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ARTICLE

Assessment of the Relationship Between C-Reactive Protein-to-Albumin Ratio and Culprit Lesion Location in Patients With ST-Segment Elevation Myocardial Infarction

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Abstract

Aims/Background The C-reactive protein to albumin ratio (CAR) has traditionally been employed to assess inflammatory status in non-cardiac diseases. Recent clinical studies suggest that CAR is a valuable indicator of inflammation in atherosclerotic coronary artery diseases. However, its relationship with ST-segment elevation myocardial infarction (STEMI) remains unclear. This study aimed to investigate the relationship between CAR and the exact location of the culprit lesion in STEMI patients and its potential clinical implications.

Methods A retrospective analysis was conducted on patients who presented with STEMI and were treated with primary percutaneous coronary intervention (PCI) within 12 hours of symptom onset between November 2018 and November 2023. Based on coronary angiography (CAG) findings, patients were categorized into three groups according to the culprit vessel: left anterior descending artery (LAD) (n = 218), left circumflex artery (LCX) (n = 31), and right coronary artery (RCA) (n = 153). Three patients with ramus occlusion were excluded from the subgroup analysis. Furthermore, based on the lesion location within the culprit vessel, patients were divided into proximal (n = 122), middle (n = 222), and distal (n = 61) segment groups. Clinical baseline characteristics and laboratory results were recorded. Statistical analyses, including analysis of variance (ANOVA), the Kruskal-Wallis H-test, Fisher's exact test, and the chi-square test, were performed based on variable types and distribution. Correlation analysis was conducted using Spearman's rank correlation coefficient. The receiver operating characteristic (ROC) curve was applied to determine the optimal cut-off value for CAR. A p-value < 0.05 was considered statistically significant.

Results A total of 405 patients were included in the study. CAR and left ventricular ejection fraction (LVEF) showed significant differences across groups stratified by culprit vessels ($p = 0.001$ for CAR; $p < 0.001$ for LVEF) and lesion location within the vessels ($p < 0.001$ for CAR and LVEF). CAR values were higher in more proximally located lesions ($r = 0.218$, $p < 0.001$), while LVEF showed an inverse relationship ($r = –0.203$, $p < 0.001$). ROC curve analysis showed that CAR could predict proximal- and mid-vessel lesions in STEMI patients, with a cut-off value of 26.16 (area under the curve [AUC]: 0.662, 95% confidence interval [CI]: 0.59–0.74, $p < 0.001$).

Conclusion CAR is an easily calculable and reliable biomarker associated with culprit lesion location in STEMI patients, providing potential clinical utility in risk stratification and disease assessment.

Key words: serum albumin; C-reactive protein (CRP); STEMI; PCI; CAG

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Introduction

Inflammation remains a critical factor in the pathophysiology, treatment, and prognosis of ST-segment elevation myocardial infarction (STEMI). It plays a key

role in the onset and progression of STEMI, and an intense inflammatory response has been identified as an independent predictor of adverse cardiovascular events following STEMI (Seropian et al, 2014; Toldo and Abbate, 2018). Several biomarkers, including tumor necrosis factor-α (TNF-α), interleukin-1 (IL-1), interleukin-6 (IL-6), and serum amyloid A (SAA), have been established as indicators of inflammation in STEMI. However, C-reactive protein (CRP) remains particularly significant due to its high sensitivity and ease of measurement (Blake and Ridker, 2003; Seropian et al, 2016; Her et al, 2017).

Furthermore, hypoalbuminemia has been associated with increased mortality in patients with acute coronary syndrome (ACS), as inflammatory processes reduce albumin synthesis while enhancing its catabolism (Nelson et al, 2000; Oduncu et al, 2013). The C-reactive protein to albumin ratio (CAR) has traditionally been used to assess inflammatory status in non-cardiac disorders, such as malignancies (Kinoshita et al, 2015) and severe sepsis (Ranzani et al, 2013; Kim et al, 2019). CAR is considered superior to individual measurements of CRP or albumin, as it accounts for the interplay and stability between inflammatory activity and nutritional status (Fairclough et al, 2009).

Recently, clinical studies have demonstrated that CAR is a valuable indicator of inflammation in atherosclerotic coronary artery disease (CAD), correlating with disease severity (Çağdaş et al, 2019) and the risk of adverse cardiovascular events (Rencuzogullari et al, 2019). However, its association with STEMI remains poorly defined. Additionally, it has been proved that the location of the culprit lesion significantly influences STEMI outcomes. Specifically, anterior infarctions, often caused by left descending artery disease, and proximally located lesions are more likely to result in adverse events (Karha et al, 2003; Harjai et al, 2006; Nienhuis et al, 2009; Backhaus et al, 2020). However, whether there is a direct association between culprit lesion location and systemic inflammation remains unclear. This study aimed to investigate the association between elevated CAR levels and lesion location, thereby further highlighting the potential role of CAR in risk assessment for STEMI patients.

