

Clinical Value of Limb-Lead R-Wave Amplitude in Predicting Cardiac Rupture After Acute Anterior Myocardial Infarction Undergoing PCI

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Background: Cardiac rupture remains a fatal complication of acute anterior myocardial infarction (AAMI), especially in the high-risk subset that develops left ventricular aneurysm (LVA). This study aimed to evaluate the predictive value of the average R-wave voltage in the electrocardiographic limb leads (AVRE) for cardiac rupture in this specific AAMI with LVA population.

Methods: We conducted a retrospective, single-center study of 249 AAMI patients undergoing primary PCI, comparing 63 with cardiac rupture (CR group) to 186 without (Control group). Key inclusion criteria were typical chest pain and ST-segment elevation on ECG. AVRE was measured on admission ECG. Multivariate logistic regression and ROC curve analysis were used to identify independent predictors and assess the predictive performance of AVRE.

Results: Patients with cardiac rupture had a significantly lower average limb-lead R-wave voltage (AVRE) than controls (2.33 vs 3.33 mV, $p < 0.001$). Multivariate analysis identified AVRE and higher left ventricular ejection fraction (LVEF) as independent predictors (OR: 0.682 and 1.057, respectively; both $p < 0.01$). The predictive performance of AVRE was significant (AUC: 0.656), with an optimal cutoff of < 2.92 mV yielding a sensitivity of 74.6% and specificity of 59.7%.

Conclusion: In this single-center study, a reduced AVRE (< 2.92 mV) was an independent predictor of cardiac rupture in patients with AAMI and LVA, suggesting its potential as an accessible tool for risk stratification within this specific high-risk cohort.

Keywords: acute anterior myocardial infarction, cardiac rupture, electrocardiography, R-wave voltage, prognosis

Introduction

Despite a relatively low incidence (approximately 1–6%),^{1,2} cardiac rupture remains one of the most lethal complications of acute myocardial infarction (AMI), with historical mortality rates exceeding 90%.³ Contemporary registries continue to report alarmingly high in-hospital mortality associated with this complication, underscoring its persistently heavy burden.⁴ This solidifies its status as a significant and ongoing global health challenge within the spectrum of AMI complications.

Cardiac rupture manifests as free wall rupture (FWR), ventricular septal rupture (VSR), or papillary muscle rupture (PMR), each leading to distinct and often dramatic clinical presentations such as sudden hemodynamic collapse,⁴ new murmurs,^{3,5,6} or cardiogenic shock.^{6,7} Despite these characteristic signs, the diagnosis remains challenging due to rapid progression and symptom overlap with other complications. FWR typically leads to hemopericardium and cardiac tamponade. Patients may present with sudden-onset severe chest pain, rapid clinical deterioration, signs of cardiogenic shock (eg, hypotension, cold extremities, altered mental status), and electromechanical dissociation.^{7,8} VSR often manifests as a sudden hemodynamic compromise accompanied by a new, harsh holosystolic murmur heard best at the left lower sternal border, signs of biventricular failure, and hypoperfusion.^{3,5} PMR results in acute severe mitral regurgitation, characterized by a new apical holosystolic murmur radiating to the axilla, pulmonary edema, and

cardiogenic shock.⁶ Despite these classic signs, the diagnosis can be challenging as symptoms may overlap with other post-AMI complications, and the window for intervention is critically narrow.^{9,10} Therefore, despite the widespread use of reperfusion strategies and a reduced incidence in recent years,^{2,3} cardiac rupture remains associated with an extremely high fatality rate and poor clinical outcomes.² Furthermore, studies have shown that acute anterior myocardial infarction (AAMI) is an important risk factor for cardiac rupture.^{1,8,10}

The dramatic and rapidly progressive nature of cardiac rupture necessitates diagnostic tools that are immediately available at the bedside for early risk stratification. The electrocardiogram (ECG) meets this critical need as a rapid, non-invasive, and universally available test, allowing for real-time assessment without delaying life-saving interventions.¹¹ We therefore focused on ECG as an ideal bedside tool for risk stratification. Specifically, we investigated the R-wave voltage in the limb leads, expressed as the average voltage of R-wave in electrocardiographic limb leads (AVRE). We hypothesized that a reduced AVRE could serve as a predictive marker for cardiac rupture. This hypothesis is plausible because the extensive transmural myocardial necrosis and wall thinning, which are known risk factors for rupture, may also result in diminished electromotive forces and lower R-wave voltage.¹² Furthermore, pericardial effusion, which is common in these patients and attenuates ECG voltage,^{13–15} could compound this effect. Thus, AVRE may represent a promising and readily obtainable parameter that reflects these underlying pathological processes. However, while low QRS voltage is a known sign of established cardiac tamponade, its utility as a specific, quantitative predictor for the impending event of cardiac rupture—distinct from markers of acute ischemia like ST-segment elevation—remains unvalidated. This study tested the hypothesis that a lower AVRE is associated with an increased risk of cardiac rupture in AAMI patients undergoing primary PCI.

