes on the ECG as predictors for CSF and no-reflow occurrences.

METHODS

This observational cohort study was carried out between October 2023 and March 2024 at Zagazig University Hospital and Nasser Institute Hospital. comprised 66 patients who had initial PCI after presenting with acute coronary syndrome were recruited from the Cardiac Cath lab of both hospitals and were subdivided according to the ECG findings into two major groups (33 cases in each group); Group-1: STEMI patients, who were sub-divided into two groups according the presence or absence of the QRS distortion or fragmentation; 25 patients with QRS bifurcation or terminal distortion (QRS+) and 8 patients with normal QRS configuration (QRS-). Group 2: Non-ST-segment elevation (NSTE)-ACS patients were further divided into three subgroups based on the millimeter-scale ST segment shift: 22 patients had ST segment depression 0.5–1.5 mm (STD1), 6 patients had ST segment depression 2–2.5 mm (STD2) and 5 patients with ST segment depression of 3mm or more (STD3+).

Ethical approval

Every patient provided written informed permission, and Zagazig University IRB #11022 approved the study. The World Medical Association's (Declaration of Helsinki) rule of ethics for human subjects' research was followed in the conduct of the study.

Inclusion criteria were patients with ACS (STEMI, NSTEMI or unstable angina) presenting within 24 hours of evolution of symptoms and had an analyzable 12-lead ECG taken before revascularization.

Exclusion criteria Patients with the following criteria were excluded**;** Bundle branch block**,** pacemaker rhythm**,** received thrombolytic therapy**,** needed mechanical ventilation at the time of admission**,** any rhythm other than sinus rhythm, pre-excitation syndrome, poor-quality ECG that is difficult to read, and echocardiography-diagnoseddilated cardiomyopathy.

Hypertension was defined as blood pressure more than 140 mmHg for SBP and/or more than 90 mmHg for DPB. There is a new category called "Elevated BP," which is defined as a BP of 120-139/70-89 mmHg in the most recent 2024 ESC guidelines [10]. This new category aims to identify more individuals at risk for heart attack and stroke and to facilitate consideration of more intensive blood pressure treatment targets, but it was not included in the risk factors of our study because of being undocumented in patients' clinical history at time of emergency admission. According to the 2019 ESC guidelines for diabetes care, diabetes mellitus was diagnosed using the following criteria: Blood sugar levels should be at least 126 mg/dl during fasting or 200 mg/dl two hours after eating if the HbA1c is greater than 6.5%. Additionally, the classic indicators of diabetes were polyuria, polydipsia, and unexplained weight loss [11]. Dyslipidemia was considered according to recommendations of SCE guidelines for management of dyslipidemia (2019) when any of the following was present after 9 to 12 hours of fasting; serum cholesterol ≥200 mg/dl, LDL ≥130%, HDL <40 mg/dl[12].

All patients underwent demographic, clinical, analysis of the patient's full ECG, the abnormality Its shape and ST-segment shift were evaluated in the final region of the QRS complex. Cardioline ECG equipment was used to perform a standard 12-lead ECG on all patients upon admission prior to PCI, with a speed of 25 mm/sec and a voltage of 10 mm/mv. To ascertain whether ST segment elevation or depression was present, the ECG's ST segment level was compared to the baseline level. A drop in the ST segment level of more than or equal to 0.5 mm in two or more contiguous leads is referred to as ST segment depression, whereas an

increase in the ST segment level of more than or equal to 1 mm in two or more contiguous leads is known as ST segment elevation. The measurement was done manually on ECG images magnified with computer software. Our reference point for elevation and depression was the isoelectric TP segment as recommended by AHA guidelines [26].

The QRS complex was also analyzed, which represents the electrical activation of the ventricles. Possible QRS configurations include normal QRS, wide QRS, terminal QRS distortion and fragmented QRS. The QRS configuration was assessed for its association with CSF and NR in ACS patients post primary PCI.The QRS complex duration is the time from the end of the PR interval to the end of the S-wave. It normally differs according to age and gender, but generally the normal QRS duration is less than 110ms. We counted the number of small boxes between these points on the ECG strip and multiplied by 0.04 seconds to get the QRS complex duration. In order to exclude wide QRS complex cases from our study, we needed to measure the QRS complex duration and compare it with the normal range. Wide QRS ECG is a term that describes QRS complex duration ≥120 ms.[13].

A sign of ventricular depolarization is the QRS complex. Due to either His-Purkinje network dysfunction or reliance on slower, muscle-to-muscle transmission of depolarization, ventricular depolarization spreads more slowly when the QRS complex widens. Numerous cardiac disorders, including bundle branch block, ventricular hypertrophy, ventricular tachycardia, and pre-excitation syndrome, can be linked to wide QRS ECGs. We did not include any of these conditions in our study.

Fragmented QRS occurs when two contiguous leads that link to a large coronary artery have more than one R', a notched R or S wave, or an extra R wave (R' prime) (fQRS). QRS must not fit into any pattern of conventional bundle branch blocks and be thin (less than 80 ms). Contiguous leads include inferior leads (II, III, and aVF), lateral leads (I, aVL, and V 6), and anterior leads (V 1–V 5) [14].

