Original Article

Echocardiographic Evaluation of Poor R-wave Progression in ECG

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Abstract

Background: *Poor R-wave progression on electrocardiography has long been associated with anterior myocardial infarction. However, in contemporary practice, its structural and functional correlates are inconsistent, and the true echocardiographic implications remain incompletely characterized.*

Objectives: *To determine the prevalence of echocardiographic abnormalities among patients with poor R-wave progression and to assess their associations with socio-demographic factors, cardiovascular risk factors, comorbidities, and clinical symptoms.*

Materials and Methods: *This hospital-based cross-sectional study included 196 adults with poor R-wave progression on standard 12-lead electrocardiography. All participants underwent transthoracic echocardiography to evaluate regional wall motion abnormalities, left ventricular hypertrophy, prior myocardial infarction patterns, and left ventricular ejection fraction. Categorical variables were summarized as frequencies and percentages. Associations between clinical variables and echocardiographic findings were assessed using Pearson's chi-square test. Multivariable binary logistic regression was performed to identify independent predictors of regional wall motion abnormalities. A two-sided p-value <0.05 was considered statistically significant.*

Results: *Regional wall motion abnormalities were present in 67.9% of participants, and 50.5% demonstrated reduced left ventricular ejection fraction (<50%). Overall, 77.0% exhibited at least one echocardiographic abnormality. Hypertension was significantly associated with reduced ejection fraction (p=0.002). Shortness of breath on exertion showed a strong association with reduced ejection fraction (p<0.001), and male gender was also significantly associated with reduced ejection fraction (p=0.022). No significant association was observed between age group and regional wall motion abnormalities.*

Conclusion: *Poor R-wave progression is frequently associated with clinically relevant structural and functional myocardial abnormalities. Echocardiographic evaluation should be considered to identify underlying ventricular dysfunction in affected patients.*

Key words: *Echocardiography, Electrocardiography, Left ventricular ejection fraction, Poor R-wave progression, Regional wall motion abnormality, Ventricular dysfunction*

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Introduction

Poor R-wave progression (PRWP) in the precordial leads is a frequently encountered electrocardiographic abnormality characterized by failure of the R wave to increase normally from leads V1 through V4. Historically, PRWP has been considered suggestive of anterior myocardial infarction (MI), based on early clinicopathological studies demonstrating loss of anterior electrical forces in patients with transmural necrosis.[1-5] Zema and Kligfield first provided a detailed synthesis of PRWP patterns and emphasized the variability of diagnostic criteria,[1,4] while DePace et al. reported that although PRWP may indicate prior MI, its predictive value remains limited when used in isolation.[3] Post-mortem correlations further supported the association between anterior wall infarction and altered R-wave progression.[5]

Subsequent investigations, however, challenged the specificity of PRWP. Gami et al. demonstrated that different PRWP definitions yield inconsistent clinical performance.[6] Moreover, PRWP has been described in a range of non-ischemic conditions,

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including left ventricular hypertrophy, dilated cardiomyopathy, chronic lung disease, and even normal physiological variants.[6-8] Technical factors such as improper lead placement and body habitus may also influence R-wave progression.[7,9] Contemporary registry data continue to explore its clinical significance in modern populations.[10]

Population-based studies have further shown that PRWP is relatively prevalent among adults without overt coronary artery disease.[11] More recently, PRWP has been associated with adverse cardiovascular outcomes, including sudden cardiac death, suggesting that it may represent an underlying myocardial substrate abnormality rather than a discrete infarction pattern.[12]

Echocardiography remains the cornerstone for structural and functional cardiac assessment. Regional wall motion abnormalities (RWMA) typically reflect localized ischemia or myocardial scar, whereas reduced left ventricular ejection fraction (LVEF) indicates global systolic dysfunction and independently predicts cardiovascular morbidity and mortality.[13-15] Cardiovascular risk factors such as hypertension and diabetes mellitus contribute significantly to myocardial remodelling and dysfunction. Hypertension induces pressure overload and ventricular hypertrophy with eventual impairment of systolic performance,[16,17] while diabetes is associated with both accelerated atherosclerosis and diabetic cardiomyopathy independent of obstructive coronary disease.[18] Given the substantial global burden of cardiovascular disease,[19] clarifying the structural correlates of PRWP is clinically relevant, particularly in resource-limited settings.