Materials and Methods

A single-center, retrospective study was designed to evaluate the correlation between AVRE and cardiac rupture after AAMI undergoing percutaneous coronary intervention (PCI). The inclusion criteria were as follows: (1) an age range of 18–90 years; (2) evidence of precordial chest pain; (3) signs of electrocardiographic ST-T deflection; and (4) a confirmed correlation of responsible lesion with clinical symptoms by coronary angiography.

The clinical data of 63 patients diagnosed with cardiac rupture (CR group) and 186 control patients with AAMI but without cardiac rupture (Control group) were retrospectively collected from Fujian Medical University Union Hospital between July 1, 2013, and July 31, 2024. The collected data encompassed demographic characteristics, medical and family history, medication use, smoking status, and relevant procedural and imaging parameters. All enrolled cases presented with typical precordial chest pain and electrocardiographic changes, with or without elevated cardiac biomarkers indicative of myocardial injury, and all fulfilled the Fourth Universal Definition of Myocardial Infarction,¹⁶ leading to a definitive diagnosis of acute ST-segment elevation myocardial infarction (STEMI). Infarct size was estimated using the peak plasma level of cardiac troponin I (cTnI) measured during hospitalization.

Every patient underwent a standard 12-lead ECG (RAGE-12, CardioCare, Amoy, CHN) at a paper speed of 25 mm/s and an amplification of 10 mm/mV, which was performed immediately upon hospital admission. AVRE was calculated as follows: first, the R-wave amplitude was measured in each of the six limb leads (I, II, III, aVR, aVL, aVF). The measurement was taken from the isoelectric line (baseline) to the peak (highest positive point) of the R wave. Amplitudes were recorded in millivolts (mV), with the standard calibration of 10 mm/mV (ie, 1mm = 0.1mV). Subsequently, the AVRE was derived as the arithmetic mean of these six individual R-wave amplitudes, using the formula: $AVRE (mV) = [R(I) + R(II) + R(III) + R(aVR) + R(aVL) + R(aVF)] / 6$.

Myocardial infarction location was determined based on ST-segment elevation in two or more adjacent leads: V1–V6 for anterior wall, II, III, aVF for inferior wall, and I, aVL for lateral wall. Killip classification was assigned for the presence and severity of heart failure in STEMI patients according to the ESC guideline.¹¹ To account for the timeliness of reperfusion, door-to-device time (D-to-D) was recorded, defined as the time from hospital arrival to the first successful device deployment (such as balloon inflation or thrombus aspiration) during primary PCI. These critically ill patients were all admitted to the coronary care unit (CCU) and underwent an immediate treatment with standard dual-antiplatelet and statins. Most of patients received β -blockers and angiotensin converting enzyme inhibitors (ACEI) / angiotensin

receptor blockers (ARB) within 24 hours after admission according to the ESC STEMI guidelines,¹⁷ unless contraindications to these drugs were indicated.

All the included patients were diagnosed as left ventricular aneurysm (LVA) by transthoracic echocardiography (TTE) (Philips iE33, Philips Medical Systems, Andover, MA, USA). The diagnostic criteria for LVA were as follows: (1) apical diameter exceeding that of the basal left ventricular segment at end-diastole; (2) outward bulging of the ventricular wall during both systole and diastole, with wide communication to the ventricular lumen; (3) akinetic or dyskinetic wall motion in the affected segment.

During hospitalization, cardiac rupture observed was classified as FWR, VSR and PMR (30, 27 and 6 cases, respectively) by TTE. FWR can produce a large volume of pericardial effusion (detected by pericardiocentesis), ultimately inducing circulatory collapse or cardiogenic shock.¹⁸ Of note, pericardial effusion, an echo-free space visualized between parietal and visceral pericardium at end diastole, can be semi-quantitatively classified into small (≤ 10 mm) and moderate to severe categories (> 10 mm).¹⁹ VSR can be first indicated by the findings of physical examination, such as cardiac systolic murmur, and subsequently confirmed by echocardiography.⁸ The diagnostic criteria of PMR may include: (1) abnormal physical examination findings, such as new systolic murmur; (2) a mobile occupying lesion in either the left atrium or ventricle by TTE; (3) flail or ruptured chordae with an abnormal-looking papillary muscle.⁶