Terminal QRS distortion (TQRSD) the development of the j-point at > 50% of the R wave in leads with qR configuration and/or the disappearance of the S wave in leads with rS configurations (leads V1-V3) were considered indicators of the terminal segment of the QRS complex on the ECG at admission [15].

Cardiac biomarkers levels were assessed to confirm the diagnosis of MI in patients who undergo primary PCI. Cardiac enzyme levels were measured using standard laboratory techniques, including the measurement of Troponin and Creatine Kinase levels (CK and CKMB). Patients with elevated levels of cardiac enzymes were subcategorized as STEMI or NSTEMI according to ECG findings, while patients with negative cardiac enzyme were subcategorized into unstable angina if they fit the before-mentioned criteria of inclusion. We measured admission Creatinine levels and HbA1c level to exclude other causes of impaired myocardial flow and poor prognosis in ACS patients undergoing primary PCI.

We analyzed the patient's coronary angiogram to investigate the relation between QRS configuration and ST segment shift and CSF and NR in ACS patients post primary PCI. We used a Phillips c-arm cathlab machine for angiography during PCI and the obtained angiograms were analyzed by assessing the degree of opacification of the coronary vessels during angiography, as well as the presence of a patent coronary artery. This involved comparing the degree of opacification to the baseline level on the angiography film to determine the presence of CSF or NR.

CSF is defined as delayed opacification of the coronary vessels during angiography, whereas NR is characterized by the failure of antegrade flow to the myocardial, even

after the restoration of epicardial blood flow, even in the presence of a patent coronary artery.

The analysis of the coronary angiogram was conducted by trained personnel who are experienced in interpreting angiography films using TIMI Flow Grading (TFG) and Myocardial Blush Grading (MBG)

TIMI Flow Grading (TFG) is an angiographic tool used to assess myocardial perfusion after PCI. The TIMI flow score ranges from 0 to 3, with 0 indicating no flow and 3 indicating normal flow.

Myocardial Blush Grading (MBG) is an additional angiographic technique used to evaluate myocardial perfusion following PCI. A score of 0 on the MBG scale means that there is no blush, while a score of 3 means that the blush is brisk and persistent.

The findings of the coronary angiography analysis were used to investigate the association between QRS configuration and ST segment shift and Coronary slow flow (CSF) and No-reflow (NR) in acute coronary syndrome (ACS) patients post primary PCI.

Following primary PCI, the enrolled patients' left ventricular function was evaluated using conventional transthoracic echocardiography utilizing the Philips Affiniti 50 echo machine's S5-1 probe. Determining the existence of any underlying structural cardiac disease that can complicate the connection between slow/no reflow phenomena and QRS/ST-segment alterations in ACS patients following primary PCI was also beneficial. Every echocardiographic test was carried out in compliance meets the standards established by ASE and the European Association of Cardiovascular Imaging [16].

Patients with dilated cardiomyopathy were excluded from the study because their underlying heart condition can affect the results and interpretation of the ECG. Therefore, by excluding patients with dilated cardiomyopathy, the study aims to more accurately Examine the connection between sluggish or nonexistent reflow and QRS/ST-segment alterations in ACS patients following primary PCI.

Assessment of LV systolic function by Simpson's Biplane method

The endocardial borders at the end diastole and end systole were manually traced, and two orthogonal views (apical two-chamber and apical four-chamber views) were acquired. The volume of each disc is determined by automated software after it has created a stack of discs oriented perpendicular to the ventricle's long axis. The end diastolic and end systolic volumes are computed from the end-diastolic and end-systolic frames, respectively.

It's calculated from this formula:

$$EF = \frac{EDV - ESV\ x\ 100}{EDV}$$

Normal EF ranges from 50 to 70%

Assessment of LV diastolic function

Pulse-containing wave Doppler imaging was used to record trans-mitral flow at the mitral leaflet terminals in the apical 4 chamber view:

To evaluate diastolic function, the peak velocities of early E and late A of atrial diastolic filling of the Doppler mitral flow and the E/A ratio were computed [17].

Statistical analysis

Basic clinical examinations, laboratory testing, outcome assessments, and data collected throughout time were all coded, entered, and analyzed using Microsoft Excel software. The data was then imported using IBM SPSS software suite version 20.0. (Armonk, New York: IBM Corp.) The qualitative data was described using numbers and percentages. The Shapiro-Wilk test was used to verify that the distribution was normal. Quantitative data were described using range (minimum and maximum), mean, standard deviation, median, and interquartile range (IQR). The results' significance (P value) was evaluated at the 5% level.

RESULTS

Table 1 showed that regarding sex in STEMI patients there was no significant difference between the two sub-groups, males > females (p = 1.0). As regards age, the mean age of the studied patients in QRS+ sub-group was 65.96 ± 13.0 and QRS- sub-group was 52.50 ± 11.55. There was a statistically significant difference between the two groups (P <0.014*). Regarding the risk factors, among the two sub-groups studied, only diabetes was found to be significantly higher in the QRS+ group (P=0.03).