Despite extensive literature on PRWP, data correlating this electrocardiographic pattern with echocardiographic abnormalities in South Asian populations remain limited. Therefore, this study aimed to describe the echocardiographic findings among adult patients with PRWP, determine the prevalence of echocardiographic abnormalities, and compare these findings across clinical subgroups defined by cardiovascular risk factors such as hypertension, diabetes mellitus, smoking status, and obesity. In addition, the study sought to evaluate differences in echocardiographic findings between patients with and without selected comorbid conditions, including ischemic heart disease, chronic obstructive pulmonary disease, and chronic kidney disease, thereby providing a comprehensive assessment of the clinical and structural correlates of PRWP in this population.

Material and Methods

This hospital-based descriptive and comparative cross-sectional study was conducted in the Department of Cardiology at Khwaja Yunus Ali Medical College and Hospital over a 12-month period from January 2024 to December 2024. The study population comprised adult indoor and outdoor patients aged 25–75 years who demonstrated poor R-wave progression (PRWP) on a standard 12-lead electrocardiogram (ECG) and subsequently underwent transthoracic echocardiography during the study period. PRWP was defined as an R-wave amplitude <3 mm in lead V3 and/or an R-wave amplitude in lead V3 less than that in lead V2. Patients with electrocardiographic evidence of Q-wave anterior myocardial infarction, left bundle branch block, left ventricular hypertrophy on ECG, Wolff–Parkinson–White syndrome, severe illness precluding echocardiographic evaluation, or inability/refusal to provide informed consent were excluded. The minimum required sample size was calculated using the single population proportion formula considering a 15% estimated prevalence of PRWP1 and 5% margin of error, yielding 196 participants; accordingly, 196 consecutive eligible patients were recruited using a consecutive sampling technique.

Data were collected using a pre-tested structured questionnaire and clinical assessment form capturing sociodemographic characteristics, presenting symptoms (chest pain and shortness of breath on exertion), cardiovascular risk factors (hypertension, diabetes mellitus, smoking status, dyslipidemia, and obesity), and comorbid conditions including ischemic heart disease, chronic obstructive pulmonary disease, and chronic kidney disease. Standard 12-lead ECGs were reviewed to confirm PRWP according to predefined criteria. Transthoracic echocardiography was performed by experienced cardiologists following standard imaging protocols, assessing regional wall motion abnormalities (RWMA), pattern of RWMA, evidence of old myocardial infarction, left ventricular hypertrophy, left ventricular dilatation, global hypokinesia, and left ventricular systolic function measured by ejection fraction. Independent variables included age, sex, presenting symptoms, cardiovascular risk factors, and comorbidities, while primary outcome variables were the presence and pattern of RWMA and left ventricular systolic dysfunction (ejection fraction <50%).

Data were entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 25. Categorical variables were summarized as frequencies and percentages. Associations between echocardiographic abnormalities (RWMA and reduced left ventricular ejection fraction) and clinical variables were assessed using Pearson's chi-square test, and multivariable binary logistic regression was performed to identify independent predictors of RWMA, reporting adjusted odds ratios with 95% confidence intervals. A two-sided p-value <0.05 was considered statistically significant. Ethical approval was obtained from the Institutional Ethics Review Board of Khwaja Yunus Ali Medical College, and written informed consent was obtained from all participants, ensuring confidentiality, anonymity, and voluntary participation.