Statistical Analysis

The data were analyzed with SPSS version 27.0 (IBM, Somers, NY, USA). The normality of the distribution for continuous variables was evaluated using the Kolmogorov–Smirnov test. Normally distributed continuous variables are presented as mean $\pm$ standard deviation and were compared between groups using the independent-samples *T* test. Non-normally distributed continuous variables are presented as median (interquartile range) and were compared using the Mann–Whitney–*U* test. Categorical variables are presented as numbers (percentages) and were compared using the Chi-square test or Fisher’s exact test, as appropriate. Variables with a *p*-value < 0.05 in the univariable analysis were included in the multivariate logistic regression analysis to identify independent predictors of cardiac rupture, with results expressed as odds ratios (OR) and 95% confidence intervals (CI).²⁰ The discriminatory performance of key predictors was evaluated by the area under the receiver operating characteristic (ROC) curve. A two-sided *p*-value < 0.05 was considered statistically significant.

This study was performed in accordance with the ethical standards of the Declaration of Helsinki and was approved by the Human Ethics Committee of Fujian Medical University Union Hospital (Approval No. 2024KY029).

Results

General Characteristics

The baseline demographic and clinical characteristics for a total of 249 patients, who were diagnosed as acute myocardial infarction with left ventricular aneurysm, are shown in Table 1, including 63 cases in the CR-group and 186 cases in the Ctrl-group. Patients in the CR-group featured an older age, a smaller mean body mass index and percentage of obese, less smoking, more males, hypertension, diabetes mellitus, fibrinolytic therapy and history of myocardial infarction, though no statistical significance was found in these indicators. Between the two groups, a resemblance was observed in myocardial infarction classification, Killip classification, and in proportions of multivessel coronary disease, mechanical circulatory support (MCS), heart rate, blood pressure, revascularization of criminal vessels (RCV) and peripheral edema. Furthermore, no significant differences were found in in-hospital management, including the use of bed rest, sedatives, laxatives, oral anticoagulant, ACEI/ARB, β -receptor blocker (β -RB) within 24 hours, as well as in the door-to-device time.

Ancillary Examination Parameters

ECG, TTE and laboratory parameters of enrolled patients are summarized in Table 2. The Wilcoxon test showed that compared with the Ctrl-group, the CR-group reported a significantly lower AVRE 2.33 (1.67, 3.17) vs 3.33 (2, 4.17),

Table 1 Comparison of Demographic and Clinical Features in the Study Groups

Variables		CR-Group (N=63)	Ctrl-Group (N=186)	F/ χ^2	P
Demographics					
Age (years)		69.84±9.01	67.24±11.56	1.839	0.068
Male, n (%)		49(77.8)	140(75.3)	0.162	0.687
Smoker, n (%)		28(44.4)	94(50.5)	0.699	0.403
BMI (kg/m ²)		22.66±2.79	23.24±3.03	-1.341	0.181
BMI>30 kg/m ² , n (%)		6(9.52)	21(11.29)	0.152	0.697
Hypertension, n (%)		39(61.9)	110(59.1)	0.150	0.699
Diabetes mellitus, n (%)		24(38.1)	55(29.6)	1.579	0.209
Fibrinolytic therapy, n (%)		3(4.8)	7(3.8)	0.000	1.000
History of MI, n (%)		3(4.8)	7(3.8)	0.000	1.000
Clinical feature					
Killip class, n (%)	I	41(65.1)	142(76.3)	1.738 ^a	0.082
	II	13(20.6)	26(14)		
	III	5(7.9)	11(5.9)		
	IV	4(6.3)	7(3.8)		
Multivessel disease		21(33.3)	40(21.5)	3.559	0.059
MCS, n (%)	IABP	8(12.7)	13(7)	3.712 ^b	0.154
	ECMO	2(3.2)	2(1.1)		
Heart rate (beats/min)		84.75±10.85	82.66±10.17	1.383	0.168
SBP (mmHg)		111.98±19.93	115.86±20.71	-1.296	0.196
DBP (mmHg)		70.59±11.55	72.68±11.95	-1.210	0.227
RCV, n (%)		28(44.4)	105(56.5)	2.727	0.099
Peripheral edema, n (%)		7(11.1)	24(12.9)	0.139	0.710
Treatment					
Bed rest, n (%)		54(85.7)	162(87.1)	0.078	0.780
Sedative, n (%)		18(28.6)	41(22)	1.109	0.292
Laxatives, n (%)		41(65.1)	134(72)	1.093	0.296
Oral anticoagulant, n (%)		7(11.1)	22(11.8)	0.024	0.878
ACEI/ARB within 24 h, n (%)		30(47.6)	113(60.8)	3.320	0.068
β-RB within 24 h, n (%)		39(61.9)	138(74.2)	3.458	0.063
D-to-D, (min)		56.38±10.85	54.91±11.13	0.932	0.387

