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Lymphocyte to c-reactive protein ratio predicts the risk of contrast-induced acute kidney injury in STEMI patients undergoing percutaneous coronary intervention

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Abstract

Background Contrast-induced acute kidney injury (CI-AKI) is a common complication of percutaneous coronary intervention (PCI) in ST-elevation myocardial infarction (STEMI) patients. Our aim was to assess the lymphocyte to C-reactive protein ratio (LCR) to predict CI-AKI in patients with acute STEMI.

Methods A total of 777 patients with STEMI undergoing primary PCI were continuously included in this study. The occurrence of CI-AKI was monitored during the follow-up period for all patients. Logistic regression analysis was employed to assess the relationship between LCR and CI-AKI. Furthermore, ROC analysis was conducted to establish the optimal LCR cut-off value for the prediction of CI-AKI.

Results The incidence of CI-AKI after PCI was 12.2% (95/777). Univariate and multivariate analysis showed that LCR was an independent factor for CI-AKI after PCI. ROC curve analysis of LCR showed the optimal cut-off value of LCR identified for predicting CI-AKI was 7875.94, yielding the area under the curve of 0.626 (95% CI: 0.572–0.679; $P<0.001$). The integration of the LCR could significantly improve the ability of the model to identify CI-AKI (IDI = 0.016[$P<0.001$], and NRI = 0.137[$P=0.006$]).

Conclusion LCR is an independent risk factor for CI-AKI in STEMI patients undergoing primary PCI. Integration of LCR can significantly improve the risk model for CI-AKI.

Keywords The lymphocyte to C-reactive protein ratio, Contrast-induced acute kidney injury, ST-segment elevation myocardial infarction, Percutaneous coronary intervention

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Introduction

Cardiovascular disease remains the leading cause of death worldwide [1, 2]. The escalating prevalence of cardiovascular diseases, with a particular emphasis on acute ST-segment-elevation myocardial infarction (STEMI), is imposing an unprecedented strain on healthcare systems worldwide, presenting a significant challenge to societal health [3]. Percutaneous coronary intervention (PCI) stands as the principal therapeutic approach for individuals experiencing acute STEMI, but contrast-induced acute kidney injury (CI-AKI) occurs in 15–35% of patients after PCI [4]. CI-AKI is linked to poor clinical outcomes, prolonged hospitalizations, and increased healthcare expenditures [5]. Given the absence of effective therapies for CI-AKI in clinical practice, accurately identifying patients at high risk is highly valuable [6].

The lymphocyte to C-reactive protein ratio (LCR) is an innovative inflammation-based metric that relies solely on lymphocyte counts and C-reactive protein levels [7]. It has emerged as a new predictive marker for gastric cancer [8], hepatocellular carcinoma [9], intrahepatic cholangiocarcinoma [7], gallbladder cancer [10], and colorectal cancer [11]. Recent studies have shown that the relationship between lymphocytes and C-reactive protein (CRP) can be used as a biomarker for evaluating cardiovascular inflammation [12, 13]. High levels of CRP may be associated with an over-activation of the innate immune response, which can intensify local kidney inflammation and subsequently result in injury to renal tubular epithelial cells [14]. Alterations in lymphocyte counts could contribute to the development of renal inflammation and subsequent dysfunction [15]. Although numerous investigations have explored the connection between LCR and cardiovascular disease (CVD), there is no data specifically examining the association between LCR and the risk of subsequent CI-AKI among patients with STEMI undergoing primary PCI. Understanding the potential role of LCR in the pathogenesis and progression of CI-AKI could provide valuable insights into its underlying mechanisms and help identify novel therapeutic targets.

Consequently, the main aim of this research was to evaluate the association between LCR and the risk of subsequent CI-AKI among patients with STEMI undergoing primary PCI.

Materials and methods

Study design and population

The present study is a single-center retrospective observational study focusing on patients with STEMI undergoing primary PCI that was conducted at Affiliated Hospital of Xuzhou Medical University from October 2020 to January 2023. Patients with missing data and outliers were excluded. Inclusion criteria: (1) Patients diagnosed with STEMI according to "the fourth universal definition of myocardial infarction" [16]: (i): Troponins at least one occasion above the 99th percentile of the upper limit of the reference value; (ii): New ST- segment elevation occurred at J point in two adjacent leads, with ≥ 2 mm in lead V2-V3 (male, ≥ 40 years old); ≥1.5 mm (in women, regardless of age); Other leads were ≥ 1.0 mm. (2) Patients undergoing primary PCI. The major exclusion criteria were consisting of the following items:1. Chronic renal dialysis patients (estimated glomerular filtration rate (eGFR) < 30 $mL{\cdot}min^{-1}{\cdot}1.73\ m^{-2}$) or those with severe hepatic abnormalities; 2. Inflammation (including active infection, systemic inflammation, and autoimmune diseases); 3. Active malignant tumor; 4. Hematological disorders; 5. Exposure to radiocontrast or nephrotoxic drugs within 48 h or 72 h preoperatively. Finally, 777 patients remained in the study sample (Fig. 1), which included 554 men (71.3%), with an average age of 63.40 ± 13.02 years. A combination of medical records and telephone interviews was used in the study to collect data. The study protocol has been approved by the Ethics Committee of the Affiliated Hospital of Xuzhou Medical University (Ethics number: XYFY2021-KL024-01).