Methods

Study Subjects

This single-center, retrospective study included patients diagnosed with STEMI who underwent primary percutaneous coronary intervention (PCI) within 12 hours of symptom onset between November 2018 and November 2023. The exclusion criteria encompassed significant valvular heart disease, chronic heart failure classified as New York Heart Association (NYHA) class III–IV, malignancy, severe hepatic or renal dysfunction, active infection, hematologic disorders, chronic obstructive pulmonary disease (COPD), history of electrical defibrillation, and recent stroke. Patients without available blood test results were also excluded.

STEMI was diagnosed according to established standards (Ibánez et al, 2017), including characteristic variations in myocardial enzyme levels; persistent ischemic symptoms (occurring within 12 hours); a new left bundle branch block pattern or

new ST-segment elevation in at least two adjacent leads, defined as ≥0.2 mV in V1–V3 or ≥0.1 mV in other leads; or the identification of new abnormal regional wall motion on imaging.

Diabetes mellitus was diagnosed based on the presence of typical symptoms (polydipsia, polyuria, polyphagia, and weight loss) along with a random plasma glucose level ≥11.1 mmol/L, fasting plasma glucose (FPG) ≥7.0 mmol/L, or 2-hour post-oral glucose tolerance test (OGTT) plasma glucose level ≥11.1 mmol/L (Jia et al, 2019). Hypertension was defined as a clinical systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg in the absence of antihypertensive medication use (Joint Committee for Guideline Revision, 2019). The study protocol was approved by the local ethics committee of Hainan General Hospital (Hainan Affiliated Hospital of Hainan Medical University) and was conducted following the principles outlined in the Declaration of Helsinki. All the participants provided written informed consent.

Data Collection

Blood samples were collected upon admission and analyzed within one hour at the clinical laboratory of the hospital. The CRP and albumin levels were measured using a Roche Cobas 8000 automated biochemical immunoassay analyzer (Roche Diagnostics, Basel, Switzerland). CAR was determined by calculating the ratio of CRP to albumin, multiplied by 100 (Fairclough et al, 2009). Echocardiographic assessment was conducted in all patients using an EPIQ 7 system (Royal Philips, Amsterdam, Netherlands) in the cardiac care unit following primary PCI. The modified Simpson's method was employed to calculate the left ventricular ejection fraction (LVEF).

Angiographic Analysis

Coronary angiography (CAG) was performed by experienced interventional cardiologists, with each coronary artery visualized in at least two distinct projections. The locations of the culprit lesions were analyzed in relation to the affected vessels, specifically the left main artery (LM), left anterior descending artery (LAD), left circumflex artery (LCX), and right coronary artery (RCA). Additionally, the precise positioning of the lesions within each diseased vessel was categorized into proximal, mid, or distal segments. The classification system established by the American Heart Association (AHA), which divides the coronary artery tree into 18 segments and is widely adopted as a standard reference by researchers, was used for segmental categorization. According to this system, segments 1, 5, 6, and 11 were designated proximal; segments 2, 7, and 13 were classified as mid; and all other segments as distal (Austen et al, 1975). Patients without an identifiable culprit lesion were excluded from the analysis. Balloon angioplasty and/or stent implantation were performed as necessary to restore thrombolysis in myocardial infarction (TIMI) grade 3 in the culprit lesion.

Table 1. Baseline clinical and laboratory characteristics by culprit vessel in STEMI patients.