Notes: a: wilcoxon test; b: fisher's precise test;

Abbreviations: ACEI, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; BMI, body-mass index; DBP, diastolic blood pressure; DSOR, duration from symptom onset to revascularization; D-to-D, door-to-device; ECMO, extra-corporeal membrane oxygenation; IABP, intra-aortic balloon pump; MCS, mechanical circulatory support; RCV, revascularization of criminal vessels; SBP, systolic blood pressure; β-RB, β-receptor blocker. Multivessel disease: severe stenosis (≥70%) in at least two diseased major epicardial coronary arteries.

Table 2 Ancillary Parameters Between the Two Groups

Variables		CR-Group (N=63)	Ctrl-Group (N=186)	F/ χ^2	P
Electrocardiography					
Cardiac rhythm	Sinus rhythm, n (%)	53(84.1)	156(83.9)	0.002	0.962
	Atrial fibrillation, n (%)	10(15.9)	30(16.1)		
Electrical axis (°)		43(4, 76)	25(7, 48.75)	-2.376 ^a	0.017
Heart block	LBBB, n (%)	13(20.6)	28(15.1)	1.073	0.585
	RBBB, n (%)	3(4.8)	10(5.4)		
Persistent ST-segment elevation, n (%)		46(73)	138(74.2)	0.034	0.854
AVRE (mV)		2.33(1.67, 3.17)	3.33(2, 4.17)	-3.711 ^a	<0.001
Echocardiography					
LVEF (%)		45.2(40.5, 52.1)	40.7(38.08, 45.9)	-3.499 ^a	<0.001
LVED (mm)		51.82±8.53	52.82±6.89	-0.935	0.350
CVWT (mm)		4.5(4.0, 5.7)	4.7(4.0, 5.1)	-0.419 ^a	0.675
LVAT, n (%)		2(3.2)	24(12.9)	4.763	0.029
Hydropericardium, n (%)	Small	32(50.8)	75(40.3)	3.438	0.179
	Moderate to severe	4(6.3)	7(3.8)		
Laboratory data					
Peak cTnI (ng/mL)		7.70(1.21, 21.00)	2.40(0.25, 13.78)	-1.559 ^a	0.119
Peak CK (ng/mL)		1054(195, 1764)	317(87, 2081)	-1.403 ^a	0.161
Peak CK-MB (ng/mL)		74.9(26.4, 143.3)	31.1(15.0, 175.8)	-1.583 ^a	0.113
Serum creatinine (μmol/L)		83(59, 137)	73(47.5, 103)	-1.672 ^a	0.094
Serum potassium (mmol/l)		4.02±0.70	3.99±0.47	0.368	0.714
Serum calcium (mmol/l)		2.19±0.25	2.22±0.16	-0.808	0.421
NT-proBNP (pg/mL)		3217(1640, 5997)	2622(810.5, 5752)	-1.871 ^a	0.061
Thyroid function	FT3 (pmol/l)	4.14±0.68	4.28±0.78	-1.203	0.230
	FT4 (pmol/l)	12.90±2.61	12.42±2.89	1.162	0.246
	sTSH (mIU/l)	1.42(0.68, 1.99)	1.26(0.66, 2.26)	-0.008 ^a	0.994

Note:a: The Wilcoxon test.

Abbreviations: AVRE, average voltage amplitude values of R-waves of electrocardiographic limb leads; CK, creatine kinase; CK-MB, creatine kinase MB; cTnI, cardiac troponin I; CVWT, criminal vessel related wall thickness; FT3, free triiodothyronine; FT4, free thyroxine; LBBB, left bundle branch block; LVAT, left ventricular apical thrombus; LVED, left ventricular end diastolic diameter; LVEF, left ventricular ejection fraction; NT-proBNP, N-Terminal pro-brain natriuretic peptide; RBBB, right bundle brunch block; sTSH, sensitive thyroid stimulating hormone.

