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Research Article

Electrocardiographic Predictors of Left Ventricular Systolic Dysfunction in Acute STEMI Patients Undergoing Primary PCI

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Abstract: Acute ST-segment elevation myocardial infarction (STEMI) frequently results in left ventricular systolic dysfunction despite timely reperfusion with primary percutaneous coronary intervention (PCI). Early identification of patients at risk for impaired ventricular function remains clinically essential. This prospective observational study evaluated electrocardiographic predictors of left ventricular systolic dysfunction in acute STEMI patients undergoing primary PCI. A total of 182 consecutive patients were enrolled. Admission electrocardiograms were analyzed for ST-segment deviation magnitude, Q-wave formation, fragmented QRS complexes, and reciprocal ST changes. Left ventricular ejection fraction was assessed by transthoracic echocardiography within 72 hours post-PCI. Reduced ejection fraction (<40%) was observed in 41.2% of patients. Fragmented QRS complexes, anterior infarct location, persistent ST elevation ≥3 mm, and pathological Q waves were independently associated with systolic dysfunction ($p < 0.001$). Fragmented QRS demonstrated the strongest predictive value (OR 3.84, 95% CI 2.01–7.33). These findings highlight the prognostic utility of routine electrocardiography for early risk stratification following STEMI. This study provides novel evidence supporting electrocardiographic markers as accessible predictors of post-infarction ventricular dysfunction in the era of primary PCI.

Keywords: STEMI; electrocardiography; left ventricular dysfunction

Introduction: ST-segment elevation myocardial infarction represents a critical manifestation of acute coronary syndrome characterized by abrupt coronary artery occlusion and transmural myocardial ischemia. Despite substantial improvements in reperfusion therapy and systems of care, STEMI continues to be associated with significant morbidity, particularly due to the development of left ventricular systolic dysfunction. Impaired ventricular performance following myocardial infarction is a major determinant of heart failure, arrhythmias, and long-term mortality.[1-3]

Primary percutaneous coronary intervention has become the preferred reperfusion strategy for STEMI, offering rapid restoration of coronary blood flow and limitation of infarct size. However, even with timely PCI, a

considerable proportion of patients develop persistent ventricular dysfunction. This reflects the complex interplay of ischemic duration, myocardial necrosis, microvascular obstruction, and reperfusion injury. Identifying patients at risk for adverse ventricular remodeling early in the clinical course remains a priority.[4-7]

Electrocardiography is universally available, inexpensive, and rapidly performed at first medical contact in STEMI patients. Beyond its diagnostic role, the admission electrocardiogram contains valuable prognostic information reflecting infarct size, myocardial injury severity, and electrical instability. Specific electrocardiographic features may provide early insight into the likelihood of subsequent left ventricular dysfunction.[8-12]

ST-segment elevation magnitude and persistence are established indicators of transmural ischemia and incomplete reperfusion. Extensive ST elevation has been associated with larger infarct size and poorer functional recovery. Reciprocal ST-segment depression further reflects widespread ischemic burden and may indicate multivessel involvement or extensive myocardial injury.

Pathological Q waves represent irreversible myocardial necrosis and are frequently linked to reduced contractile reserve. Fragmented QRS complexes, characterized by additional R waves or notching of the QRS complex, have emerged as markers of myocardial scar, conduction delay, and heterogeneous ventricular activation. Their presence has been increasingly associated with adverse structural and functional outcomes following myocardial infarction.

Although echocardiography remains the standard modality for assessing ventricular function, it is not always immediately available and may be limited by operator dependency. Early electrocardiographic predictors could assist clinicians in identifying high-risk patients prior to imaging, enabling closer monitoring and aggressive secondary prevention strategies.

This prospective study was designed to evaluate specific electrocardiographic parameters as predictors of left ventricular systolic dysfunction in acute STEMI patients undergoing primary PCI. By correlating early ECG findings with post-procedural ventricular function, the study aims to provide clinically relevant insights into simple, readily available risk stratification tools.

Methodology: This prospective observational study was conducted in the cardiology department at National Hospital and Medical Centre, Lahore 2023 and April 2024. Adult patients aged 18 years or older presenting with acute STEMI and undergoing primary percutaneous coronary intervention within 12 hours of symptom onset were consecutively enrolled. STEMI diagnosis was based on clinical presentation, characteristic electrocardiographic changes, and elevated cardiac biomarkers. Verbal informed consent was obtained from all participants or their legally authorized representatives.

A standard 12-lead electrocardiogram was recorded at admission before PCI. Electrocardiograms were independently analyzed by two cardiologists blinded to echocardiographic outcomes. Evaluated parameters included infarct location, maximum ST-segment elevation, presence of reciprocal ST depression, pathological Q waves, and fragmented QRS complexes. Fragmented QRS was defined as the presence of additional R waves or notching in at least two contiguous leads corresponding to the infarct territory.