Table 2 showed the coronary angiography findings in STEMI patients; Regarding Coronary TIMI flow after primary PCI in STEMI patients, 92% of the patients with QRS fragmentation or terminal distortion (QRS+) had a No-reflow or Slow-flow end-result (TIMI<3), while 50% of the patients with normal QRS (QRS-) had TIMI<3 flow. There was significant difference between the two groups (P = 0.020). Regarding Coronary MBG after primary PCI in STEMI patients, 80% of the patients in QRS+ group had No-reflow or Slow-flow end-result (MBG<3), while 50% of the patients in QRS- had MBG<3 flow. There was a significant difference between the two groups (P = 0.030). Regarding the number of stents and balloons used during the PCI, there was no significant difference between the two groups (P = 1.00, P= 0.597 respectively). Regarding post-stent dilatation, it was found to be significantly lower in QRS+ group with about 96% of the cases did not require post-stent dilatation versus 50% of the cases in the QRS- group (P = 0.008). Regarding the number of diseased vessels found during coronary angiography, there was no statistically significant difference between the two groups (P = 1.0).

Table 3 showed that the Echo data in STEMI patients, LVEF by M mode in QRS+ group Mean ± SD was 43.72 ± 7.58 and in QRS –ve group 47.38 ± 5.37. There was statistically significant decrease in EF in QRS+ve group (p = 0.021).

Table 4 showed Troponin level in QRS+ group Mean ± SD (0.84 ± 0.69) And QRS –ve group Mean ± SD. (0.24 ± 0.40). There was a statistically significant increase in Troponin level in the QRS+ group (P = 0.010). Regarding HbA1c level, it was found to be significantly higher in QRS+ patients (P=0.016). According to CKMB and Creatinine levels, there was no statistically significant difference between the two groups (P=0.2).

Figure 1 displays the Receiver Operating Characteristic (ROC) curve for the QRS configuration's ability to predict sub-optimal coronary flow (TIMI < 3) in STEMI patients following primary PCI. The ROC curve visually represents the trade-off between sensitivity and specificity across various thresholds.

Table 5 Regarding Gender in NSTE-ACS patients, there was no significant difference between three groups, males > females (p = 0.744). As regards age, the mean age of the studied patients in STD1 group was 52.23 ± 9.18 and in STD2 group was 59.33 ± 7.53 and in STD3+ group was 64.40 ± 7.64. So, the mean age was higher in STD3 group compared to STD1 group (P=0.023) with a statistically significant difference between the three groups (P = 0.017*). Regarding risk factors, there was no significant difference between three groups concerning diabetes (P=0.590), hypertension (p = 0.304) and other risk factors such as dyslipidemia and smoking (P=0.503).

Table 6 Ejection fraction (EF), the three groups did not differ significantly (P=0.283). The three groups did not differ statistically significantly in terms of left ventricular diastolic and systolic dimensions or diastolic function. (P=0.7).

Table 7 regarding Cardiac enzymes (Troponin and CKMB) levels, Troponin levels in group 3 were significantly higher than those in groups 2 (P=0.039) and 1 (P=0.001). There was no discernible difference in the three groups' HbA1C levels (P=0.384). Additionally, there was

no discernible variation in creatinine levels across the three groups (P=0.503).

Table 8 showed that there was statistically significant positive correlation between fragmented QRS or terminal QRS distortion (QRS+) and the occurrence of sub-optimal coronary flow (TIMI < 3) after primary PCI in acute coronary syndrome patients. (P= 0.002*). Meanwhile, there was no significant correlation between the other studied parameters and TIMI flow grade.

In STEMI table 9, QRS configuration (bifurcation or terminal distortion) in the QRS+ group was found to have statistically significant difference in predicting no reflow compared to the other group with normal QRS configuration (P=0.02). In NSTE-ACS, ST segment shift more than 3 mm was found to have statistically significant difference in predicting no reflow compared to the other twogroups(P=0.05).

Table (1): Comparison between the two sub-groups studied according to Demographic data, Risk factors and ECG Diagnosis

	STEMI				**Test of Sig.**	**p**
	QRS- (n = 8)		**QRS+ (n = 25)**			
	No.	**%**	**No.**	**%**		
Demographics						
Gender						
Male	7	87.5	20	80.0	χ^2= 0.229	^{FE}p= 1.000
Age (years)						
Min. – Max.	33.0 – 64.0		36.0 – 89.0		t= 12.97	0.014*
Mean ± SD.	52.50 ± 11.55		65.96 ± 13.0			
Risk factors	**No.**	**%**	**No.**	**%**	**Test of Sig.**	**P value**
DM	2	25	18	72.0	χ^2= 0.0179	FEp=0.035*
HTN	4	50.0	11	44.0	χ^2= 0.088	^{FE}p=1.000
Dyslipidemia	6	75.0	16	64.0	χ^2= 0.330	^{FE}p= 0.687
Smoking	6	75.0	16	64.0	χ^2= 0.330	^{FE}p= 0.687
Diagnosis						
INF	2	25.0	5	20.0	FET 2.879	0.372
INF-POST	1	12.5	1	4.0		
ANT	4	50.0	18	72.0		
POST	1	12.5	1	4.0		