$p < 0.001$, higher left ventricular ejection fraction (LVEF) 45.2 (40.5, 52.1) vs 40.7 (38.08, 45.9), $p < 0.001$, and an apparently larger value of the electrical axis 43 (4, 76) vs 25 (7, 48.75), $p = 0.017$, though the latter fell within the normal range. Meanwhile, compared with the Ctrl-group, the CR-group showed a lower proportion of left ventricular apical thrombus (LVAT) (3.2 vs 12.9, $p = 0.029$). Nevertheless, between the two groups, no obvious differences were found in the left ventricular end diastolic diameter (LVED), criminal vessel related wall thickness (CVWT), hydropericardium, and the incidences of atrial fibrillation, heart block and persistent ST-segment elevation ($p > 0.05$ for all); In terms of

laboratory indicators, serum potassium and serum calcium were compared by independent-samples *T* test (4.02 ± 0.70 vs 3.99 ± 0.47 , 2.19 ± 0.25 vs 2.22 ± 0.16 , respectively; $p > 0.05$ for both); no statistical difference was found in Peak cTnI, Peak creatine kinase (CK), Peak creatine kinase MB (CK-MB), serum creatinine, N-Terminal pro-brain natriuretic peptide (NT-proBNP) by the Wilcoxon test ($p > 0.05$ for all); and no apparent discrepancy in thyroid function including free triiodothyronine (FT3), free thyroxine (FT4), sensitive thyroid stimulating hormone (sTSH) was reported in any of the groups by independent-samples *T* test and Wilcoxon test ($p > 0.05$ for all).

Logistic Regression Analysis and ROC Curve Analysis

Variables with $p < 0.05$ in the univariate analysis (Table 2) and clinically relevant factors (including Peak cTnI, β -RB within 24 h, ACEI/ARB within 24h, and D-to-D time) were included in the multivariate logistic regression model presented in Table 3. Multivariate logistic regression revealed that two factors were independently associated with cardiac rupture: AVRE (OR: 0.682, 95%CI: 0.522–0.938, $p < 0.01$), LVEF (OR: 1.057, 95%CI: 1.020–1.095, $p < 0.01$). The ROC curve analysis served to determine the critical value of continuous variables (AVRE and LVEF) for identifying patients with cardiac rupture. The criterion for optimal cut-off point selection was comprehensive optimization results of sensitivity and specificity.²⁰ An obvious difference was observed in AVRE and LVEF, with a respective under-the-curve area of 0.656 (95%CI: 0.582–0.73) and 0.648 (95%CI: 0.564–0.731) ($p < 0.001$ for both). The threshold value in ROC curves indicates that cardiac rupture is more likely to occur if AVRE is below 2.92 mV (Figure 1A) or LVEF exceeds 43.55% (Figure 1B). The predictive performance of these indicators, including the combination of AVRE and LVEF (joint indicators), is summarized in Table 4.

Discussion

Cardiac rupture, though less common in the reperfusion era,² remains a highly fatal complication of AAMI,³ necessitating tools for early risk stratification.⁸ The electrocardiogram (ECG), as a rapid and universally available bedside test, is ideally suited for this purpose. We therefore investigated a specific ECG parameter—the average R-wave voltage in the limb leads (AVRE). Our principal finding is that a reduced AVRE at admission is an independent predictor of cardiac rupture in AAMI patients with LVA, complementing the predictive value of LVEF.

The biological plausibility of AVRE as a predictor is rooted in the pathophysiology of cardiac rupture. The extensive transmural necrosis and wall thinning that predispose to rupture inherently diminish electromotive forces, leading to

Table 3 Multivariate Analysis of Factors Associated with Cardiac Rupture in Patients with AMVA

Variables	Multivariate Logistic Regression Analysis	
	Adjusted OR (95%CI)	P
AVRE	0.682(0.522, 0.938)	<0.01
LVEF	1.057(1.020, 1.095)	<0.01
LVAT	2.65 (0.649, 12.38)	0.173
Electrical axis	0.995 (0.988, 1.002)	0.145
β -RB within 24 h	0.85 (0.45, 1.61)	0.613
ACEI/ARB within 24h	0.79 (0.42, 1.49)	0.467
Peak cTnI	1.02 (0.99, 1.05)	0.185
D-to-D time	1.01 (0.99, 1.03)	0.401

Abbreviations: ACEI, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; AVRE, average voltage amplitude values of R-waves of electrocardiographic limb leads; cTnI, cardiac troponin I; D-to-D, door-to-device; LVAT, left ventricular apical thrombus; LVEF, left ventricular ejection fraction; β -RB, β -receptor blocker.