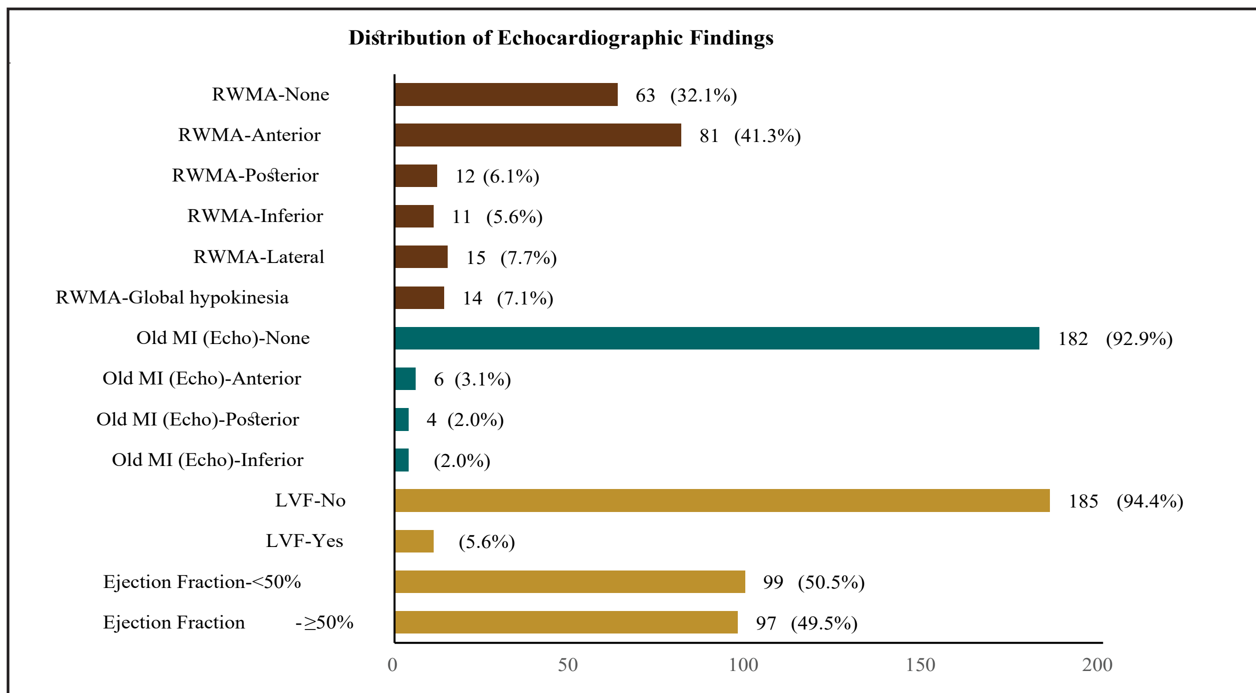
Results

Table I: Socio-demographic characteristics, clinical symptoms, and physical examination findings of the study participants (n= 196)

Variables	Category	Frequency	Percentage
Age group (years)	25–45	39	19.9
	46–65	113	57.7
	>65	44	22.4
Sex	Male	115	58.7
	Female	81	41.3
Cough	No	160	81.6
	Yes	36	18.4
Chest pain	No	96	49.0
	Yes	100	51.0
Chest discomfort on exertion	No	134	68.4
	Yes	62	31.6
Shortness of breath on exertion	No	105	53.6
	Yes	91	46.4
Systolic blood pressure (mmHg)	<140	158	80.6
	≥140	38	19.4
Diastolic blood pressure (mmHg)	<90	179	91.3
	≥90	17	8.7
Cardiac auscultation findings	Normal	193	98.5
	Added sound	3	1.5
Pulmonary auscultation findings	Normal	137	69.9
	Crepitations	49	25.0
	Rhonchi	9	4.6
	Crepitations + rhonchi	1	0.5

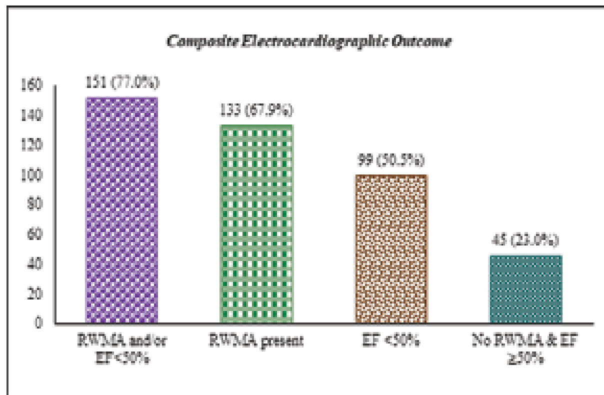
Table I summarizes the socio-demographic profile, presenting symptoms, and physical examination findings of the 196 study participants with poor R-wave progression on ECG. The majority of participants were aged 46–65 years (57.7%), with a male predominance (58.7%). Chest pain was reported by approximately half of the patients (51.0%), while shortness of breath on exertion was present in 46.4%, indicating a substantial burden of cardiopulmonary symptoms. Elevated systolic blood pressure (≥140 mmHg) was observed in 19.4% of participants, whereas raised diastolic blood pressure (≥90 mmHg) was less common (8.7%). Cardiac auscultation findings were largely unremarkable, with normal heart sounds documented in 98.5% of cases. In contrast, abnormal pulmonary findings were relatively frequent, with crepitations noted in 25.0% and rhonchi in 4.6% of participants, reflecting concurrent respiratory involvement in a subset of patients.

