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RESEARCH ARTICLE
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PREVALENCE AND ASSOCIATED FACTORS OF EARLY REPOLARIZATION PATTERNS IN ECGS OF CHEST PAIN PATIENTS

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Abstract

Objective: This study aimed to investigate the prevalence and associated factors of early repolarization (ER) patterns in patients presenting with chest pain. The study aimed to identify factors influencing ER patterns, including demographic, clinical, and ECG parameters.

Study Design: A cross-sectional descriptive study

Place and Duration: This study was conducted at, People's University of Medical and Health Sciences for Women Nawabshah for a period of 1 year from June 2023 to June 2024.

Methodology: This study recruited 144 individuals aged 18–80 presenting with chest pain. Initial 12-lead ECGs were used to evaluate ER, identified by J-point elevation ≥0.1 mV accompanied by notching or slurring in at least two contiguous leads. Multivariable binary logistic regression was used to analyze factors associated with ER, presenting odds ratios (OR) and 95% confidence intervals (CI).

Results: Of the 144 patients, 92 (63.9%) did not exhibit ER, and 52 (36.1%) had an ER pattern. The ER group had significantly lower BMI (24.5 ± 3.2 vs. 25.8 ± 3.6, $p < 0.001$), heart rate (74.2 ± 7.3 vs. 78.5 ± 9.2 bpm, $p = 0.008$), and T-wave duration (80 [80-100] ms vs. 100 [80-140] ms, $p = 0.011$). The non-ER group exhibited a higher prevalence of STEMI compared to the ER group (21.7% vs. 15.4%, $p=0.045$). Multivariable logistic regression revealed that ER was significantly

linked to lower heart rate (OR=0.92, p=0.005), shorter T-wave duration (OR=0.97, p=0.007), and reduced BMI (OR=0.81, p=0.001).
Conclusion: ER patterns are prevalent in chest pain patients, particularly in younger males and those with lower BMI. Although ER can mimic more serious conditions, effective risk stratification tools are needed for accurate diagnosis and management. The significance of ER patterns for long-term prognosis in patients with chest pain should be investigated in future studies.

Keywords: Early repolarization, chest pain, ECG, myocardial infarction, heart rate.

Introduction

Chest pain is among the most frequent complaints encountered in emergency departments (EDs) worldwide, accounting for approximately 5-10 % of all adult ED visits globally [1]. Its etiology spans a broad spectrum, from benign musculoskeletal conditions to life-threatening cardiac events like acute myocardial infarction (AMI), a primary contributor to global morbidity and mortality [2]. Therefore, it is crucial to necessitate rapid identification of cardiac causes. Electrocardiography (ECG) serves as a cornerstone in the early evaluation of chest pain [3]. Guidelines recommend performing an ECG within 10-15 minutes of ED arrival as a key quality metric [4]. The ECG enables rapid identification of ischemic changes suggestive of AMI, arrhythmias, and other critical cardiac conditions, effectively triaging patients who require urgent intervention [3, 5].

Among the various ECG patterns observed, early repolarization (ER) has emerged as a significant finding due to its potential to mimic the ECG manifestations of chest pain [6]. ER is traditionally characterized on the 12-lead ECG by a J-point (Jp) elevation ≥ 0.1 mV in at least two contiguous leads, usually accompanied by end-QRS notching or slurring and a smoothly up-sloping, concave ST-segment; the QRS duration is otherwise normal, and no reciprocal changes are present [7, 8]. However, modern consensus definitions incorporate additional criteria reflective of variant ER phenotypes. These include explicit recognition of J-wave morphology, horizontal or down-sloping ST segments, multi-lead distribution, and a distinction between benign and malignant subtypes [9]. Specifically, the horizontal/down-sloping ST pattern in inferior leads has emerged as a potential marker for heightened arrhythmogenic risk, whereas the convex/upsloping variant appears benign [9, 10]. Epidemiologically, ER occurs in approximately 5.8–13.1 % of healthy individuals, though prevalence estimates vary by population and diagnostic criteria [11]. Among physically active individuals, including athletes and military personnel, the prevalence rises to approximately 33.9% [12].