PCI method and medications

PCI was performed by experienced interventional cardiologists based on standard clinical practice. All patients received a loading dose of aspirin 300 mg, clopidogrel 300 mg or ticagrelor 180 mg, and 100 U/kg of intravenous heparin before PCI. The contrast agent used was a low-osmolar nonionic contrast agent with an osmotic concentration of 600–800 mOsm/Kg. High-risk patients should be administered 0.9% saline through intravenous infusion at a rate of approximately 1 mL/kg per hour, commencing 6–12 h prior to the procedure and continuing for up to 12–24 h post-radiographic examination, provided diuresis is appropriate and the cardiovascular condition permits. Post-procedure, based on each patient's specific health status, an interventional cardiologist provided an adequate volume of fluid hydration to aid in the clearance of the contrast agent from the body [17]. Intravenous hydration was continued for a longer duration in cases where CI-AKI developed at the discretion of the attending physicians.

Data collection and definitions

The basic clinical characteristics of the patients were collected, including basic information, previous diseases, PCI-related information, and medication. Antecubital venous blood samples were collected before and after PCI, and the blood samples were uniformly tested and reported in the hospital laboratory. The LCR was derived by lymphocyte counts divided by the C-reactive protein levels.

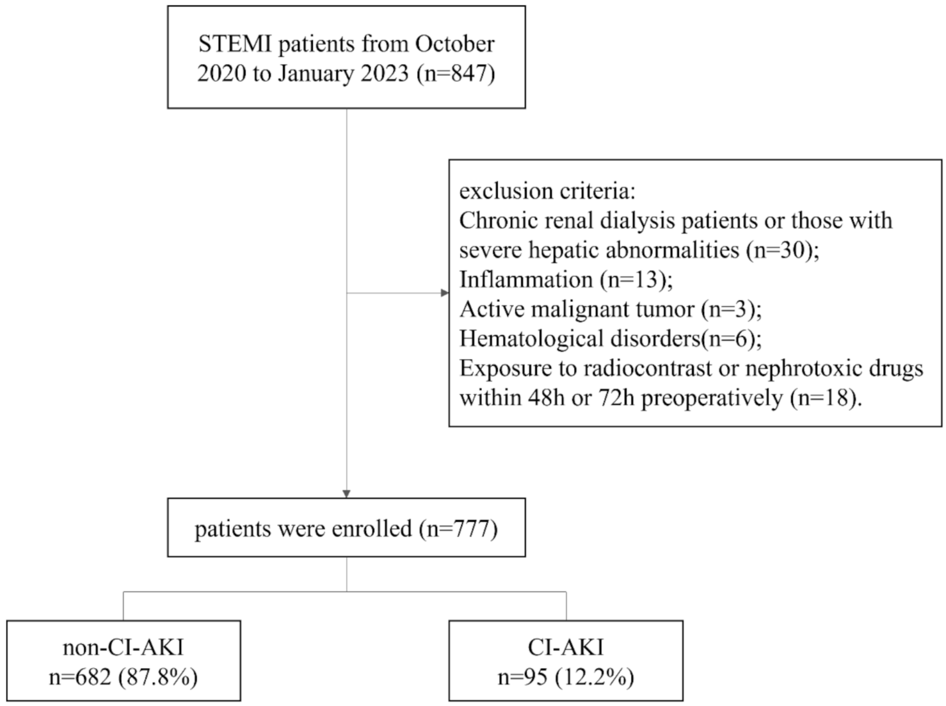

Fig. 1 The study flowchart of participants. CI-AKI, contrast-induced acute kidney injury

Clinical endpoints

Diagnostic criteria for CI-AKI depend on the Kidney Disease: Improving Global Outcomes (KDIGO): an increase in serum creatinine (SCr) ≥ 26.5μmol/L within 48 h, or ≥ 1.5 times baseline SCr within seven days, or urine output < 0.5 mL·kg^{-1}·h for six consecutive hours after the administration of contrast agents [18, 19].

Statistical analysis

We performed statistical analysis with the use of Statistical Package for Social Sciences (SPSS) version 27, and the figures were generated by GraphPad software 9. Ink. For continuous variables, the variables are displayed as the mean ± standard deviation, while the categorical variables were presented as counts and percentages (%). A t-test or an ANOVA was conducted to compare the continuous variables between groups. Pearson's chi-squared (χ^2) test or Fisher's exact test, depending on the circumstance, was used to compare categorical variables. Univariate and multivariate logistic regression modeling was used to analyze the independent predictors of CI-AKI in STEMI patients after PCI. All the significant covariates with $P < 0.10$ in the univariate analysis were further selected for the multivariate analysis to determine whether the LCR can be served as the independent predictors for the CI-AKI of the STEMI patients, and the estimated hazard ratio (HR) and 95% confidence interval (CI) were applied in the analysis. In addition, the receiver operating curve (ROC) analysis was utilized to calculate their corresponding area under the curve (AUC) and the optimal cut-off value of LCR to predict CI-AKI according to the Youden index. The Net Reclassification Improvement (NRI) and Integrated Discrimination Improvement (IDI) were calculated to determine how much the model improves the prediction accuracy and ability compared to clinical risk factors. All analysis was conducted two-sided, and a P-value < 0.05 was considered statistically significant for all analyses.