Variable	LAD (n = 218)	LCX (n = 31)	RCA (n = 153)	F/H/χ^2 value	*p*-value
Age (years)	60.69 ± 11.94	58.27 ± 9.61	60.72 ± 11.83	1.280	0.527
Male, n (%)	183 (83.94)	28 (90.32)	130 (84.97)	0.861	0.650
Hypertension, n (%)	99 (45.41)	16 (51.61)	89 (58.17)	5.864	0.053
Diabetes, n (%)	40 (18.35)	6 (19.35)	22 (14.38)	1.150	0.563
Smoking, n (%)	131 (60.09)	21 (67.74)	87 (56.86)	1.346	0.510
Ischemia time (hours)	4.0 (3.0–6.0)	4.0 (3.0–5.0)	4.0 (3.0–5.25)	2.256	0.324
Hemoglobin (g/dL)	143.49 ± 16.35	141.57 ± 15.66	135.52 ± 17.49	19.734	<0.001
WBC (10^3/mm^3)	12.64 ± 3.44	11.49 ± 2.99	11.69 ± 3.25	9.090	0.011
Neutrophils (10^3/mm^3)	10.61 ± 3.17	9.39 ± 2.71	9.80 ± 3.02	7.720	0.021
Lymphocytes (10^3/mm^3)	1.14 (0.85–1.58)	1.30 (0.91–1.77)	1.08 (0.80–1.56)	2.516	0.284
Platelet count (10^3/mm^3)	243.00 (209.50–287.50)	246.00 (201.25–276.75)	241.00 (196.00–275.50)	1.709	0.425
Creatinine (mg/dL)	66.00 (56.50–78.50)	70.80 ± 15.21	73.00 (58.50–86.00)	5.190	0.075
ALT (IU/L)	55.50 (38.10–80.60)	45.60 (28.83–66.33)	43.50 (31.20–70.65)	7.335	0.026
AST (IU/L)	217.40 (106.70–416.10)	163.60 (87.23–303.35)	121.60 (67.25–207.05)	32.930	<0.001
LDL-C (mg/dL)	3.22 ± 1.06	2.89 ± 0.98	2.85 ± 0.89	14.782	0.001
HDL-C (mg/dL)	1.32 ± 0.25	1.23 ± 0.23	1.21 ± 0.26	21.815	<0.001
CK (IU/L)	2851.10 (1167.15–5773.45)	2597.45 (1524.20–4615.30)	1376.00 (677.60–2975.60)	27.746	<0.001
CK-MB (IU/L)	220.00 (113.50–402.40)	214.25 (114.75–308.55)	123.20 (70.75–230.65)	24.164	<0.001
Troponin T (ug/L)	6.97 (1.77–10.00)	3.17 (0.80–8.03)	2.27 (0.82–5.84)	35.356	<0.001
Albumin (g/L)	39.03 ± 3.78	38.66 ± 3.14	37.65 ± 3.61	6.431	0.002
CRP (mg/dL)	12.12 (5.50–24.66)	6.84 (2.91–15.11)	7.69 (4.49–13.10)	16.735	<0.001
NT-proBNP (pg/mL)	248.00 (80.00–896.50)	98.50 (36.25–282.75)	114.00 (57.50–290.50)	21.660	<0.001
CAR (×100)	30.35 (13.85–64.66)	18.24 (7.26–39.95)	20.27 (11.41–37.02)	13.984	0.001
LVEF (%)	48.00 (44.00–56.00)	54.50 (49.00–64.00)	60.00 (52.00–64.50)	61.629	<0.001

Note: Data are presented as mean ± standard deviation (SD), n (%), or median (interquartile range).

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; CAR, C-reactive protein to albumin ratio; CK, creatine kinase; CK-MB, creatine kinase-myocardial band; CRP, C-reactive protein; HDL-C, high-density lipoprotein cholesterol; LAD, left anterior descending artery; LCX, left circumflex artery; LDL-C, low-density lipoprotein cholesterol; LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide; RCA, right coronary artery; WBC, white blood cell; STEMI, ST-segment elevation myocardial infarction.

Table 2. Baseline clinical and laboratory characteristics according to the location within the culprit vessel.