ER is highly relevant in the context of chest pain, as it can closely resemble ECG patterns seen in AMI and pericarditis [13]. ER resembles more severe disorders in appearance by having concave ST-segment elevation and J-point notching or slurring [13]. Such resemblance can lead to inappropriate processing and hospitalization, and the diagnosis and treatment of individuals with chest pain can be problematic [13, 14]. Recent studies have attempted to justify the high frequency of ER changes in ECG patterns and also establish risk factors of this pattern in those presenting with chest pain [15, 16]. These factors are extremely important in clinical practice. Proper identification and risk stratification of ER patterns can prevent unnecessary diagnostic tests, admissions, and procedures [15].

Various factors, including the nature of underlying cardiac conditions, gender, and age, influence the occurrence of ER patterns in ECG. Younger age and male sex are consistently significant predictors of ER presence [17]. Athletic conditioning magnifies prevalence, with elite adolescents showing ER in up to one-third of participants [18]. Moreover, lower body-mass index and shorter T-wave duration have been linked with ER in chest pain cohorts [17]. Additionally, ER associates with ion-channel mutations (most notably in KCNJ8, ABCC9, CACNA1C, and SCN5A) that influence potassium and calcium currents and modulate repolarization properties [19].

Despite our global understanding, local studies on patients with chest pain remain limited. Small-scale tertiary-center research in Pakistan has suggested notable ER occurrence but lacks the broader characterization necessary for robust diagnostic strategies. Building on these gaps, the ongoing study aims to quantify ER prevalence in patients with chest pain at a tertiary cardiac hospital in Pakistan and assess associations with demographic factors (age, sex), clinical factors (BMI, comorbidities), and ECG findings.

Methodology

In this cross-sectional descriptive study, non-probability consecutive sampling included patients aged 18-80 years, both genders, presenting with chest pain at the emergency department. Patients with prior cardiac surgery or interventions or those unwilling to consent were excluded.

The study secured institutional review board approval and verbal informed consent from participants. A 12-lead ECG was conducted for each patient to record the ER pattern and other ECG parameters, such as QRS duration (ms), P-R interval (ms), QTc interval (ms), R-R interval (ms), heart rate (bpm), and T-wave duration (ms). Upon arrival, demographic information was recorded, including age, gender, and BMI (kg/m^2). Medical history covered hypertension, diabetes, smoking, obesity, and family history. All patients received standard care per hospital protocols.

Final diagnoses, including unstable angina, STEMI (ST-segment elevation myocardial infarction), NSTEMI (non-ST elevation myocardial infarction), and non-cardiac chest pain, relied on ECG findings, cardiac biomarkers like high-sensitivity troponin levels, and chest pain duration.

Sample size calculation yielded N=144 at 95% confidence and 4% margin of error. SPSS version 21 was used to analyze the data. Using the Shapiro-Wilk test, the variables' normality was evaluated. For continuous variables, descriptive statistics included the mean ± SD or median (IQR). For categorical variables, such as gender, age group, hypertension, diabetes, smoking, obesity, family history, left ventricular hypertrophy, early repolarization, and diagnosis, frequencies and percentages were reported.

Individuals were categorized into groups based on the presence or absence of the ER pattern. Multivariable binary logistic regression with backward conditional selection evaluated clinical factors linked to early repolarization, reporting odds ratios (OR) with 95% CI. Statistical significance was defined as a two-sided p-value less than 0.05.