Results

Baseline characteristics

A total of 777 STEMI patients who underwent PCI were included in the final analysis of the present study, including 554 men (71.3%), with the mean age of (63.40 ± 13.02) years, and the incidence of CI-AKI was 12.2% (95/777). The two groups' clinical features and laboratory indicators are shown in Table 1. Significant differences were found between the CI-AKI and non-CI-AKI groups regarding clinical characteristics and laboratory indicators, including age, LVEF, neutrophil, lymphocyte, monocyte, fasting blood glucose (FBG), peak high sensitivity C-reactive protein (hs-CRP), peak high sensitivity troponin T (hs-TnT), peak N-terminal pro-B-type natriuretic peptide (NT- proBNP), LCR, diabetes mellitus, infarct-related artery (IRA) left circumflex artery (LCX) and right coronary artery (RCA) ($P < 0.05$).

Table 1 Clinical characteristics of the study population stratified by CI-AKI

	non- CI-AKI (*N* = 682)	CI-AKI (*N* = 95)	*P*
Age (years)	63.07 ± 13.33	66.16 ± 9.79	**0.003**
Female, *n* (%)	190 (27.86)	33 (34.74)	0.165
LVEF, %	52.43 ± 6.81	48 ± 7.24	**< 0.001**
Heart rate, bpm	80.15 ± 14.47	82.05 ± 13.59	0.228
SBP, mmHg	127.28 ± 20.59	128.12 ± 20.49	0.709
DBP, mmHg	79.03 ± 14.12	79.51 ± 14.27	0.760
BMI, kg/m^2	24.61 ± 3.85	25.37 ± 4.08	0.074
Duration of surgery	59.73 ± 20.23	63.29 ± 19.43	0.106
WBC,10^9/L	10.25 ± 3.17	10.63 ± 3.21	0.272
N,10^9/L	7.98 ± 3.84	8.85 ± 3.21	**0.034**
L,10^9/L	1.74 ± 1.17	1.27 ± 0.58	**< 0.001**
Monocyte,10^9/L	0.57 ± 0.32	0.46 ± 0.27	**0.001**
RBC,10^12/L	4.6 ± 0.57	4.6 ± 0.54	0.973
HGB, g/L	140.14 ± 16.75	139.61 ± 16.85	0.774
Platelet,10^9/L	217.19 ± 59.75	209.76 ± 57.62	0.255
Blood urea nitrogen, mmol/L	6.06 ± 1.91	5.78 ± 1.82	0.181
Serum creatinine, μmol/L	67.35 ± 20.91	66.2 ± 19	0.611
eGFR, mL/min/1.73 m	102.32 ± 20.97	97.98 ± 20.86	0.059
FBG, mmol/L	6.7 ± 2.71	7.96 ± 3.51	**< 0.001**
Total cholesterol, mmol/L	4.3 ± 1.01	4.34 ± 0.9	0.725
Triglycerides, mmol/L	1.51 ± 1.1	1.31 ± 0.66	0.080
HDL-C, mmol/L	0.98 ± 0.25	1.01 ± 0.15	0.350
LDL-C, mmol/L	2.76 ± 0.88	2.82 ± 0.81	0.540
Peak hs-CRP, mg/L	2.30 (0.50, 7.77)	3.90 (1.49, 10.35)	**0.003**
Peak hs-TnT, ng/L	452.20 (76.33, 1864.75)	716.10 (177.75, 1675.50)	**0.021**
Peak NT-proBNP, pg/mL	1164.50 (464.25, 2882.37)	2670.00 (1262.61, 4284.00)	**< 0.001**
LCR,	6553.57 (1624.63, 22000.00)	3181.82 (1197.51, 7191.28)	**< 0.001**
Hypertension, *n* (%)	304 (44.57)	47 (49.47)	0.369
Diabetes mellitus, *n* (%)	166 (24.34)	34 (35.79)	**0.017**
CKD, *n* (%)	20 (2.93)	1 (1.05)	0.471
History of CABG, *n* (%)	4 (0.59)	1 (1.05)	0.48
History of ACS, *n* (%)	39 (5.72)	8 (8.42)	0.301
Smoking, *n* (%)	316 (46.33)	42 (44.21)	0.697
IABP, *n* (%)	18 (2.64)	6 (6.32)	0.104
Killip class, *n* (%)			0.123
I	587 (86.07)	75 (78.95)	
II	32 (4.69)	4 (4.21)	
III	3 (0.44)	0 (0.00)	
IV	60 (8.80)	16 (16.84)	
infarct-related artery			
LCX, *n* (%)	326 (47.80)	56 (58.95)	**0.042**
LAD, *n* (%)	71 (10.41)	10 (10.53)	0.972
RCA, *n* (%)	282 (41.35)	29 (30.53)	**0.044**
Others, *n* (%)	3 (0.44)	0 (0.00)	0.999
Aspirin, *n* (%)	680 (99.71)	95 (100.00)	0.999
P2Y12, *n* (%)	681 (99.85)	95 (100.00)	0.999
Statins, *n* (%)	678 (99.41)	95 (100.00)	0.999
ACEI/ARB/Sac/Val, *n* (%)	323 (47.36)	52 (54.74)	0.178
β-blockers	598 (87.68)	81 (85.26)	0.506
Nitrates, *n* (%)	271 (39.74)	32 (33.68)	0.257