IQR: Inter quartile range,SD: Standard deviation,t: Student t-test,χ^2: Chi square test ، FET: Fisher Exact test FEp: Probability calculated by Fisher Exact test p: p value for comparing between the two studied groupsANT: Anterior INF: Inferior INF-POST: Infero-posterior POST: Posterior

Table (2): Comparison between the two sub-groups according to Coronary Angiography Data

Coronary angiography	**STEMI**				**Test of Sig.**	**p**
	QRS- (n = 8)		**QRS+ (n = 25)**			
	Num	**%**	**Num**	**%**		
CA Findings						
One	6	75.0	18	72.0	FET= 1.126	1.000
Two	2	25.0	5	20.0		
Multivessel	0	0.0	2	8.0		
Lesions						

LM	0	0.0	1	4.0	$\chi2$=0.330	FEp=1.000
LAD	4	50.0	21	84.0	$\chi2$=3.815	FEp=0.074
LCX	3	37.5	3	12.0	$\chi2$=2.649	FEp=0.137
RCA	2	25.0	9	36.0	$\chi2$=0.330	FEp=0.687
TIMI grade						
0	0	0.0	3	12.0	FET= 4.049	0.211
I	1	12.5	3	12.0		
II	3	37.5	17	68.0		
III	4	50.0	2	8.0		
TIMI class						
Suboptimal (TIMI<3)	4	50.0	23	92.0	χ^2=7.186	^{FE}p=0.020*
Normal flow (TIMI 3)	4	50.0	2	8.0		
MBG grade						
0	0	0.0	3	12.0	FET= 1.629	0.746
I	1	12.5	3	12.0		
II	3	50.0	14	56.0		
III	4	37.5	5	20.0		
MBG class Suboptimal (MBG) Normal flow	 4 4	 50.0 50.0	 22 3	 80 20	χ^2=5.391	^{FE}p=0.030*
Number of stents						
No	0	0.0	2	8.0	FET= 0.978	1.000
1	4	50.0	13	52.0		
2	3	37.5	8	32.0		
3	1	12.5	2	8.0		
Balloon						
No	1	12.5	2	8.0	FET= 1.946	0.597
1	6	75.0	14	56.0		
2	1	12.5	8	32.0		
3	0	0.0	1	4.0		
Post-stent dilatation						
No	4	50.0	24	96.0	χ^2=9.975*	^{FE}p=0.008*
Yes	4	50.0	1	4.0		

t: Student t-test χ^2: Chi square test FET: Fisher Exact test FEp: Probability calculated by Fisher Exact test p: p value for comparing between the three studied groups

Table (3): Comparison between the two studied sub-groups according to Echo data

Echocardiography	STEMI		Test of sig.	p
	QRS- (n = 8)	QRS+ (n = 25)		
LVEF				
Min. – Max.	40.0 – 55.0	25.0 – 53.0	t=2.431*	0.021*
Mean ± SD.	49.63 ± 5.85	43.0 ± 6.94		
Median (IQR)	50.50(45.50 – 55.0)	45.0(40.0 – 48.0)		
LVDd				
Min. – Max.	50.0 – 65.0	47.0 – 75.0	t= 1.261	0.221
Mean ± SD.	55.75 ± 4.77	58.72 ± 8.22		
Median (IQR)	54.50 (52.50 – 58.50)	56.0 (53.0 – 65.0)		
LVSd				
Min. – Max.	35.0 – 50.0	33.0 – 60.0	t= 1.568	0.132
Mean ± SD.	40.75 ± 4.83	44.44 ± 8.09		
Median (IQR)	40.0 (37.0 – 43.50)	40.0 (39.0 – 53.0)		

Diastolic Dysfunction				
I	8(100.0%)	9(36.0%)	FET= 8.429	0.020*
II	0(0.0%)	9(36.0%)		
III	0(0.0%)	5(20.0%)		

IQR: Inter quartile range,SD: Standard deviation,FET: Fisher Exact test ,t: Student t-test
p: p value for comparing between the two studied groups *: Statistically significant at p ≤ 0.05