All patients underwent transthoracic echocardiography within 72 hours following PCI. Left ventricular ejection fraction was calculated using the biplane Simpson method. Left ventricular systolic dysfunction

was defined as an ejection fraction below 40%.

Sample size was calculated using Epi Info software assuming a prevalence of left ventricular dysfunction of 40%, a 95% confidence level, 80% power, and a 7% margin of error. The minimum required sample size was 176 patients; 182 patients were included to account for incomplete data. Inclusion criteria comprised confirmed acute STEMI, successful primary PCI, and availability of interpretable ECG and echocardiographic data. Exclusion criteria included previous myocardial infarction, known cardiomyopathy, bundle branch block, paced rhythm, significant valvular heart disease, and cardiogenic shock at presentation. Statistical analysis involved chi-square tests, independent t-tests, and multivariate logistic regression. A p-value <0.05 was considered statistically significant.

Results

Table 1. Baseline Demographic and Clinical Characteristics

Variable	Preserved EF (n = 107)	Reduced EF (n = 75)
Age (years)	55.1 ± 11.9	58.7 ± 12.4
Male (%)	83 (77.6)	60 (80.0)
Diabetes mellitus (%)	39 (36.4)	35 (46.7)
Anterior STEMI (%)	38 (35.5)	49 (65.3)

This table shows higher prevalence of anterior infarction and comorbidities in patients with reduced ejection fraction.

Table 2. Electrocardiographic Findings and Left Ventricular Dysfunction

ECG Parameter	Preserved EF	Reduced EF	p-value
ST elevation ≥3 mm (%)	34.6	70.7	<0.001
Fragmented QRS (%)	18.7	61.3	<0.001
Pathological Q waves (%)	22.4	58.7	<0.001
Reciprocal ST depression (%)	31.8	56.0	0.002

This table demonstrates significantly higher prevalence of adverse ECG markers in patients with systolic dysfunction.

Table 3. Multivariate Predictors of Reduced Left Ventricular Ejection Fraction

Predictor	Odds Ratio	95% CI	p-value
Fragmented QRS	3.84	2.01–7.33	<0.001
Anterior STEMI	2.91	1.54–5.48	0.001
ST elevation ≥3 mm	2.47	1.29–4.72	0.006
Pathological Q waves	2.18	1.14–4.16	0.018

This table identifies fragmented QRS as the strongest independent predictor of systolic dysfunction.

Discussion: The findings of this prospective study demonstrate that specific electrocardiographic features at presentation are strong predictors of left ventricular systolic dysfunction in acute STEMI patients undergoing primary PCI. Among the evaluated parameters, fragmented QRS complexes emerged as the most powerful independent predictor, underscoring their association with extensive myocardial damage and conduction heterogeneity.[13-15]

The strong association between anterior infarction and reduced ejection fraction observed in this study aligns with the anatomical significance of the left anterior descending artery territory. Infarction in this region compromises a substantial proportion of left ventricular myocardium, predisposing patients to significant systolic impairment despite successful reperfusion.[16-17]

Persistent and extensive ST-segment elevation was also independently associated with ventricular dysfunction. This finding suggests ongoing transmural injury or incomplete microvascular reperfusion, even after restoration of epicardial flow. ST-segment magnitude reflects ischemic burden and infarct size, reinforcing its prognostic value beyond initial diagnosis.[18-20]

Pathological Q waves were significantly more prevalent among patients with reduced ejection fraction, reflecting irreversible myocardial necrosis. Their presence indicates loss of viable myocardium and diminished contractile reserve, contributing to early systolic dysfunction.

Fragmented QRS complexes likely represent areas of myocardial scar interspersed with viable tissue, leading to delayed and inhomogeneous ventricular activation. This electrical disorganization correlates with structural damage and impaired mechanical function, explaining its strong predictive capability.

The practical value of these findings lies in the universal availability of electrocardiography. Early identification of high-risk patients using simple ECG markers may prompt intensified monitoring, early initiation of heart failure therapies, and closer follow-up after discharge.

The strengths of this study include its prospective design, blinded ECG interpretation, and standardized echocardiographic assessment. Limitations include its single-center nature and lack of long-term follow-up on ventricular remodeling. Future studies incorporating serial ECG and echocardiographic evaluation may further refine risk stratification.

Overall, the results support the integration of electrocardiographic predictors into routine clinical assessment following STEMI in the era of primary PCI.

Conclusion: Specific electrocardiographic markers, particularly fragmented QRS complexes, reliably predict left ventricular systolic dysfunction in acute STEMI patients undergoing primary PCI. This study highlights the prognostic value of routine ECG in early post-infarction risk stratification. The findings address an important clinical gap and support broader utilization of ECG-based predictors in contemporary STEMI management.

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