Table 1 (continued)

	non- CI-AKI (*N* = 682)	CI-AKI (*N* = 95)	*P*
Heparin, *n* (%)	565 (82.84)	78 (82.11)	0.858
Diuretics, *n* (%)	371 (54.40)	59 (62.11)	0.157

LVEF = left ventricular ejection fraction; SBP = systolic blood pressure; DBP = diastolic blood pressure; BMI = body mass index; WBC = white blood cells; N = neutrophils; L = lymphocytes; RBC = red blood cells; HGB = hemoglobin; eGFR = estimated glomerular filtration rate; FBG = fasting blood glucose; HDL-C = high-density leptin cholesterol; LDL-C = low-density leptin cholesterol; hs-CRP = high sensitivity C-reactive protein; hs-TnT = high sensitivity troponin T; NT-pro BNP = N-terminal pro-B-type natriuretic peptide; LCR = lymphocyte to C-reactive protein ratio; CKD = chronic kidney disease; IABP = intra-aortic balloon pump; LCX = left circumflex artery; LAD = left anterior descending; RCA = right coronary artery; ACEI = angiotensin-converting-enzyme inhibitor; ARB = angiotensin II receptor blocker

Association between LCR and CI-AKI in STEMI patients

To examine the link between various indicators and the development of CI-AKI, both univariate and multivariate logistic regression analyses was conducted with CI-AKI as the outcome variable and each relevant indicator as a predictor. In the univariate logistic regression analysis, LCR was a significant independent predictor of CI-AKI (HR, 0.798; 95% CI 0.706–0.902; $P < 0.001$) (Table 2). Furthermore, within the univariate regression analysis, age, LVEF, lymphocyte, monocyte, peak hs-TnT, peak NT- proBNP, FBG, history of diabetes mellitus, IRA LCX and RCA were identified as relevant factors for CI-AKI. Candidate variables with statistical differences in univariate analysis were included in multivariate logistic regression analysis, and the results showed that LVEF, peak NT-proBNP, FBG and LCR were independent risk factors for CI-AKI ($P < 0.05$). The higher the preprocedural LCR levels, the lower the risk of developing CI-AKI. We further evaluated the association between LCR and CI-AKI in subgroup analysis. The results indicated a significant interaction between LCR and subgroups (gender, age) (p for interaction < 0.05), but no interaction between subgroups (diabetes, and hypertension) (p for interaction > 0.05) for presence of CI-AKI. Notably, the association between LCR and CI-AKI appeared to be more pronounced within the non-diabetic and non-hypertensive population. (Table S1).

The optimal cut-off value of LCR for predicting CIAKI

Figure 2D illustrated the ROC curve analysis of the LCR for predicting the occurrence of contrast nephropathy after primary PCI in patients with STEMI. And a comparative analysis of LCR with other established biomarkers for CI-AKI was shown in Fig. 2 and Figure S1, indicating LCR could be a novel marker for predicting CI-AKI. The optimal cut-off value of LCR identified for predicting CI-AKI was 7875.94, yielding the area under the curve of 0.626 (95% CI: 0.572–0.679; $P < 0.001$) (Table 3). This analysis substantiates the favorable predictive accuracy of LCR concerning CI-AKI.

Incremental prognostic value of LCR in patients with STEMI

In a multivariable model, LCR was an independent predictor of CI-AKI (HR: 0.182; 95%CI: 0.071–0.463; $P = 0.003$) (Table 2). LCR significantly increased discriminant and reclassification indexes when added to a model with clinical risk factors (AUC = 0.730vs0.704[$P < 0.001$], IDI = 0.016[$P < 0.001$], and NRI = 0.137[$P = 0.006$]) (Fig. 3). The reference model included clinical risk factors only, including LVEF, Peak NT-proBNP, and FBG.