Table (4): Comparison between the two studied sub-groups according to Labs

Labs	STEMI		U	p
	QRS- (n = 8)	QRS+ (n = 25)		
Troponin				
Min. – Max.	0.01 – 1.20	0.01 – 3.0	40.50*	0.010*
Mean ± SD.	0.24 ± 0.40	0.84 ± 0.69		
Median (IQR)	0.06(0.03 – 0.25)	0.70(0.40 – 1.0)		
CKMB				
Min. – Max.	4.0 – 294.0	10.0 – 995.0	70.000	0.220
Mean ± SD.	91.75 ± 92.71	165.3 ± 228.6		
Median (IQR)	59.0(41.50 – 117.5)	91.0 (65.0 – 125.0)		
HbA1c				
Min. – Max.	5.60 – 8.0	5.0 – 9.70	162.50 *	0.016*
Mean ± SD.	6.08 ± 0.79	7.42 ± 1.10		
Median (IQR)	5.85(5.70 – 5.95)	7.40(6.80 – 8.10)		
Creatinine				
Min. – Max.	0.60 – 1.60	0.60 – 2.30	69.500	0.204
Mean ± SD.	1.01 ± 0.34	1.22 ± 0.41		
Median (IQR)	1.05 (0.70 – 1.20)	1.20 (0.90 – 1.40)		

IQR: Inter quartile range,SD: Standard deviation,U: Mann Whitney test p: p value for comparing between the two studied groups

Comparison for NSTE-ACS group

Table (5): Comparison between the three studied sub-groups according to demographic data and risk factors

Demographics	NSTE-ACS						Test of sig.	P
	STD1 (n = 22)		STD2 (n = 6)		STD3+ (n = 5)			
	No.	%	No.	%	No.	%		
Gender								
Male	14	63.6	5	83.3	3	60.0	FET= 0.959	0.744
Female	8	36.4	1	16.7	2	40.0		
Age (years)								
Min. – Max.	37.0 – 71.0		47.0 – 68.0		54.0 – 72.0		F= 4.719*	0.017*
Mean ± SD.	52.23 ± 9.18		59.33 ± 7.53		64.40 ± 7.64			
Median (IQR)	52.0 (45.0 -57.0)		59.50(56.0–66.0)		67.0(59.0 – 70.0)			
Sig.between groups	p_1=0.198, p_2=0.023*, p_3=0.608							
	NSTE-ACS							

Demographics	NSTE-ACS			Test	P
Risk factors	STD 0.5-1.5 (n = 22)	STD 2-2.5 (n = 6)	STD 3+ (n = 5)	FET	p
DM	8	36.4	3	50.0	3
HTN	10	45.5	2	33.3	4
Dyslipidemia	12	54.5	5	83.3	3

IQR: Inter quartile range,SD: Standard deviation,FET: Fisher Exact testF: F for One way ANOVA test, pairwise comparison bet. each 2 groups were done usingPost Hoc Test (Tukey)STD1:ST segment depression of 0.5to1.5mmSTD2:STsegmentdepressionof2to2.5mmSTD3+: ST segment depression of 3 mm or morep: p value for comparing between the three studied groupsp_1: p value for comparing between STD1 and STDp_2: p value for comparing between STD1 and STD3+p_3: p value for comparing between STD2 and STD 3+ *: Statistically significant at $p \leq 0.05$

Table (6): Comparison between the three studied groups according to Echo data

Echocardiography	NSTE-ACS			Test of sig.	p
	STD1 (n = 22)	STD2 (n = 6)	STD 3+ (n = 5)		
EF%					
Min. – Max.	30.0 – 57.0	35.0 – 60.0	20.0 – 55.0	**F**=1.317	0.283
Mean ± SD.	45.82 ± 7.03	48.83 ± 8.61	40.0 ± 16.58		
Median (IQR)	47.0(40.0 – 50.0)	49.0(45.0 – 55.0)	45.0(25.0 – 55.0)		
LVDd					
Min. – Max.	42.0 – 74.0	50.0 – 75.0	46.0 – 77.0	**F**=0.351	0.707
Mean ± SD.	56.77 ± 8.86	57.33 ± 9.07	60.80 ± 13.85		
Median (IQR)	55.0 (49.0 – 64.0)	54.50(52.0 – 58.0)	55.0 (52.0 – 74.0)		
LVSd					
Min. – Max.	26.0 – 57.0	35.0 – 60.0	32.0 – 60.0	**F**=0.283	0.755
Mean ± SD.	42.14 ± 8.27	41.33 ± 9.50	45.20 ± 12.52		
Median (IQR)	41.0 (37.0 – 49.0)	38.0 (35.0 – 42.0)	40.0 (37.0 – 57.0)		
Diastolic Dysfunction					
I	11(50.0%)	4(66.7%)	4(80.0%)	**FET=** 2.514	0.702
II	7(31.8%)	1(16.7%)	0(0.0%)		
III	4(18.2%)	1(16.7%)	1(20.0%)		

IQR: Inter quartile range,SD: Standard deviation,F: F for One way ANOVA test,FET: Fisher Exact test p: p value for comparing between the three studied groups,STD1: ST segment depression of 0.5 to 1.5 mm STD2:STsegmentdepressionof2to2.5mm,STD3+:STsegmentdepressionof3mmormore