Variable	Proximal (n = 122)	Mid (n = 222)	Distal (n = 61)	F/H/χ^2 value	*p*-value
Age (years)	60.74 ± 12.02	60.15 ± 11.98	60.93 ± 10.12	0.615	0.735
Male, n (%)	104 (85.24)	187 (84.23)	53 (86.89)	0.276	0.871
Hypertension, n (%)	62 (50.82)	108 (48.65)	35 (57.38)	1.461	0.482
Diabetes, n (%)	18 (14.75)	42 (18.92)	9 (14.75)	1.231	0.540
Smoking n (%)	69 (56.56)	133 (59.91)	38 (62.30)	0.641	0.726
Ischemia time (hours)	4.0 (3.0–6.0)	4.0 (3.0–6.0)	4.0 (3.0–5.0)	0.679	0.712
Hemoglobin (g/dL)	141.36 ± 17.62	141.33 ± 16.65	134.30 ± 17.20	9.596	0.008
WBC (10^3/mm^3)	12.75 ± 3.74	11.83 (9.95–14.15)	10.51 (9.42–12.92)	11.291	0.004
Neutrophils (10^3/mm^3)	10.73 ± 3.41	9.82 (8.18–11.81)	8.96 (7.63–11.00)	8.891	0.012
Lymphocytes (10^3/mm^3)	1.16 (0.84–1.66)	1.13 (0.85–1.59)	1.14 ± 0.56	5.095	0.078
Platelet count (10^3/mm^3)	250.86 ± 57.26	245.58 ± 59.71	242.50 (188.00–276.75)	1.944	0.378
Creatinine (mg/dL)	70.00 (60.00–80.75)	67.00 (56.00–80.00)	71.18 ± 18.75	0.931	0.628
ALT (IU/L)	59.75 (43.43–88.43)	48.30 (32.20–72.10)	40.90 (29.10–66.23)	21.768	<0.001
AST (IU/L)	197.40 (94.65–414.13)	167.40 (90.00–306.60)	120.75 (61.38–226.68)	18.328	<0.001
LDL-C (mg/dL)	3.12 ± 0.98	3.06 ± 1.04	2.86 ± 0.94	5.060	0.080
HDL-C (mg/dL)	1.26 (1.11–1.45)	1.22 (1.07–1.39)	1.28 ± 0.31	2.603	0.272
CK (IU/L)	2949.3 (1137.85–5790.93)	2114.20 (1037.10–4070.00)	1444.75 (633.13–3076.35)	14.743	0.001
CK-MB (IU/L)	220.95 (88.60–409.08)	178.50 (101.70–287.60)	157.75 (72.73–271.95)	9.055	0.011
Troponin T (ug/L)	5.18 (1.79–10.00)	4.19 (1.13–9.88)	3.17 (0.89–7.24)	9.909	0.007
Albumin (g/L)	38.61 ± 3.61	38.73 ± 3.84	37.42 ± 3.25	5.774	0.056
CRP (mg/dL)	11.66 (6.55–23.43)	9.08 (4.93–17.07)	5.81 (3.10–9.05)	23.567	<0.001
NT-proBNP (pg/mL)	196.00 (68.50–690.50)	153.00 (64.00–528.00)	118.00 (78.25–302.75)	2.113	0.348
CAR (×100)	29.83 (16.46–59.79)	24.15 (12.29–45.18)	14.26 (7.73–25.81)	21.147	<0.001
LVEF (%)	50.50 (44.25–60.75)	52.00 (47.00–62.00)	60.00 (52.00–64.00)	17.351	<0.001

Note: Data are presented as mean ± SD, n (%), or median (interquartile range).

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; CAR, C-reactive protein to albumin ratio; CK, creatine kinase; CK-MB, creatine kinase-myocardial band; CRP, C-reactive protein; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide; WBC, white blood cell.

Statistical Analysis

Statistical analyses were conducted using SPSS version 21.0 (IBM Corp., Chicago, IL, USA). The Kolmogorov-Smirnov test was employed to determine the normality of variable distributions. For continuous variables, normally distributed data were presented as mean ± standard deviation (SD) and analyzed using analysis of variance (ANOVA). Non-normally distributed continuous variables were reported as median values with interquartile ranges (IQRs) and compared using the Kruskal-Wallis H-test. Categorical variables were expressed as counts (percentages) and analyzed using Fisher's exact test or chi-square tests.

Additional pairwise comparisons were conducted for some primary variables like CAR and LVEF. Given that these variables were not normally distributed, Spearman's rank correlation coefficient was employed for the analysis of correlations.

The receiver operating characteristic (ROC) curve was employed to determine the optimal cut-off value of CAR. Youden's J statistic was used to predict the discriminatory power of CAR in lesion localization. A p-value < 0.05 was considered statistically significant.

Results

Baseline Clinical Data

A total of 405 patients were recruited in this study. Based on CAG findings, patients were categorized into three groups: LAD (218 patients), LCX (31 patients), and RCA (153 patients). Three additional patients with ramus occlusion were excluded from the subgroup analysis due to the small sample size. Patients were further classified based on the location of the culprit lesion within the affected vessel into proximal (122 patients), mid (222 patients), and distal (61 patients) segment groups. Tables 1,2 summarize the baseline clinical characteristics of the study population.

No statistically significant differences were observed among groups stratified by either culprit vessel or lesion location in terms of age, sex, hypertension, diabetes, smoking history, time from symptom onset, lymphocyte count, platelet count, and creatinine levels. However, levels of low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), N-terminal pro-B-type natriuretic peptide (NT-proBNP), and albumin varied significantly among groups categorized by culprit vessel, but not by specific lesion location within the vessels.

In contrast, significant differences in CRP, CAR, and myocardial enzyme levels, including creatine kinase (CK), creatine kinase-myocardial band (CK-MB), and troponin T, as well as LVEF, were observed among groups categorized by culprit vessel and lesion locations within the vessels.