Discussion

This study pioneers the investigation into the correlation between LCR and the risk of CI-AKI in STEMI patients undergoing PCI. Our study unveiled several new findings, including: (1) a notable decrease in LCR levels among patients who developed CI-AKI compared to those who did not experience this complication; (2) declined LCR level was determined to be independently linked to an increased risk of CI-AKI in STEMI patients undergoing PCI; (3) the LCR stood out as a substantial independent risk predictor in STEMI patients undergoing PCI, with an optimal cut-off value of 7875.94 identified for forecasting the risk of CI-AKI. (4) integration of LCR into the model with clinical risk factors showed significantly increased discrimination and reclassification ability for CI-AKI for STEMI patients.

STEMI is a severe and potentially fatal form of coronary heart disease, characterized by the rupture of unstable atherosclerotic plaques in the coronary arteries [20]. Over recent years, both the incidence and mortality rates of STEMI have shown an annual upward trend [21]. For individuals suffering from STEMI, undergoing PCI at the site of the blockage can mitigate the risk of cardiovascular mortality or further myocardial infarction [21]. CI-AKI is a common complication arising from PCI and stands as one of the predominant causes of hospital-acquired renal impairment [22]. The negative impact of CI-AKI on clinical outcomes, coupled with increased length of hospitalization and elevated treatment expenses, consistently poses a significant constraint on the use of contrast angiography, particularly for high-risk STEMI patients [5]. While the exact mechanisms behind CI-AKI are not completely understood, it is established that the condition may be associated with factors like nephrotoxic effects, inflammatory responses, oxidative stress, reactive oxygen species generation, and ischemia in the renal medulla [23]. Therefore, early and accurate

Table 2 Univariate and multivariate logistic analysis for predicting CI-AKI after PCI

	Univariate		Multivariate	
	OR (95%CI)	***P***	**OR (95%CI)**	***P***
Age (years)	1.019 (1.002 ~ 1.037)	**0.030**		
LVEF, %	0.920 (0.893 ~ 0.947)	**< 0.001**	0.929 (0.900 ~ 0.960)	**< 0.001**
Heart rate, bpm	1.009 (0.994 ~ 1.024)	0.228		
SBP, mmHg	1.002 (0.992 ~ 1.012)	0.709		
DBP, mmHg	1.002 (0.987 ~ 1.018)	0.760		
BMI, kg/m^2	1.051 (0.995 ~ 1.109)	0.074		
Duration of surgery	1.008 (0.998 ~ 1.018)	0.107		
WBC,10^9/L	1.037 (0.972 ~ 1.107)	0.271		
N,10^9/L	1.048 (0.998 ~ 1.100)	0.058		
L,10^9/L	0.516 (0.371 ~ 0.718)	**< 0.001**		
Monocyte,10^9/L	0.194 (0.075 ~ 0.499)	**< 0.001**		
RBC,10^12/L	1.006 (0.690 ~ 1.468)	0.973		
HGB, g/L	0.998 (0.985 ~ 1.011)	0.774		
Platelet,10^9/L	0.998 (0.994 ~ 1.002)	0.254		
Peak hs-CRP, mg/L	1.004 (0.997 ~ 1.010)	0.312		
Blood urea nitrogen, mmol/L	0.920 (0.814 ~ 1.039)	0.181		
Serum creatinine, μmol/L	0.997 (0.987 ~ 1.008)	0.610		
eGFR, mL/min/1.73 m	0.991 (0.981 ~ 1.000)	0.060		
Peak hs-TnT, ng/L	1.162 (1.030 ~ 1.310)	**0.014**		
Peak NT-proBNP, pg/mL	1.531 (1.283 ~ 1.826)	**< 0.001**	0.182 (0.071 ~ 0.463)	**0.003**
FBG, mmol/L	1.131 (1.063 ~ 1.203)	**< 0.001**	1.090 (1.017 ~ 1.168)	**0.015**
Total cholesterol, mmol/L	1.039 (0.839 ~ 1.288)	0.724		
Triglycerides, mmol/L	0.766 (0.570 ~ 1.029)	0.077		
HDL-C, mmol/L	1.522 (0.632 ~ 3.665)	0.349		
LDL-C, mmol/L	1.080 (0.846 ~ 1.378)	0.539		
LCR	0.798 (0.706 ~ 0.902)	**< 0.001**	0.182 (0.071 ~ 0.463)	**0.003**
Female, *n* (%)	1.378 (0.875 ~ 2.171)	0.166		
Hypertension, *n* (%)	1.218 (0.792 ~ 1.871)	0.369		
Diabetes mellitus, *n* (%)	1.733 (1.100 ~ 2.729)	**0.018**		
CKD, *n* (%)	0.352 (0.047 ~ 2.654)	0.311		
History of CABG, *n* (%)	1.803 (0.199 ~ 16.305)	0.600		
History of ACS, *n* (%)	1.516 (0.686 ~ 3.350)	0.304		
Smoking, *n* (%)	0.918 (0.596 ~ 1.414)	0.697		
IABP, *n* (%)	2.487 (0.962 ~ 6.431)	0.060		
Killip class > 1	1.648 (0.961 ~ 2.824)	0.069		
infarct-related artery				
LCX, *n* (%)	1.568 (1.014 ~ 2.424)	**0.043**		
LAD, *n* (%)	1.012 (0.503 ~ 2.038)	0.972		
RCA, *n* (%)	0.623 (0.392 ~ 0.990)	**0.045**		
ACEI/ARB/Sac/Val, *n* (%)	1.344 (0.873 ~ 2.068)	0.179		
β-blockers, *n* (%)	0.813 (0.441 ~ 1.498)	0.506		
Nitrates, *n* (%)	0.770 (0.490 ~ 1.211)	0.258		
Heparin, *n* (%)	0.950 (0.542 ~ 1.665)	0.858		
Diuretics, *n* (%)	1.374 (0.884 ~ 2.135)	0.158		