Figure 1 illustrates the distribution of major echocardiographic parameters among patients presenting with poor R-wave progression on electrocardiography. Regional wall motion abnormality (RWMA) was identified in 133 (67.9%) participants, with anterior wall involvement being the most common subtype (41.3%), followed by lateral (7.7%), posterior (6.1%), inferior (5.6%), and global hypokinesia (7.1%). Old myocardial infarction (MI) was detected in 14 (7.1%) patients, predominantly anterior in location (3.1%). Left ventricular hypertrophy (LVH) was observed in 11 (5.6%) cases. Reduced left ventricular ejection fraction (EF <50%) was present in 99 (50.5%) participants.



RWMA=Regional wall motion abnormality; MI= Myocardial infarction (MI); LVF=Left Ventricular Hypertrophy

Figure 1: Echocardiographic findings of the study participants (n = 196)



RWMA = regional wall motion abnormality; EF = ejection fraction

Figure 2: Distribution of composite echocardiographic outcome and its individual components among study participants (n = 196)

Figure 2 demonstrates the distribution of the composite echocardiographic outcome. Overall, 151 (77.0%) participants exhibited at least one structural or functional abnormality, defined as the presence of RWMA and/or reduced ejection fraction (<50%). RWMA was present in 133 (67.9%) patients, while reduced EF (<50%) was observed in 99 (50.5%). A total of 45 (23.0%) participants had normal echocardiographic findings (no RWMA and EF ≥50%).

Table II: Association of clinical symptoms and socio-demographic characteristics with echocardiographic abnormalities (RWMA and EF) among study participants (n = 196)

Factors	Category	RWMA present n (%)	RWMA absent n (%)	*p*-value	EF <50% n (%)	EF ≥50% n (%)	*p*-value
Clinical symptoms							
Cough	No (n=160)	110 (68.8)	50 (31.2)	0.573	76 (47.5)	84 (52.5)	0.076
	Yes (n=36)	23 (63.9)	13 (36.1)		23 (63.9)	13 (36.1)	
Chest pain	No (n=96)	59 (61.5)	37 (38.5)	0.060	47 (49.0)	49 (51.0)	0.670
	Yes (n=100)	74 (74.0)	26 (26.0)		52 (52.0)	48 (48.0)	
Shortness of breath on exertion	No (n=105)	71 (67.6)	34 (32.4)	0.939	40 (38.1)	65 (61.9)	0.001
	Yes (n=91)	62 (68.1)	29 (31.9)		59 (64.8)	32 (35.2)	
Socio-demographic characteristics							
Age group (years)	25-45 (n=39)	32 (82.1)	7 (17.9)	0.086	20 (51.3)	19 (48.7)	0.949
	46-65 (n=113)	71 (62.8)	42 (37.2)		56 (49.6)	57 (50.4)	
	>65 (n=44)	30 (68.2)	14 (31.8)		23 (52.3)	21 (47.7)	
Gender	Male (n=115)	84 (73.0)	31 (27.0)	0.064	66 (57.4)	49 (42.6)	0.022
	Female (n=81)	49 (60.5)	32 (39.5)		33 (40.7)	48 (59.3)	

RWMA = regional wall motion abnormality (including global hypokinesia); EF = ejection fraction; p-values were calculated using Pearson's chi-square test and Fisher's exact test applied where appropriate.