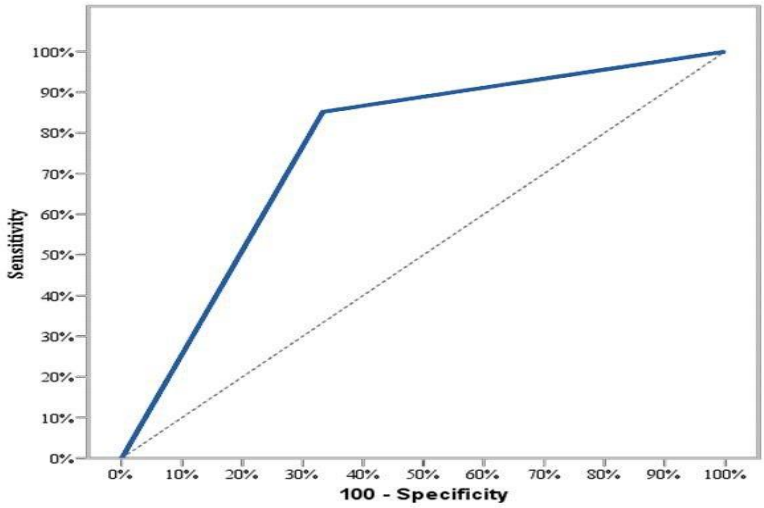

Fig. 1: ROC curve for QRS configuration to predict sub-optimal coronary flow (TIMI < 3) in STEMI after primary PCI

Table (7): Comparison between the three studied groups of (NSTE-ACS) according to Labs

Labs	NSTE-ACS			H	p
	STD1 (n = 22)	STD2 (n = 6)	STD3+ (n = 5)		
Troponin					
Min. – Max.	0.09 – 1.50	0.20 – 1.30	1.10 – 2.0	8.558*	0.014*
Mean ± SD.	0.78 ± 0.37	0.87 ± 0.37	1.52 ± 0.40		
Median (IQR)	0.75(0.50 – 1.10)	0.90(0.80 – 1.10)	1.70(1.10 – 1.70)		
Sig. between groups	p_1=0.400, p_2=0.001*, p_3=0.039*				
CKMB					
Min. – Max.	26.0 – 260.0	70.0 – 225.0	85.0 – 215.0	4.676	0.097
Mean ± SD.	113.1 ± 60.49	167.7 ± 56.95	166.8 ± 51.64		
Median (IQR)	89.0 (75.0 – 165.0)	163.0 (160.0 – 225.0)	190.0 (149.0 – 195.0)		
HbA1c					
Min. – Max.	5.40 – 9.50	5.10 – 9.50	6.10 – 8.80	1.912	0.384
Mean ± SD.	6.68 ± 1.15	7.08 ± 2.02	7.44 ± 1.23		
Median (IQR)	6.35 (5.80 – 7.30)	6.75 (5.30 – 9.10)	6.80 (6.80 – 8.70)		
Creatinine					
Min. – Max.	0.50 – 2.30	0.80 – 1.80	0.70 – 1.40	1.375	0.503
Mean ± SD.	1.12 ± 0.39	1.25 ± 0.34	1.18 ± 0.29		
Median (IQR)	1.10 (0.90 – 1.30)	1.25 (1.0 – 1.40)	1.30(1.10 – 1.40)		

IQR: Inter quartile range ,SD: Standard deviation ,H: H for Kruskal Wallis testp: p value for comparing between the three studied groupsSTD1: ST segment depression of 0.5 to 1.5 mm,STD2: ST segment depression of 2 to 2.5 mm,STD3+: ST segment depression of 3 mm or more

Table (8): Logistic regression analysis for the studied parameters and their correlation with suboptimal coronary flow (TIMI < 3) after primary PCI in total ACS sample

Variables	Sub-optimal coronary flow (TIMI < 3) after pPCI	
	p	OR (LL – UL 95% C.I)
Gender (Female)	0.586	1.394(0.422 – 4.599)
DM	0.144	2.160(0.769 – 6.073)
HTN	0.678	1.241(0.448 – 3.436)
Dyslipidemia	0.845	0.900(0.313 – 2.592)
Positive QRS	0.002*	12.075(2.514 – 58.001)

OR: Odd`s ratioC.I: Confidence interval,LL: Lower limit ,UL: Upper Limit#: All variables with p<0.05 was included in the multivariate, *: Statistically significant at $p \leq 0.05$

Table (9): Prognostic performance of QRS configuration and ST segment shift to predict sub-optimal coronary flow after primary PCI in ACS patients

ECG	STEMI cases			
	Normal flow (n = 6)		No Reflow (n = 27)	
	No.	%	No.	%
QRS config.				
Negative	4	66.7	4	14.8
Positive	2	33.3	23	85.2
χ^2 (p)	7.187(^{FE}p=0.0202)			
	NSTE-ACS cases			
	Normal flow (n=17)		No Reflow (n=16)	
ST segment shift				
STD1	13	76.5	9	56.2
STD2	4	23.5	2	12.5
STD3+	0	0	5	31.3
χ^2 (p)	6.208(^{FE}p=0.049)			

χ^2: Chi square test ,FE: Fisher Exact testp: p value for association between different categories

*: Statistically significant at $p \leq 0.05$

DISCUSSION

According to our study's demographic information and risk assessment, 74% of the patients were men and 26% of the patients were women. We observed that the elderly and diabetic patients are at higher risk for developing QRS distortion and fragmentation (QRS+) with STEMI. It was in agreement with previously published data by *García-Rubira et al.* [18] , *Postma et al.* [19] and *Bakirci et al.* [20]. They represent a high-risk population with less capability for new collateral vessels development.