LVEF = left ventricular ejection fraction; SBP = systolic blood pressure; DBP = diastolic blood pressure; BMI = body mass index; WBC = white blood cells; N = neutrophils; L = lymphocytes; RBC = red blood cells; HGB = hemoglobin; hs-CRP = high sensitivity C-reactive protein; eGFR = estimated glomerular filtration rate; hs-TnT = high sensitivity troponin T; NT-pro BNP = N-terminal pro-B-type natriuretic peptide; FBG = fasting blood glucose; HDL-C = high-density leptin cholesterol; LDL-C = low-density leptin cholesterol; LCR = lymphocyte to C-reactive protein ratio; CKD = chronic kidney disease; IABP = intra-aortic balloon pump; LCX = left circumflex artery; LAD = left anterior descending; RCA = right coronary artery; ACEI = angiotensin-converting-enzyme inhibitor; ARB = angiotensin II receptor blocker

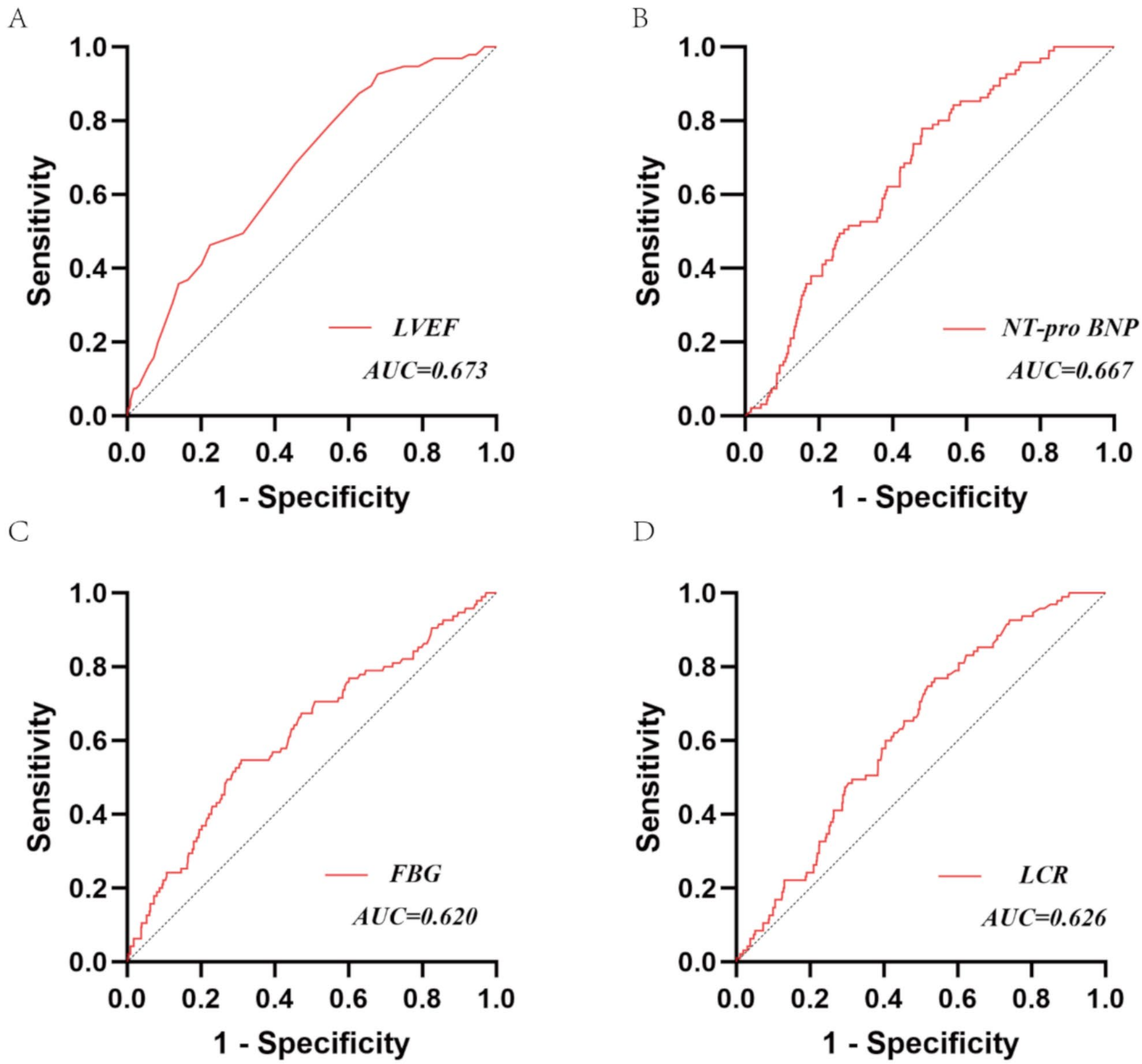

Fig. 2 ROC curve of the level of A LVEF, B NT pro BNP, C FBS, D LCR in predicting the occurrence of CI-AKI after primary PCI. LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide; FBG, fasting blood glucose; LCR, lymphocyte to C-reactive protein ratio; CI-AKI, contrast-induced acute kidney injury

Table 3 ROC curve analysis results in predicting the occurrence of CI-AKI after primary PCI