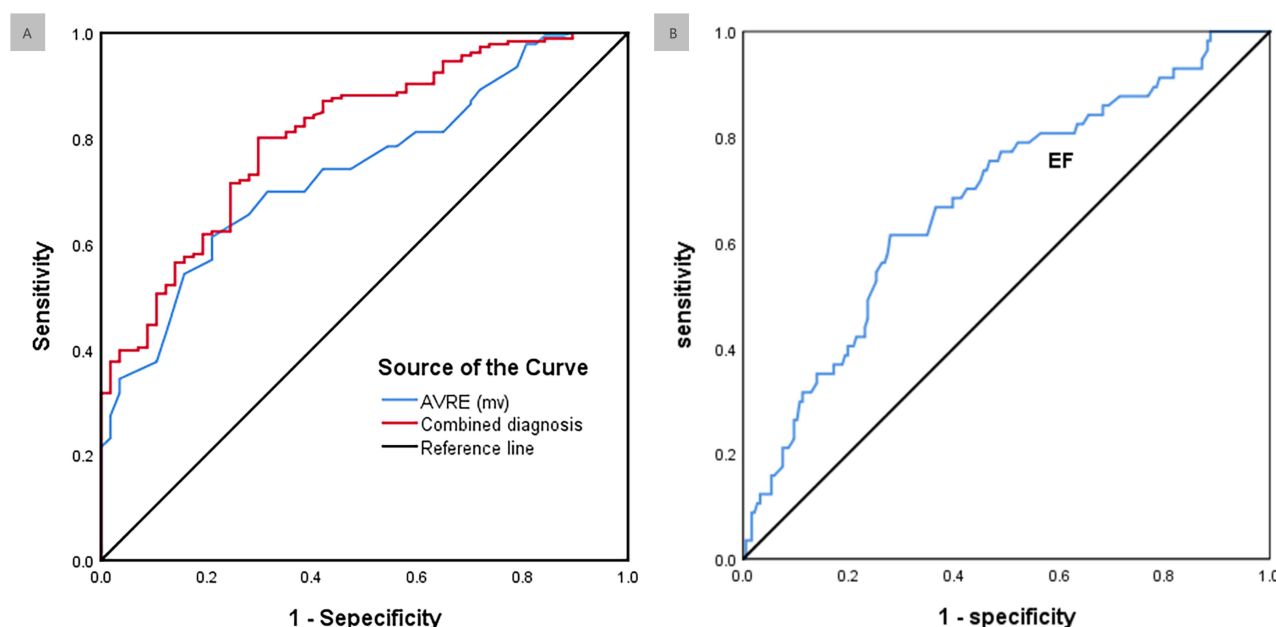


Figure 1 Receiver-operating characteristic (ROC) curves for predicting cardiac rupture. **(A)** ROC curve for the AVRE. The AUC is 0.656 (95% CI: 0.582, 0.73). The optimal cut-off value is <2.92 mV (sensitivity 74.6%, specificity 59.7%). **(B)** ROC curve for LVEF. The AUC is 0.648 (95% CI: 0.564, 0.731). The optimal cut-off value is >43.55% (sensitivity 57.1%, specificity 69.4%).

lower R-wave voltages.¹² Furthermore, pericardial effusion, a common sequela in impending rupture,⁷ acts as a current shunt and increases the heart-electrode distance, further attenuating ECG voltages.^{13–15} Thus, AVRE likely captures the combined electrophysiological consequences of profound myocardial damage and associated pericardial reaction.

Our study, focusing on a cohort of AMI patients with LVA, found well-balanced baseline demographics and most clinical characteristics between the rupture and control groups, enhancing the reliability of the identified predictors. Multivariable logistic regression confirmed that both lower AVRE (OR: 0.682) and higher LVEF (OR: 1.057) were independently associated with cardiac rupture. To rigorously test the independence of these associations, we adjusted for key clinical covariates known to influence rupture risk: peak cTnI (a surrogate for infarct size),^{8,10,21} early use of β -blockers and ACEI/ARBs (guideline-directed medications that reduce wall stress),^{2,10} and door-to-device time (a critical measure of reperfusion efficacy).^{2,22,23} The persistence of both AVRE and LVEF as significant predictors after controlling for these established factors underscores their unique and complementary value in risk stratification. Subsequently, ROC curve analysis quantified this risk, establishing AVRE < 2.92 mV and LVEF > 43.55% as critical thresholds for a significantly increased rupture risk.

Unlike previous studies on cardiac rupture that often enrolled broad AMI populations with significant heterogeneity in baseline risks and infarct locations,⁸ the present study specifically focused on a high-risk yet homogeneous cohort of

Table 4 ROC Curve Analysis of Key Indexes Between the Two Groups

Variables	AUC (95%CI)	SE	P	Critical Value	Sensitivity	Specificity	Youden Index
AVRE	0.656(0.582, 0.73)	0.038	<0.001	2.92	0.746	0.597	0.343
LVEF	0.648(0.564, 0.731)	0.042	<0.001	43.55	0.571	0.694	0.265
Joint indicators	0.740(0.666, 0.814)	0.038	<0.001	/	0.651	0.758	0.409

Note: Joint indicators: a combination of AVRE and LVEF.