Our study showed that, STEMI patients with QRS bifurcation or terminal distortion (QRS+) have a mean of age (65.96 ± 13.0) years. Meanwhile in the other group without such QRS configuration, there was a notable disparity between the two groups, with the mean age being 52.50 ± 11.55 years (P =0.014). In the study by *García-Rubira et al.* [18] which aimed at studying the elder group (which has a mean age older than the patients in our study) 30% of the patients in the elder group (age>75 years) was found to have QRS distortion in the initial ECG,

compared to 20% of the non-elder group, which is statistically significant. (P=0.023) Similar results were obtained in the study by Postma et al. [19], which discovered that high-risk patient features like diabetes (P=0.014) and advanced age were associated with Grade 3 ischemia (G3I), which is defined by the distortion of the terminal component of the QRS complex. (P<0.001), which appear to be linked to poor myocardial reperfusion and a worse prognosis.

Concerning risk factors of acute coronary syndrome, our study found that QRS+ group had more diabetic patients that constituted 72% of QRS+ patients compared to 25% of QRS- group, which is a significant difference between the two groups (P=0.0351). But we found no significant difference concerning hypertension (P=1.0).Our results are in agreement with a study by *Postma et al* [19] the findings showed that diabetes was more common in the group with terminal QRS distortion (P=0.014), while the two groups' levels of hypertension did not differ significantly (P=0.414).In disagreement with our study, *Bakirci et al* [20] who aimed at studying the correlation between grade 3 ischemia and terminal QRS distortion and the severity of CAD found no significant difference concerning the occurrence of diabetes mellitus between ischemia in grades two and three. (P=0.178)

Other risk variables such as smoking and dyslipidemia did not significantly differ between the two groups in this study (P>0.05), which is consistent with earlier research by *Tanriverdi et al* [21], *Bakirci et al* [20] and *Postma et al [19]* that found no statistically significant difference (P>0.05).In our study, we also observed that Troponin T levels in a group with QRS+ patients is significantly higher as compared to the QRS-ve group and that was in disagreement with data obtained from a previous study by *Bakirci et al.* [20] which found that G3I was independently related to higher SYNTAX score which explain troponin levels revealed no discernible difference between grade 2 and grade 3 ischemia, despite the patients' poor prognosis. Regarding serum Creatinine level, Between the two groups, we could not find any discernible differences. (P=0.204) which is in agreement with a study by *Tanriverdi et al* [21] (P=0.067).

In our investigation, the group with QRS+ configuration had a significantly lower LVEF by echocardiography than the QRS- group (P=0.021) and that was matching with a previous study by *García-Rubira et al.* [18] which found QRS+ as one of the only three variables (along with Killip ≥ II at admission, and history of previous infarction) significantly related to major adverse events after primary PCI (P=0.006). *Tanriverdi et al.* [21] also found LVEF to be significantly lower among the group with fragmented QRS in comparison to the group with normal QRS configuration (P <0.001).

Our results regarding the QRS+ group's reduced ejection % also concur with the findings of the study by *Bakirci et al.* [20] which found terminal QRS distortion (G3I) to be more associated with Killip class ≥ II

In this study, we discovered that QRS distortion on the admission ECG is a significant predictor of poorer TIMI flow grade among STEMI patients who got primary PCI. Inadequate coronary flow (TIMI flow < 3) accounted for 92% of the patients in QRS+ group as compared to 50% of the patients in QRS- group (P=0.02).This agrees with the results of a the study by *Tanriverdi et al.* [21] that investigated the predictive significance of fragmented QRS and terminal QRS distortion for reperfusion success in STEMI, these ECG alterations were found to independently predict that myocardial reperfusion,asmeasured electrocardiographicallyand angiographically following primary PCI, would not be achieved (P < 0.05). Similarly, the data obtained from a previous study by *Bakirci et al.* [20] who studied the predictive value of terminal

QRS distortion found that G3I was independently related to higher SYNTAX score and lower TIMI flow grade (TIMI III flow rates were lower in G3I than G2I group), which account for the poor outcome in these patients. Moreover, *Bakirci et al.* [20] observed that angiographic no-reflow was significantly more frequently seen with higher SYNTAX score in G3I group that show terminal QRS distortion on ECG, which agrees with our findings.In a study by *Valle-Caballero et al.* [22], a larger infarct size as assessed by CMR five to seven days after the infarction was linked to QRS distortion on the admission ECG prior to perfusion. suggesting that a sizable region of the myocardium is probably at risk for terminal QRS distortion.