	AUC	95% CI	*P*	Cut-off	Sensitivity	Specificity
LVEF	0.673	0.619～0.728	< 0.001	55.5	0.926	0.321
Peak NT-proBNP	0.667	0.616～0.718	< 0.001	1249.17	0.779	0.521
FBG	0.620	0.558～0.682	< 0.001	6.82	0.547	0.691
LCR	0.626	0.572～0.679	< 0.001	7875.94	0.768	0.462

LVEF = left ventricular ejection fraction; NT-proBNP = N-terminal pro-B-type natriuretic peptide; FBG = fasting blood glucose; LCR = lymphocyte to C-reactive protein ratio

risk stratification and individualized preventive measures have important clinical value.

Inflammation plays an important role in the development and progression of CI-AKI after myocardial infarction [17, 23, 24]. Currently, there are numerous inflammation-based risk prediction models utilized in the medical field [25–27]. A reduced lymphocyte count is associated with a poor prognosis in patients with

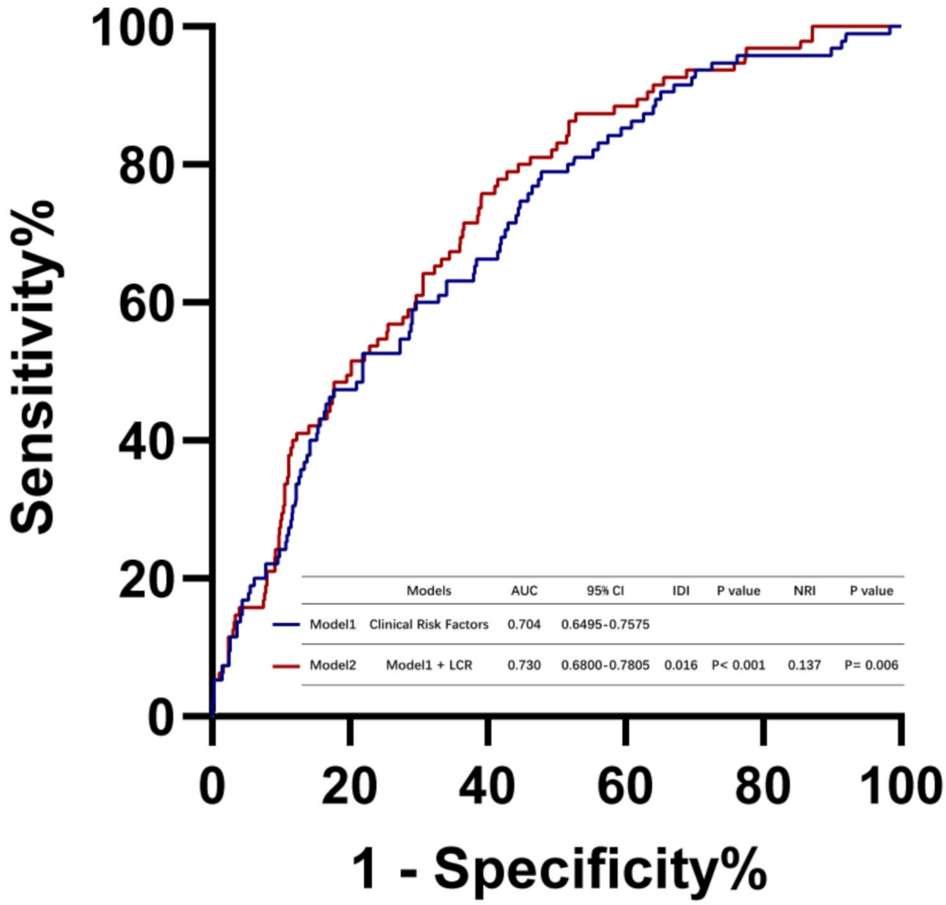

Fig. 3 Incremental value of LCR in predicting the occurrence of CI-AKI in patients with STEMI after primary PCI. AUC, area under the curve; LCR, lymphocyte to C-reactive protein ratio; CI-AKI, contrast-induced acute kidney injury; CI, confidence interval; IDI, integrated discrimination improvement (IDI); NRI, net reclassification improvement; clinical risk factors, including LVEF, Peak NT-proBNP, and FBG