Abbreviations: AUC, area under the curve; AVRE, average voltage amplitude values of R-waves of electrocardiographic limb leads; LVEF, left ventricular ejection fraction; ROC, receiver operating characteristic.

AAMI patients who developed LVA. This specific focus on a comparable population strengthens the validity of our findings by minimizing confounding. Our results confirm LVEF as a risk factor. This is mechanistically plausible, as preserved or even enhanced systolic function in the context of a thinned, aneurysmal wall may elevate mechanical stress on the vulnerable myocardium, thereby predisposing it to rupture. More importantly, we introduce AVRE as a novel, independent predictor. This finding is mechanistically supported by this established pathophysiological link, wherein the extensive transmural necrosis that predisposes to rupture also diminishes electromotive forces, as reflected by a lower AVRE.¹² This effect is likely compounded by pericardial effusion, a common sequela of rupture that attenuates ECG voltage.^{13–15} Thus, our study translates this established pathophysiology into a quantifiable and readily available ECG marker, extending the findings of previous studies that linked low voltage to cardiac tamponade to the prediction of the preceding rupture event itself.

Based on our findings, the admission AVRE value offers a practical tool for immediate bedside risk stratification. We propose that patients with AAMI and LVA can be stratified into higher-risk (AVRE < 2.92 mV) and lower-risk (AVRE ≥ 2.92 mV) categories. Those in the higher-risk group may warrant intensified monitoring and early preventive strategies. While LVEF was also an independent predictor, the AVRE—derived from the admission ECG performed within minutes of presentation—provides a uniquely rapid and accessible metric. This advantage in timeliness and availability over echocardiographic parameters like LVEF makes AVRE particularly suitable for initial risk assessment, aligning with the critical need for early decision-making in this acute setting.

Limitations

This study has several limitations. First, its retrospective and single-center design may introduce selection bias and limits the generalizability of our findings; external validation in prospective, multi-center cohorts is needed. Second, the measurement of AVRE, while performed following a standardized protocol, is subject to potential variability due to physiological factors (eg, body habitus, lead placement) and manual measurement error; future studies could benefit from automated, algorithm-based measurements to enhance reproducibility. Finally, our analysis relied solely on the initial admission ECG. The lack of dynamic ECG monitoring means we could not capture evolving changes in R-wave amplitude. It is plausible that such dynamic changes might provide additional prognostic information and reflect the dynamic pathological process leading to rupture.

Conclusions

A reduced AVRE (< 2.92 mV) is an independent predictor of cardiac rupture in this specific cohort of AMI patients with left ventricular aneurysm. Given its timeliness and accessibility, it holds potential as a practical, adjunctive bedside marker for immediate risk stratification at admission. However, considering its modest predictive accuracy, it should complement rather than replace comprehensive clinical assessment. Future studies are needed to validate its utility in guiding intensified monitoring and preventive therapy.

Data Sharing Statements

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request. Data are located in controlled access data storage at Fujian Medical University Union Hospital.

Ethics Approval and Consent to Participate

This retrospective study was approved by the ethics committee of the Fujian Medical University Union Hospital (Approval No:2024KY029) and complies with the Declaration of Helsinki. The Ethics Committee granted a waiver for individual written informed consent due to the study's retrospective design, the use of fully de-identified data, and no additional risk to participants.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