Results

This study involved 144 patients (n = 144), with 92 (63.9%) in the Absent ER group and 52 (36.1%) in the Present ER group. The gender distribution was comparable between groups, with the Absent group comprising 56 males (60.9%) and 36 females (39.1%), and the Present group including 32 males (61.5%) and 20 females (38.5%) (p=0.421). BMI in the Present group averaged 24.5 ± 3.2, significantly lower than the Absent group's 25.8 ± 3.6 (p<0.001). Compared to the Present group, the Absent group exhibited a higher heart rate (78.5 ± 9.2 bpm vs. 74.2 ± 7.3 bpm; p=0.008) and longer T-wave duration (100 [80–140] ms vs. 80 [80–100] ms; p=0.011). Regarding the final diagnosis, STEMI was more prevalent in the Absent group (20 [21.7%] vs. 8 [15.4%]; p=0.045).

Table 1: Comparison of Clinical Data, ECG Parameters, Co-morbid Conditions, and Final Diagnosis in Patients with and without ER Pattern (N=144).

	ER Pattern (Total = 144)		**P-value**
	Absent (N = 92, 63.9%)	**Present (N = 52, 36.1%)**	
Gender			
Male	56 (60.9%)	32 (61.5%)	0.421
Female	36 (39.1%)	20 (38.5%)	
Age (years)			
Mean ± SD	55.5 ± 9.8	54.3 ± 10.2	0.100
≤45 years	13 (14.1%)	10 (19.2%)	0.268
46-55 years	33 (35.9%)	19 (36.5%)	
56-65 years	30 (32.6%)	15 (28.8%)	
>65 years	16 (17.4%)	8 (15.4%)	

BMI (kg/m²)	25.8 ± 3.6	24.5 ± 3.2	<0.001
ECG Parameters			
Left Ventricular Hypertrophy	5 (5.4%)	3 (5.8%)	0.856
Heart Rate (bpm)	78.5 ± 9.2	74.2 ± 7.3	0.008
P–R Interval (ms)	149 [130-150]	140 [120-150]	0.093
R–R Interval (sec)	0.75 [0.68-0.8]	0.76 [0.70-0.8]	0.346
T-wave Duration (ms)	100 [80-140]	80 [80-100]	0.011
QRS Duration (ms)	70 [80-100]	80 [70-90]	0.150
QTc Interval (ms)	320 [290-380]	310 [280-360]	0.254
Co-morbid Conditions			
Family History of CAD	3 (3.3%)	4 (7.7%)	0.340
Obesity	4 (4.3%)	4 (7.7%)	0.005
Smoking	9 (9.8%)	6 (11.5%)	0.511
Diabetes Mellitus	20 (21.7%)	12 (23.1%)	0.780
Hypertension	56 (60.9%)	26 (50.0%)	0.134
Final Diagnosis			
Non-cardiac	9 (9.8%)	9 (17.3%)	0.117
Unstable Angina	7 (7.6%)	5 (9.6%)	0.903
STEMI	20 (21.7%)	8 (15.4%)	0.045
NSTEMI	56 (60.9%)	30 (57.7%)	0.475

The multivariable binary logistic regression analysis showed that female gender had an odds ratio (OR) of 0.52 [0.29-1.00], with a marginal significance (p = 0.054). BMI was significantly associated with ER, with an OR of 0.81 [0.74 - 0.90] (p=0.001), suggesting lower BMI was linked to ER. T-wave duration was significantly associated with ER (OR 0.97 [0.97 - 0.99], p=0.007), as was heart rate (OR 0.92 [0.88 - 0.96], p=0.005). STEMI showed a significant negative association with ER in both models (OR 0.23 [0.06 - 0.68], p=0.011). Obesity (OR 0.55 [0.14 - 2.10], p=0.389) and family history of CAD (OR 0.60 [0.15 - 2.55], p=0.531) were not significant.