chronic coronary artery disease [28], unstable angina pectoris [29], and STEMI [30]. Moreover, CRP is a typical inflammatory marker and is involved in the pathogenesis of myocardial infarction [30]. High CRP levels are a good predictor of death in patients with acute coronary syndrome [31]. LCR, the ratio of lymphocyte count to C-reactive protein levels, is a recognized marker that reflects the systemic inflammatory state and can be a cost -effective and easily obtained initial screening tool, especially in resource-limited environments. It provides a more accurate indication of the body's inflammatory and immune status during myocardial infarction. LCR offers a more precise prediction of adverse outcomes in myocardial infarction patients post-PCI than using lymphocyte counts or CRP levels in isolation [32]. LCR has good predictive value in different diseases. Baseline LCR has been identified as a standalone prognostic indicator in hemodialysis patients, offering an effective prediction of patient survival rates [33]. Gao et al. reported preoperative LCR is an independent predictor of NOAF in patients with acute myocardial infarction after percutaneous coronary intervention [12]. Liu et al. found that preoperative LCR is a novel and valuable prognostic indicator for predicting major adverse cardiovascular events (MACE) in STEMI patients both during hospitalization and throughout long-term follow-up post-PCI [32]. However, investigations into the predictive power of LCR for CI-AKI in STEMI patients post-PCI are scarce, which makes the ability to identify those at high risk critically important from a clinical perspective. ROC curve indicated that LCR possesses predictive value for the development of CI-AKI in STEMI patients following PCI. High sensitivity (0.768) of it can help to recognize high-risk patients early and intervene promptly. Our study revealed that an inverse relationship between LCR and the risk of CI-AKI following PCI in STEMI patients remained significant after accounting for potential confounding factors. It significantly increased discriminant and reclassification indexes when added to a model with clinical risk factors. CI-AKI typically manifests within 24 to 72 h following PCI. Early measurement of LCR post-PCI can offer timely and valuable prognostic insights for clinical evaluation [34]. For example, patients with a high LCR may require more aggressive pre- and post-PCI hydration and low-osmolar or iso-osmolar contrast agents.

The predictive cut-off value for LCR differs across various diseases due to the diversity of risk factors and pathophysiological mechanisms specific to each condition. Previous research has included numerous studies that have examined the sensitivity and specificity of diverse LCR cut-off values among patients with CAD. The threshold value of 1513.1 was identified as the optimal cut-off for LCR to predict mortality in hemodialysis patients, with an LCR of 1513.1 or higher being an independent predictor of death [33]. An elevated preoperative LCR, exceeding a threshold of 106.3, independently predicted a lower risk for long-term MACEs in patients with STEMI following primary PCI [32]. An LCR < 0.197 successfully identified patients susceptible to NOAF following AMI [12]. The optimal cutoff values of the pre and postoperative LCR were 23,800 and 13,033 respectively in patients with gastric cancers [35]. A higher baseline LCR, reaching or exceeding 2361.11, correlated positively with extended progression-free and overall survival in hepatocellular carcinoma patients undergoing radiotherapy [9]. However, research on the optimal cut-off value of LCR for predicting CI-AKI among STEMI patients remains unknown. Our ROC curve analysis of LCR determined that the optimal cut-off value of LCR for predicting CI-AKI in the STEMI population was 7875.94, yielding an AUC of 0.626. This result indicates that LCR has a promising predictive accuracy for prognosis.

In summary, the study's results add to the current understanding of LCR's role in cardiovascular diseases and offer insights into the possible clinical application of LCR as a predictive marker for CI-AKI in patients with STEMI.

Study limitations

Several limitations are associated with our research. Firstly, we recognize it as a single-center, retrospective observational study, which may limit the generalizability of our results and could introduce selection bias in participant recruitment. Additionally, the study did not stratify patients by age for a more granular analysis. Finally, the relatively small sample size might affect the statistical power and accuracy of our findings. Despite internal validation, further multi-center studies with larger cohorts are necessary to confirm the model's applicability. We hope to conduct a multi-center prospective study with a larger population and complete data collection and preprocess in collaboration with partner hospitals, and subsequently initiate external validation studies to generate preliminary validation reports in the future.

Conclusion

This study indicates, for the first time, that a lower LCR is an independent risk factor for CI-AKI in STEMI patients undergoing primary PCI. It suggests that LCR levels prior to PCI could aid in risk assessment for patient with STEMI undergoing primary PCI. Integration of LCR can significantly improve the risk model for CI-AKI.

Supplementary Information

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Supplementary Material 1

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Not applicable.

Author contributions
LX and BQ drafted the manuscript and analyzed the data. LC CW, WZ, LL and GY collected the data. FA, CF, XL and JA designed the study. YL, WC revised the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The requirement for signed written informed consent was waived owing to no risk to the patient in accordance with the relevant IRB regulatory guidelines. This study was approved by the Ethics Committee of Xuzhou Medical University Affiliated Hospital.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Not applicable.

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