Pairwise Comparison of CAR and LVEF

The pairwise comparison revealed that CAR was significantly higher in the LAD lesion group compared to the RCA group (30.35 [13.85–64.66] vs. 20.27 [11.41–37.02], $p = 0.002$). However, no significant differences were observed be-

tween the LCX and LAD groups (18.24 [7.26–39.95] vs. 30.35 [13.85–64.66], p = 0.091) or between the LCX and RCA groups (18.24 [7.26–39.95] vs. 20.27 [11.41–37.02], p = 1.000) (Fig. 1a).

LVEF was significantly lower in the LAD lesion group compared to the LCX group (48.00 [44.00–56.00] vs. 54.50 [49.00–64.00], p = 0.001) and the RCA group (48.00 [44.00–56.00] vs. 60.00 [52.00–64.50], $p < 0.001$). However, no significant difference in LVEF was observed between the LCX and RCA groups (54.50 [49.00–64.00] vs. 60.00 [52.00–64.50], p = 1.000) (Fig. 1b).

When analyzed based on lesion location within the culprit vessel, CAR values in the distal lesion were significantly lower than those in the proximal (14.26 [7.73–25.81] vs. 29.83 [16.46–59.79], $p < 0.001$) and mid (14.26 [7.73–25.81] vs. 24.15 [12.29–45.18], p = 0.003) lesion groups. However, no statistically significant difference was observed between the proximal- and mid-lesion groups (29.83 [16.46–59.79] vs. 24.15 [12.29–45.18], p = 0.08) (Fig. 1a).

Similarly, LVEF was significantly higher in the distal lesion group compared to the proximal (60.00 [52.00–64.00] vs. 50.50 [44.25–60.75], $p < 0.001$) and mid (60.00 [52.00–64.00] vs. 52.00 [47.00–62.00], p = 0.011) lesion groups. However, no significant difference was observed between the proximal- and mid-lesion groups (50.50 [44.25–60.75] vs. 52.00 [47.00–62.00], p = 0.115) (Fig. 1b).

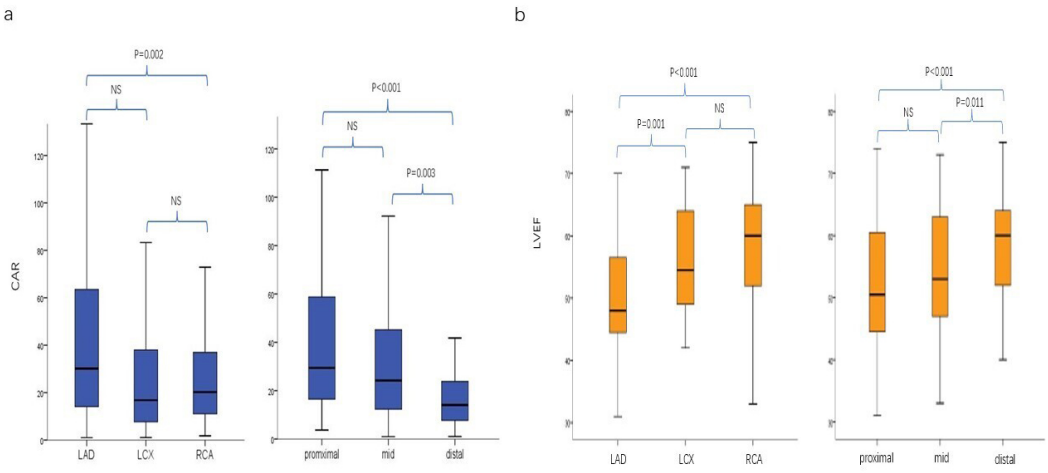

Fig. 1. Distribution of CAR and LVEF across different culprit lesions. (a) Distribution of the CAR among different culprit lesions. (b) Distribution of LVEF among different culprit lesions. NS, no statistical significance; CAR, C-reactive protein to albumin ratio; LVEF, left ventricular ejection fraction; LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery.

Correlation Analysis Between CAR, LVEF, and the Culprit Lesion Location

Scatter plots illustrating the relationships between CAR, LVEF, and culprit lesion segments are presented in Fig. 2. Spearman's rank correlation coefficient analysis revealed a weak but statistically significant correlation between CAR, LVEF, and lesion location within the culprit vessel. Notably, CAR values were higher in

Table 3. Correlation between CAR, LVEF and the location within the culprit vessel.

Variable	Spearman's rank correlation coefficient (r)	*p*-value
CAR	0.218	<0.001
LVEF	–0.203	<0.001

Abbreviations: CAR, C-reactive protein to albumin ratio; LVEF, left ventricular ejection fraction.

more proximally located lesions (r = 0.218, $p < 0.001$), whereas LVEF was lower in these cases (r = –0.203, $p < 0.001$) (Table 3).