Table 2: Analysis of ER-Associated Factors in ECG Using Multivariable Logistic Regression

Characteristics	**Initial Model**		**Final Model**	
	Odds ratio [95% CI]	**P-value**	**Odds ratio [95% CI]**	**P-value**
Female	0.47 [0.23 - 0.97]	0.045	0.52 [0.29 - 1.00]	0.054
Age (years)	0.98 [0.95 - 1.03]	0.469	-	-
BMI (kg/m²)	0.83 [0.73 - 0.95]	0.022	0.81 [0.74 - 0.90]	0.001
ECG Parameters				
P–R Interval (ms)	1.00 [0.99 - 1.01]	0.756	-	-
R–R Interval (sec)	9.99 [0.42 - 225.01]	0.140	-	-
QRS Duration (ms)	1.00 [0.99 - 1.02]	0.732	-	-
QTc Interval (ms)	1.00 [0.99 - 1.01]	0.693	-	-
Heart Rate (bpm)	0.94 [0.89 - 0.99]	0.078	0.92 [0.88 - 0.96]	0.005
Left Ventricular Hypertrophy	1.30 [0.36 - 4.72]	0.656	-	-
T-wave Duration (ms)	0.97 [0.97 - 0.99]	0.006	0.97 [0.97 - 0.99]	0.007
Co-morbid Conditions				
Family History of CAD	0.60 [0.15 - 2.55]	0.531	-	-

Obesity	0.55 [0.14 - 2.10]	0.389	-	-
Smoking	0.75 [0.35 - 1.61]	0.486	-	-
Diabetes Mellitus	1.55 [0.80 - 3.13]	0.160	1.68 [0.92 - 3.16]	0.066
Hypertension	0.74 [0.40 - 1.37]	0.320	-	-
Final Diagnosis				
STEMI	0.23 [0.06 - 0.85]	0.030	0.21 [0.06 - 0.68]	0.011
NSTEMI	0.18 [0.05 - 0.65]	0.009	0.19 [0.06 - 0.60]	0.006
Non-cardiac	Reference category	Reference category	Non-cardiac	Reference category
Unstable Angina	0.42 [0.08 - 2.05]	0.289	0.38 [0.09 - 1.68]	0.212

Table 3 shows that the heart rate in the 1st quartile (<75 bpm) was significantly associated with early repolarization (OR = 2.40, p=0.010). T-wave duration also had significant associations, with the 1st and 2nd quartiles showing strong associations (OR = 3.42, p=0.019 and OR = 3.01, p=0.002, respectively). However, the 3rd quartile of T-wave duration showed no significant association (OR = 1.30, p = 0.535). Lower BMI (1st and 2nd quartiles) is strongly associated with early repolarization (OR = 3.74, p=0.001 and OR = 3.62, p=0.002, respectively), while the 3rd quartile of BMI showed a weaker association (OR = 2.12, p=0.074).

Table 3: Association Between ER Pattern, Heart Rate, T-Wave Duration, and Body Mass Index: Binary Logistic Regression Analysis

Parameters	**Odds Ratio [95% CI]**	**P-value**
Heart Rate (bpm)		
Below 75 bpm (1st quartile)	2.40 [1.26 - 4.59]	0.010
75-77bpm (2nd quartile)	1.53 [0.77 - 3.07]	0.248
78-80 bpm (3rd quartile)	1.69 [0.82 - 3.52]	0.165
>80 bpm (4th quartile)	Reference category	
T-wave Duration (ms)		
<80 ms (1st quartile)	3.42 [1.27 - 9.34]	0.019
80-109 ms (2nd quartile)	3.01 [1.53 - 5.68]	0.002
110-160 ms (3rd quartile)	1.30 [0.59 - 2.84]	0.535
>160 ms (4th quartile)	Reference category	
BMI (kg/m²)		
<23.4 kg/m² (1st quartile)	3.74 [1.73 - 8.11]	0.001
23.4-25.6 kg/m² (2nd quartile)	3.62 [1.67 - 7.84]	0.002
25.7-27.8 kg/m² (3rd quartile)	2.12 [0.96 - 4.72]	0.074
>27.8 kg/m² (4th quartile)	Reference category	