In our study, we noticed that cases with QRS bifurcation or terminal distortion on admission ECG often required post-dilatation with non-compliant (NC) balloons, with a statistically significant difference from the group with normal QRS configuration (P = 0.008). This is most probably due to heavy calcification which often occurs in elder patients and accounts for sub-optimal coronary perfusion after primary PCI [5].

NSTE-ACS group

In the NSTE-ACS group in our study, we investigated the predictive value of ST segment shift on admission ECG for the occurrence of sub-optimal coronary slow (TIMI flow grade < 3) after primary PCI. This group had 33 patients, 22 of them were males, and we sub-classified the patients in this group according to the degree of ST segment depression on admission ECG into 3 subgroups:

STD1: patients with ACS and ST depression 0.5-1.5mm on admission ECG

STD2: patients with ACS and ST depression 2-2.5mm on admission ECG

STD3+: patients with ACS and ST depression ≥ 3mm on admission ECG

The three groups did not differ significantly in terms of gender with men outnumbering women in all categories (p = 0.744).

In our study we also observed that patients with more ST depression are older with a mean of age (64.40 ± 7.64) in ST depression equal or more than 3 mm compared to mean of age (52.23 ± 9.18) within 0.5 to 1.5 mm of ST depression. The STD3+ and STD1 groups differed significantly in terms of age (P=0.017)

This agrees with a study from *Kosuge et al.* [23] Studies describing the clinical effects of persistent ST segment depression after admission in patients with non-ST segment elevation acute coronary syndrome found that patients with ST segment depression were older, more likely to have multivessel disease and hypertension, and had a longer history of coronary disease. The risk variables for smoking, dyslipidemia, diabetes mellitus, and hypertension did not significantly differ among the three groups (P > 0.05).

We discovered that the group with ST depression ≥ 3mm (STD3+) had a considerably greater Troponin T level than the other two groups (P=0.014). A considerable proportion of patients had three vessels or left main coronary disease, according to the FRISC II ECG sub-study, which examined the degree of coronary artery lesions in NSTE-ACS in relation to the existence or lack of ST segment depression. In a study by *Huziuk et al.* [25], it was discovered that an increased Troponin T level was independently linked to the risk of multivessel coronary artery disease, which agrees with our findings regarding higher Troponin T level with the more extensive ischemia in STD3+ group.

We found ST-segment depression more than 3mm on admission ECG to be more correlated with sub-optimal coronary flow after primary PCI compared to the other groups with lower extent of ST-segment deviation (p ≤ 0.05). Regarding the quantity of stents and post-stent dilatation balloons utilized during initial PCI, there was no discernible variation among the three groups.Our findings also agree with

the study by *Kaul et al.* [24] that investigated the significance of ST segment depression as a prognostic factor on baseline ECG in acute coronary syndromes and discovered that it was the most reliable indicator of death within a year, representing 35% of the predictive ability of the model. Individuals with ST segment depression ≥ 2 mm had around a six-fold increased risk of dying within a year than for those without. Additionally, the risk of dying within a year was nearly ten times higher for patients with ST segment depression ≥ 2 mm in more than one lead than for those without ST segment depression.

According to the findings of the aforementioned research, risk classification in NSTE-ACS can be facilitated by ST segment analysis performed soon after admission. More severe medical treatment and coronary intervention are likely to be most beneficial for patients with significant ST segment depression.

Future research should focus on elucidating the underlying mechanisms linking QRS configuration, ST segment shifts, and microvascular dysfunction in ACS patients after primary PCI. Prospective studies incorporating larger patient cohorts and longitudinal follow-up are warranted to establish definitive guidelines for incorporating ECG-derived parameters into routine clinical practice for risk assessment and therapeutic decision-making.

The limitations of the study:

Study limitations include the dual-center design and the comparatively small sample size, which could limit how broadly the results can be applied. Therefore, before routinely using these ECG characteristics as predictors of coronary slow flow following pPCI, the current findings must be validated in a larger multicenter investigation. Furthermore, the study's exclusion of individuals who had thrombolytic therapy limited our understanding of this patient category. The study is also limited by the variability in image analysis, as all coronary angiograms were assessed manually without the aid of specialized software, which may introduce observer bias and affect reproducibility. Additionally, QRS configuration analysis was restricted to binary categorization (presence or absence) rather than a graded or numeric scale, as no specific cutoff was available. This binary approach may limit the precision of QRS as a predictive metric and underscores the need for standardized, quantitative criteria on larger, more diverse samples in future studies to strengthen these findings.

Conclusions

In conclusion, QRS configuration and ST segment shift on ECG represent valuable tools for identifying and predicting coronary slow flow and no reflow phenomena after primary PCI in ACS patients. These ECG markers offer insights into underlying myocardial pathology and microvascular dysfunction, guiding clinicians in early risk stratification and tailored therapeutic interventions aimed at improving clinical outcomes in this high-risk patient population.

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