Table II presents the associations of socio-demographic characteristics and clinical symptoms with echocardiographic abnormalities among the study participants. The presence of RWMA did not differ significantly by cough status, chest pain, or shortness of breath on exertion (p>0.05). However, reduced ejection fraction (<50%) was significantly more frequent among participants reporting shortness of breath on exertion compared to those without this symptom (64.8% vs. 38.1%, p = 0.001). Chest pain and cough were not significantly associated with reduced ejection fraction. Regarding socio-demographic characteristics, a higher proportion of RWMA was observed among younger participants aged 25–45 years (82.1%), although the association did not reach statistical significance (p = 0.086). Reduced ejection fraction showed no significant variation across age groups (p = 0.949). Male participants exhibited a significantly higher prevalence of reduced ejection fraction compared to females (57.4% vs. 40.7%, p = 0.022), while the association between gender and RWMA approached but did not reach statistical significance (p = 0.064).

Table III: Association of cardiovascular risk factors and comorbidities with echocardiographic abnormalities (RWMA and EF) among study participants (n = 196)

Factor	Category	RWMA present n (%)	RWMA absent n (%)	*p*-value†	EF <50% n (%)	EF ≥50% n (%)	*p*-value†
Cardiovascular risk factors							
Hypertension	No (n=105)	73 (69.5)	32 (30.5)	0.591	64 (61.0)	41 (39.0)	0.002
	Yes (n=91)	60 (65.9)	31 (34.1)		35 (38.5)	56 (61.5)	
Diabetes mellitus	No (n=120)	75 (62.5)	45 (37.5)	0.044	57 (47.5)	63 (52.5)	0.290
	Yes (n=76)	58 (76.3)	18 (23.7)		42 (55.3)	34 (44.7)	
Smoking	No (n=151)	99 (65.6)	52 (34.4)	0.208	78 (51.7)	73 (48.3)	0.557
	Yes (n=45)	34 (75.6)	11 (24.4)		21 (46.7)	24 (53.3)	
Comorbidities							
History of COPD	No (n=159)	107 (67.3)	52 (32.7)	0.727	79 (49.7)	80 (50.3)	0.632
	Yes (n=37)	26 (70.3)	11 (29.7)		20 (54.1)	17 (45.9)	
History of CKD	No (n=178)	122 (68.5)	56 (31.5)	0.520	91 (51.1)	87 (48.9)	0.589
	Yes (n=18)	11 (61.1)	7 (38.9)		8 (44.4)	10 (55.6)	
Bronchial asthma	No (n=182)	124 (68.1)	58 (31.9)	0.767	91 (50.0)	91 (50.0)	0.606
	Yes (n=14)	9 (64.3)	5 (35.7)		8 (57.1)	6 (42.9)	
Family history of IHD	No (n=175)	116 (66.3)	59 (33.7)	0.174	88 (50.3)	87 (49.7)	0.856
	Yes (n=21)	17 (81.0)	4 (19.0)		11 (52.4)	10 (47.6)	

RWMA = regional wall motion abnormality (including global hypokinesia); EF = ejection fraction; IHD = ischemic heart disease; COPD = chronic obstructive pulmonary disease; CKD = chronic kidney disease. p-values were calculated using Pearson's chi-square test and Fisher's exact test applied where appropriate. Statistically significant values are shown in bold.

Table III summarizes the associations of cardiovascular risk factors and comorbidities with echocardiographic abnormalities. Among cardiovascular risk factors, diabetes mellitus was significantly associated with the presence of RWMA, with a higher prevalence observed among diabetic participants compared to non-diabetics (76.3% vs. 62.5%, p = 0.044). Hypertension and smoking status were not significantly associated with RWMA. In contrast, hypertension demonstrated a significant association with reduced ejection fraction, where participants without hypertension showed a higher prevalence of reduced ejection fraction compared to hypertensive individuals (61.0% vs. 38.5%, p = 0.002). This inverse association likely reflects confounding factors such as treatment status or differences in clinical presentation. Diabetes mellitus and smoking status were not significantly associated with reduced ejection fraction.

None of the assessed comorbidities, including chronic obstructive pulmonary disease, chronic kidney disease, bronchial asthma, or family history of ischemic heart disease, showed

statistically significant associations with either RWMA or reduced ejection fraction (all $p > 0.05$).