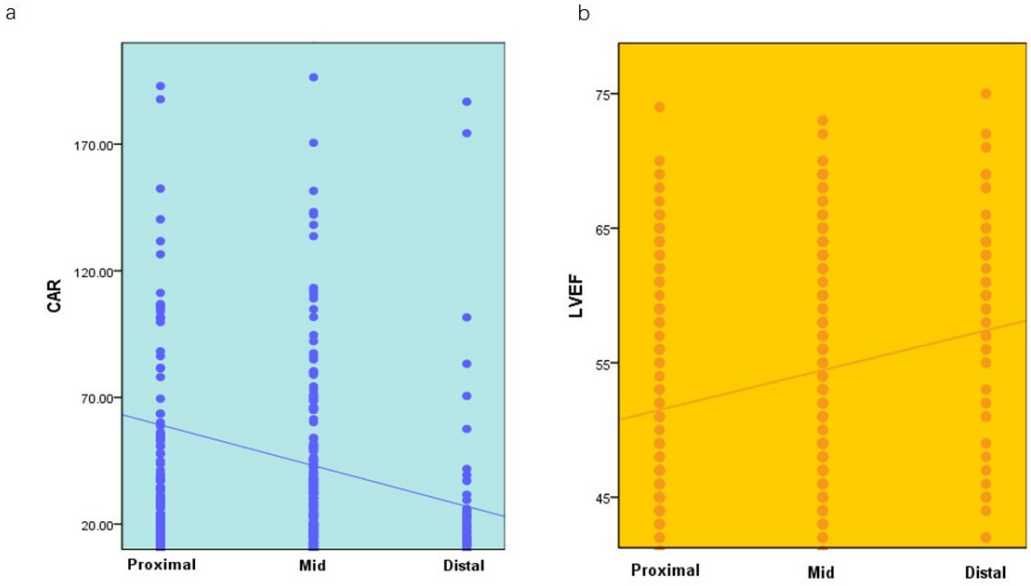

Fig. 2. Correlation between CAR, LVEF, and the location of the culprit vessel. (a) Scatter plots showing the correlation between CAR and the location within the culprit vessel. (b) Scatter plots showing the correlation between LVEF and the location within the culprit vessel. CAR, C-reactive protein to albumin ratio; LVEF, left ventricular ejection fraction.

Predictive Value of CAR for the Culprit Lesion

CAR demonstrated predictive capability for proximal-mid lesion, with an optimal cut-off value of 26.16, an area under the curve (AUC) of 0.662, a sensitivity of 51.2%, and a specificity of 78.7% (95% confidence interval [CI]: 0.59–0.74, $p < 0.001$; Fig. 3).

Discussion

In this study, we evaluated the correlation between CAR and the location of the culprit lesion in STEMI and observed that CAR reflects the relative position of the lesion. These findings suggest that CAR may play a potential role in risk stratification and prognostic prediction in STEMI patients.

With the continuous advancements in coronary intervention and intravascular imaging, the pathogenesis of acute myocardial infarction has been gradually clari-

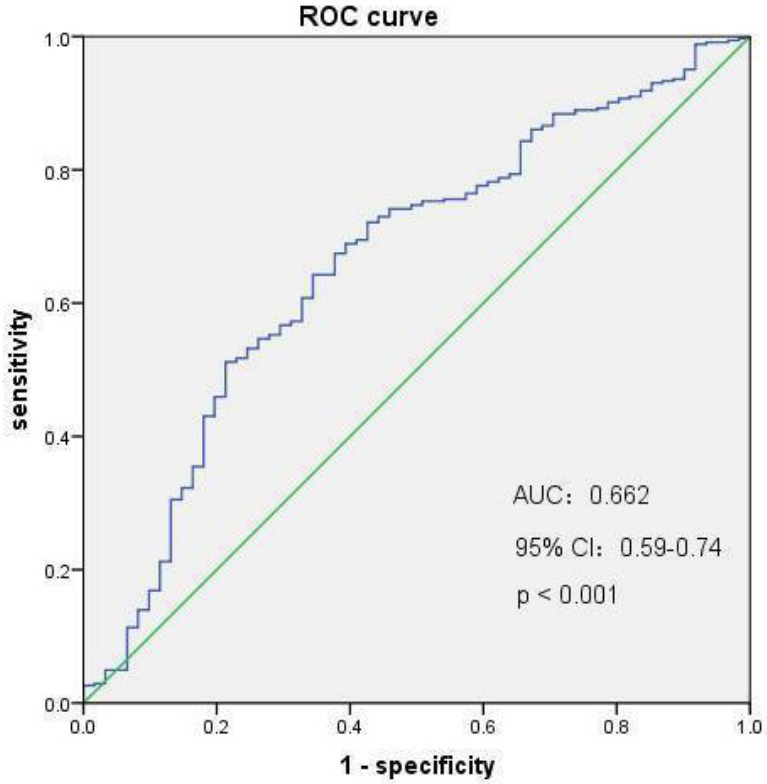

Fig. 3. ROC curve analysis of CAR for predicting proximal-mid lesion in STEMI. CAR, C-reactive protein to albumin ratio; STEMI, ST-segment elevation myocardial infarction; AUC, area under the curve; CI, confidence interval; ROC, receiver operating characteristic.