- Figueras J, Alcalde O, Barrabes JA, et al. Changes in hospital mortality rates in 425 patients with acute ST-elevation myocardial infarction and cardiac rupture over a 30-year period. *Circulation*. 2008;118(25):2783–2789. doi:10.1161/CIRCULATIONAHA.108.776690
- Honda S, Asaumi Y, Yamane T, et al. Trends in the clinical and pathological characteristics of cardiac rupture in patients with acute myocardial infarction over 35 years. *J Am Heart Assoc*. 2014;3(5):e000984. doi:10.1161/JAHA.114.000984
- Poulsen SH, Praestholm M, Munk K, et al. Ventricular septal rupture complicating acute myocardial infarction: clinical characteristics and contemporary outcome. *Ann Thorac Surg*. 2008;85(5):1591–1596. doi:10.1016/j.athoracsur.2008.01.010
- Elbadawi A, Elgendy IY, Mahmoud K, et al. Temporal trends and outcomes of mechanical complications in patients with acute myocardial infarction. *JACC Cardiovasc Interv*. 2019;12(18):1825–1836. doi:10.1016/j.jcin.2019.04.039
- Bajaj A, Sethi A, Rathor P, et al. Acute complications of myocardial infarction in the current era: diagnosis and management. *J Investig Med*. 2015;63(7):844–855. doi:10.1097/JIM.0000000000000232
- Leroux E, Chauvette V, Voisine P, et al. Clinical and echocardiographic presentation of postmyocardial infarction papillary muscle rupture. *Echocardiography*. 2019;36(7):1322–1329. doi:10.1111/echo.14402
- Slater J et al. (2000). Cardiogenic shock due to cardiac free-wall rupture or tamponade after acute myocardial infarction: a report from the SHOCK Trial Registry. Should we emergently revascularize occluded coronaries for cardiogenic shock?. *J Am Coll Cardiol*, 36(3 Suppl A), 1117–22. doi:10.1016/s0735-1097(00)00845-7
- Lopez-Sendon J, Gurfinkel EP, Lopez De SAE, et al. Factors related to heart rupture in acute coronary syndromes in the global registry of acute coronary events. *Eur Heart J*. 2010;31(12):1449–1456. doi:10.1093/eurheartj/ehq061
- Yoneyama K, Ishibashi Y, Koeda Y, et al. Association between acute myocardial infarction-to-cardiac rupture time and in-hospital mortality risk: a retrospective analysis of multicenter registry data from the cardiovascular research consortium-8 universities (CIRC-8U). *Heart Vessels*. 2021;36(6):782–789. doi:10.1007/s00380-020-01762-2
- Hao W, Lu S, Guo R, et al. Risk factors for cardiac rupture complicating myocardial infarction: a PRISMA meta-analysis and systematic review. *J Investig Med*. 2019;67(4):720–728. doi:10.1136/jim-2018-000841
- Ibanez B, James S, Agewall S, et al. 2017 ESC guidelines for the management of acute myocardial infarction in patients presenting with st-segment elevation: the task force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *Eur Heart J*. 2018;39(2):119–177. doi:10.1093/eurheartj/ehx393
- Madias JE. Low QRS voltage and its causes. *J Electrocardiol*. 2008;41(6):498–500. doi:10.1016/j.jelectrocard.2008.06.021
- Bruch C, Schmermund A, Dagres N, et al. Changes in QRS voltage in cardiac tamponade and pericardial effusion: reversibility after pericardiocentesis and after anti-inflammatory drug treatment. *J Am Coll Cardiol*. 2001;38(1):219–226. doi:10.1016/S0735-1097(01)01313-4
- Argula RG, Negi SI, Banchs J, et al. Role of a 12-lead electrocardiogram in the diagnosis of cardiac tamponade as diagnosed by transthoracic echocardiography in patients with malignant pericardial effusion. *Clin Cardiol*. 2015;38(3):139–144. doi:10.1002/clc.22370
- Ang KP, Nordin RB, Lee SCY, et al. Diagnostic value of electrocardiogram in cardiac tamponade. *Med J Malaysia*. 2019;74(1):51–56.
- Thygesen K, Alpert JS, Jaffe AS, et al. Fourth universal definition of myocardial infarction (2018). *J Am Coll Cardiol*. 2018;72(18):2231–2264. doi:10.1016/j.jacc.2018.08.1038
- Collet J et al. (2021). 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. *Eur Heart J*, 42(14), 1289–1367. doi:10.1093/eurheartj/ehaa575

18. Kolte D *et al.* (2014). Trends in incidence, management, and outcomes of cardiogenic shock complicating ST-elevation myocardial infarction in the United States. *J Am Heart Assoc*, 3(1), e000590. doi:10.1161/JAHA.113.000590
19. Imazio M, Adler Y. Management of pericardial effusion. *Eur Heart J*. 2013;34(16):1186–1197. doi:10.1093/eurheartj/ehs372
20. Pencina M J, D'Agostino R B. (2004). Overall C as a measure of discrimination in survival analysis: model specific population value and confidence interval estimation. *Stat Med*, 23(13), 2109–23. doi:10.1002/sim.1802
21. Nozoe M, Sakamoto T, Taguchi E, et al. Clinical manifestation of early phase left ventricular rupture complicating acute myocardial infarction in the primary PCI era. *J Cardiol*. 2014;63(1):14–18. doi:10.1016/j.jjcc.2013.06.012
22. Rencuzogullari I, Cagdas M, Karabag Y, et al. Association of the SYNTAX Score II with cardiac rupture in patients with ST-segment elevation myocardial infarction undergoing a primary percutaneous coronary intervention. *Coron Artery Dis*. 2018;29(2):97–103. doi:10.1097/MCA.0000000000000571
23. Qian G, Jin RJ, Fu ZH, et al. Development and validation of clinical risk score to predict the cardiac rupture in patients with STEMI. *Am J Emerg Med*. 2017;35(4):589–593. doi:10.1016/j.ajem.2016.12.033

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