Discussion

Poor R-wave progression (PRWP) has traditionally been considered a marker of anterior myocardial infarction, although its diagnostic specificity has long been debated.[1-3] Early vector-cardiography and autopsy-correlation studies showed that PRWP reflects attenuation of anterior depolarization forces and may occur with or without transmural infarction.[4,5] More recent population data have linked PRWP to coronary artery disease and sudden cardiac death.[6,7] However, structured echocardiographic correlation in clinically characterized cohorts remains limited. Our study provides imaging-based evidence that PRWP frequently corresponds to structural and functional myocardial abnormalities.

In this cohort, 67.9% had regional wall motion abnormalities (RWMA), 50.5% had reduced left ventricular ejection fraction (EF <50%), and 77% met the composite echocardiographic endpoint. These proportions exceed the prevalence of PRWP reported in general populations,[7] suggesting that in symptomatic or hospital-based patients, PRWP is less likely to represent a benign variant. Although earlier studies questioned the diagnostic value of PRWP in isolation,[2,9] our findings indicate that systematic echocardiographic evaluation often reveals objective myocardial dysfunction. The predominance of anterior wall involvement aligns with classical pathophysiological explanations linking impaired anterior depolarization with anterior myocardial injury.[3,5] The coexistence of global hypokinesia and reduced EF further suggests that PRWP may reflect diffuse ventricular dysfunction in addition to localized infarction.

Male sex was significantly associated with reduced EF, consistent with established sex-related differences in ischemic heart disease and ventricular remodeling.[8,12] Age was not independently predictive, paralleling heterogeneous age associations reported previously.[7] Diabetes mellitus independently predicted RWMA, which is biologically plausible given its roles in atherosclerosis, microvascular dysfunction, myocardial fibrosis, and metabolic remodeling.[13,14] Diabetic cardiomyopathy and silent ischemia may further explain the coexistence of PRWP and systolic impairment.[11,18]

Hypertension showed an inverse association with reduced EF in unadjusted analysis. Although seemingly paradoxical, hypertension often progresses from concentric remodeling and diastolic dysfunction to later systolic impairment,[8,15] and treated patients may undergo earlier surveillance. Smoking was not significantly associated with RWMA or EF reduction despite its established atherogenic effects,[16] possibly reflecting sample size limitations or exposure variability. Exertional dyspnea was strongly associated with reduced EF, consistent with established hemodynamic mechanisms,[17] whereas chest pain showed only borderline association with RWMA, underscoring its limited specificity.[3,10]

Overall, these findings reinforce that PRWP should not be dismissed as a nonspecific electrocardiographic anomaly. While earlier literature emphasized limited diagnostic precision,[2] contemporary evidence highlights its prognostic implications, including associations with sudden cardiac death.[6,7,19] Our results provide structural corroboration, demonstrating frequent underlying myocardial pathology. In clinical practice, particularly among patients with diabetes or exertional dyspnea, PRWP should prompt echocardiographic assessment. In resource-constrained settings where ECG serves as a primary screening tool, such stratified evaluation may facilitate early detection of ventricular dysfunction.[20,21] Future prospective studies are needed to determine whether PRWP independently predicts adverse cardiovascular outcomes after imaging adjustment, and advanced modalities such as cardiac magnetic resonance may further clarify underlying scar and fibrosis patterns.[22]

Conclusion

This study demonstrates that poor R-wave progression is frequently accompanied by objective structural and functional myocardial abnormalities on echocardiography in a clinically evaluated population. A substantial proportion of patients exhibited regional wall motion abnormalities or reduced left ventricular ejection fraction, indicating that PRWP often reflects underlying myocardial pathology rather than a purely electrocardiographic variant. Although PRWP alone cannot confirm prior myocardial infarction, its presence particularly in individuals with cardiometabolic risk factors or exertional symptoms appears to identify patients at increased likelihood of ventricular dysfunction. These findings support a more cautious and clinically integrated interpretation of PRWP in routine practice. Targeted echocardiographic assessment in such patients may facilitate earlier detection of subclinical myocardial impairment. Future prospective studies are needed to clarify the independent prognostic value of PRWP and its potential role in cardiovascular risk stratification.

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