fied, primarily involving plaque erosion, plaque rupture, and calcified nodules (Jia et al, 2013). Inflammation is involved in all of these pathways leading to acute events, reinforcing the concept that coronary atherosclerosis is fundamentally an inflammatory disease, which mainly involves T lymphocytes and macrophages (Falk et al, 2013; Libby et al, 2014).

CRP and albumin are both acute-phase reactant proteins and classic markers associated with adverse outcomes after myocardial infarction, including heart failure, left ventricular thrombosis, recurrent myocardial infarction, and long-term mortality, as demonstrated in previous studies (Shacham et al, 2014; Milwidsky et al, 2017; Lechner et al, 2022). In recent years, CAR has emerged as a superior marker of systemic inflammation in patients with atherosclerotic coronary artery disease. Acet et al (2021) proposed that the combination of CAR and the global registry of acute coronary events (GRACE) score is associated with the risk of major adverse cardiovascular events (MACE) in STEMI patients undergoing primary PCI. Several studies have confirmed the prognostic significance of elevated CAR in STEMI patients in many ways, such as thrombus burden (Duman et al, 2019; Kaplangoray et al, 2023), non-reflow phenomenon (Gayretli Yayla et al, 2022), acute kidney injury (AKI) (Karabağ et al, 2019), and stent restenosis (Rencuzogullari et al, 2019). However, limited evidence exists to validate the relationship between CAR and the location of the culprit lesion.

Söğüt et al (2021) grouped STEMI patients based on electrocardiogram (ECG) findings into inferior STEMI, anterior STEMI, and other STEMI (including lateral, right, and posterior STEMI) and found no statistically significant differences in CAR among these groups. However, the study did not rely on CAG, which remains the gold standard for diagnosing STEMI. In our study, patients were grouped based on the exact location of the culprit lesion as determined by CAG. For the first time, we observed statistically significant differences in CAR levels across different culprit vessels and segments within the culprit vessel, with the most notable difference observed between proximal and distal lesions, mid and distal lesions, and LAD and RCA lesions.

It is well established that occlusion in the proximal- or mid-segment lesions leads to larger areas of myocardial necrosis and more adverse clinical outcomes compared to distal occlusion. Fuernau et al (2016) confirmed this in their clinical study, demonstrating a significant increase in 1-year mortality in patients with proximal-segment occlusion, although no statistical differences were observed among LAD, LCX, and RCA occlusions. In contrast, Backhaus et al (2020) proposed that LAD occlusion was associated with larger necrotic area, more frequent impairment of systolic and atrial function, as evidenced by cardiac magnetic resonance imaging. Their multivariate analysis further identified LAD occlusion as an independent predictor of MACE. Our study found that CAR levels were significantly higher in proximal-mid lesions compared to distal lesions, with a significant correlation between CAR and lesion location ($p < 0.05$). These findings suggest that inflammation is more intense when the occlusion occurs in the proximal- or mid-segment of the vessel. Similarly, LVEF was significantly lower in proximal- and mid-segment lesions compared to distal lesions. LVEF was also significantly correlated with lesion location ($p < 0.05$), suggesting more severe cardiac dysfunction with more proximally located lesions. These findings are consistent with clinical experience and previous studies that demonstrate the inferior outcomes associated with proximal lesions.

Interestingly, while LVEF was significantly lower in the LAD group than in the RCA and LCX groups, a significant difference in CAR levels was observed only between the LAD and RCA groups, with no significant difference in CAR between the LAD and LCX or LCX and RCA groups. Whether the intensity of the inflammatory response is directly associated with infarct location or infarct size, specifically, whether a proximal- or mid-segment lesion or a larger infarct size leads to a worse prognosis due to a more intense inflammatory response, remains unconfirmed. Further pathophysiological studies are required to confirm this association.