Discussion:

This study was conducted to investigate the prevalence of ER patterns among patients exhibiting chest pain. We also explored the ER-associated factors among the patients. Our study found that 36.1% of patients exhibited an ER pattern, a figure notably higher than the global average. For example, a study conducted in Pakistan found an ER prevalence of 33.9% among patients with chest pain [20]. Another study focusing on preoperative ECGs in low-risk surgical patients reported that ER was prevalent in 7.2% of the patients [21]. In our study, ER was more prevalent among males (60.9%) compared to females (39.1%), aligning with a study that reported ER is more prevalent in men and younger populations, with the highest prevalence observed in physically active individuals [22].

In terms of final diagnoses, our study found a higher prevalence of STEMI in the non-ER group compared to the ER group. This finding contrasts with some studies that have indicated that certain ER patterns, particularly those with horizontal or descending ST segments, are associated with an increased risk of sudden cardiac death [9]. In one study, Oka et al. (2019) [23] investigated the ER-ECG pattern in acute myocarditis, focusing on its prevalence and mechanisms. They used cardiac magnetic resonance to examine affected individuals. 30% of cases exhibited the ER-ECG pattern. They proposed that acute myocarditis-induced inflammation and swelling in the left ventricular epicardium could produce a voltage gradient across the ventricular wall. Notably, the ER-ECG pattern did not correlate with life-threatening ventricular tachyarrhythmias in these patients [23]. In another study, Sucu et al. (2019) found a relationship between J-wave and slurring early repolarization patterns and coronary slow flow in patients with stable angina or positive treadmill test results [24]. Moreover, Kitamura et al. noted that early repolarization patterns, especially those with daily fluctuations, predict ventricular fibrillation recurrence in vasospastic angina patients. For high-risk vasospastic angina patients, implanting an implantable cardioverter defibrillator is a suitable approach to prevent ventricular fibrillation [25].

Additionally, our data revealed a significant difference in BMI between the two groups, with the ER group having a lower BMI. This observation is consistent with findings from other studies suggesting that lower BMI may be associated with the presence of ER patterns [20, 21]. Electrocardiographic parameters also varied between the two groups in our study. Notably, the ER group exhibited a lower heart rate and shorter T-wave duration compared to the non-ER group. This aligns with a study by Movahed et al., reporting that a link between a lower heart rate and a higher ER prevalence among African American individuals. In contrast, the study also revealed that a higher BMI was associated with an increased occurrence of ER within this group [26].

In cases of cardiac arrest linked to ER syndrome, up to 58% of patients showed no ER pattern on their ECG during hospitalization [9]. At present, no tests can reliably detect concealed ER, and effective tools to assess the risk of malignant ER are lacking, despite some ECG features indicating higher risk [9, 20]. Thus, ECG variations in patients with asymptomatic ER, especially without a family history of malignant ER events, should be considered normal variations until a more accurate stratification tool is developed [9, 14]. Regardless of ER’s symptoms, managing modifiable cardiac risk factors remains crucial.

One of this study's limitations is its cross-sectional design, which makes it more difficult to determine the causal links between ER patterns and clinical outcomes. Furthermore, the results of this study are not applicable to other populations or healthcare settings because it was only carried out at single tertiary-care hospital. Lastly, while the study accounted for key clinical variables, other potential confounders, such as genetic factors or long-term cardiovascular health, were not assessed.

Conclusion

The findings of this study highlight the significant prevalence of ER patterns in chest pain patients, particularly in younger males and those with lower BMI. Despite its clinical relevance, ER patterns can mimic other serious cardiac conditions, complicating diagnosis and treatment. Future research should focus on developing accurate stratification tools to differentiate benign from malignant ER patterns and assess their long-term prognostic value. Effective risk assessment strategies are crucial for improving patient management.

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