As an inflammatory marker closely related to CRP, CAR has been demonstrated in numerous studies to possess risk stratification and prognostic value. In a study by Karabağ et al (2019), STEMI patients who developed AKI following PCI exhibited elevated levels of CRP and CAR, along with reduced levels of albumin. Notably, CAR was independently associated with AKI (odds ratio [OR]: 2.307, 95% CI: 1.397–3.809; $p = 0.001$), whereas CRP and albumin did not exhibit predictive value in univariate and multivariate logistic regression analyses. Similarly, research by Duman et al (2019) identified elevated CRP and CAR levels,

along with lower albumin levels, as significant predictors of thrombotic burden in patients with ACS. Comparative analysis further revealed that CAR outperformed CRP in predicting thrombotic burden (AUC of CAR: 0.697; AUC of CRP: 0.653; $p < 0.05$). Additionally, a study by Çağdaş et al (2019) demonstrated that CAR was more effective than both CRP and albumin in predicting cardiac surgery (synergy between percutaneous coronary intervention with TAXUS and cardiac surgery, SYNTAX) scores in CAD patients (OR: 1.020; 95% CI: 1.009–1.031; $p < 0.001$), reinforcing its role as a superior inflammatory marker for assessing CAD severity.

Additionally, a study by Acet et al (2021) demonstrated that CAR outperformed CRP and albumin in predicting short-term MACE among STEMI patients undergoing PCI (AUC of CAR: 0.770; AUC of CRP: 0.761; AUC of albumin: 0.658). Collectively, these findings indicate that CAR serves as a crucial indicator for risk stratification and prognosis in patients with STEMI.

Our investigation further revealed an association between CAR levels and the precise localization of culprit lesions in STEMI patients. Although its predictive ability for proximal-mid lesions was somewhat limited, with a sensitivity of only 51.2%, CAR remains clinically relevant due to its incorporation of two significant inflammatory biomarkers and ease of measurement. If elevated CAR levels indicate proximal-mid segment lesion or LAD disease, both associated with larger infarct sizes, its significance in risk stratification for STEMI patients becomes even more evident. This observation may also partially explain the frequent association between elevated CAR and poor prognosis. Consequently, CAR-based risk stratification may serve as a valuable tool for guiding selective anti-inflammatory therapy. With an increasing understanding and ongoing research on inflammation and its role in acute myocardial infarction (AMI), there has been a growing focus on anti-inflammatory interventions (Seropian et al, 2014). However, no anti-inflammatory agent has definitively shown improved outcomes beyond standard care to date. This may be attributed to the lack of individualized medication strategies in previous studies, where undifferentiated anti-inflammatory therapies were administered without considering the potential benefits of specific inflammatory responses, such as those involved in tissue repair. If risk stratification based on CAR levels could be used to selectively administer anti-inflammatory therapy to high-risk patients, outcomes might improve. However, our findings remain preliminary due to limitations inherent in our study. Future research should aim to validate these observations through larger, randomized, controlled clinical trials.

This study has several limitations. First, as a retrospective study, we used LVEF measured by cardiac ultrasound during hospitalization as an observational indicator for short-term prognosis of STEMI rather than conducting long-term follow-up, which may limit the persuasiveness of our findings. Second, post-STEMI inflammatory status is dynamic, with corresponding fluctuations in the relevant markers over time, which may not fully capture their prognostic significance. Third, variations in coronary anatomy could influence the relationship between CAR and different culprit vessel localization, potentially affecting our results. Finally, as a single-center study with a relatively small sample size, our findings are subject to inherent limitations and may not be fully generalizable.

Conclusion

CAR is a readily obtainable and reliable inflammatory marker that correlates with the location of the culprit lesion in STEMI patients, providing potential clinical utility in risk stratification and disease assessment.

Key Points

- In STEMI patients, the LAD lesion group exhibits higher CAR levels and lower LVEF.
- STEMI patients with proximal- or mid-segment lesions have higher CAR levels and lower LVEF compared to those with distal lesions.
- CAR levels increase while LVEF decreases as the lesion location shifts closer to the proximal segment.
- CAR predicts proximal-mid segment lesion with a cut-off value of 26.16 and an AUC value of 0.662, demonstrating a sensitivity of 51.2% and a specificity of 78.7%.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

YD made substantial contributions to the conception and design, analysis and interpretation of the data, as well as drafting the manuscript. XH jointly completed the conception and design. JP and CW made contributions to the acquisition, visualization, and curation of the data. All authors contributed to revising the manuscript critically for important intellectual content. All authors gave final approval of the version to be published. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

The study protocol was approved by the local ethics committee of Hainan General Hospital (Hainan Affiliated Hospital of Hainan Medical University) (ethical lot number: EC-LC-2024-25-01) and was conducted following the principles outlined in the Declaration of Helsinki. All the participants provided written informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

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