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Article

Predictive Value of the Lipoprotein(a) to Prealbumin Ratio and of the NT-proBNP to LVEF Ratio for Major Adverse Cardiovascular Events Following Percutaneous Coronary Intervention in Patients with Acute Coronary Syndrome

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Abstract

Objective: To investigate the lipoprotein(a) [Lp(a)] to prealbumin (PA) ratio and the N-terminal pro-brain natriuretic peptide (NT-proBNP) to left ventricular ejection fraction (LVEF) ratio for the prediction of major adverse cardiovascular events (MACE) in patients with acute coronary syndrome (ACS) after percutaneous coronary intervention (PCI). **Methods**: A 1:1 matched case-control study was performed to retrospectively analyze ACS patients who underwent PCI from January 2022 to June 2022. Patients with MACE were selected as the case group (n = 55), and age- and gender-matched patients without MACE were selected as the control group (n = 55). Clinical data for the two groups was compared by univariate and multivariate logistic regression analysis. Risk factors and the odds ratio (OR) for MACE in ACS patients were evaluated, and receiver operating characteristic curve (ROC) were used to evaluate the Lp(a)/PA ratio, the NT-proBNP/LVEF ratio, and their combination for the prediction of MACE in ACS patients. **Results**: The MACE and non-MACE groups showed statistically significant differences for time from onset to PCI, LVEF, NT-proBNP, white blood cell (WBC), Lp(a), PA, Lp(a)/PA, NT-proBNP/LVEF, number of catheterizations, number of implanted stents >2, and support diameter >3 ($p < 0.05$). Multivariate logistic regression analysis showed that LVEF, Lp(a)/PA and NT-proBNP/LVEF were independent risk factors for MACE. ROC curve analysis for Lp(a)/PA showed that the area under the curve (AUC) for the prediction of MACE was 0.779 (0.693–0.864), the cut-off point was 1.36, the sensitivity was 69.1%, and the specificity was 74.5%. The AUC for NT-proBNP/LVEF in predicting MACE was 0.827 (0.75–0.904), the cut-off point was 61.04, the sensitivity was 65.5%, and the specificity was 92.7%. For the combination of Lp(a)/PA and NT-proBNP/LVEF, the AUC for the prediction of MACE was 0.889 (0.830–0.947), the cut-off point was 0.37, the sensitivity was 81.8%, and the specificity was 81.8%. **Conclusion**: The combination of Lp(a)/PA and NT-proBNP/LVEF at admission showed good predictive value for the occurrence of MACE in ACS patients after PCI.

Keywords

Lipoprotein(a) to prealbumin ratio; NT-proBNP to LVEF ratio; MACE; acute coronary syndrome; PCI

Introduction

Cardiovascular disease is one of the most common causes of death worldwide, with ischemic heart disease (IHD) being the leading cause of mortality [1,2]. Percutaneous coronary artery intervention (PCI) is the most important treatment for patients with acute coronary syndrome (ACS), allowing rapid opening of infarct-related arteries and restoring blood supply to the heart muscle [1]. Although PCI can rapidly restore blood supply to the myocardium, the high incidence of major adverse cardiovascular events (MACE) after the procedure can seriously affect patient prognosis [3,4]. Early identification of MACE after PCI is critical, and it is therefore important to identify the risk factors. Lipoprotein(a) [Lp(a)] has emerged in recent years as a potential new target for lipid intervention [5]. It is composed of low density lipoprotein-like (LDL-like) particles containing ApoB100, oxidised phospholipids, cholesterol and Apo(a). Lp(a) is currently thought to promote atherosclerotic cardiovascular disease (ASCVD) through dyslipidemia, as well as inflammatory and thrombogenic effects [5]. Prealbumin (PA) is a negative acute-phase reactive protein that reflects not only the inflammatory status of the patient, but also their nutritional status [6]. Elevated Lp(a) levels can independently predict the risk of long-term ASCVD and coronary heart disease in asymptomatic people. Elevated PA levels predict the short-term prognosis of patients with ACS, but little research has been done on the predictive value of Lp(a)/PA for MACE in patients with ACS. The release of N-terminal pro-brain natriuretic peptide (NT-proBNP) in ACS patients can be stimulated by increased tension in necrotic myocardium, as well as by the inflammatory response triggered by plaque rupture. Therefore, NT-proBNP not only reflects cardiac insufficiency, but also indirectly reflects the inflammatory

state during myocardial infarction. In combination with left ventricular ejection fraction (LVEF), NT-proBNP may provide a more sensitive assessment of heart failure [7]. There have been few studies to date on the predictive value of the NT-proBNP to left ventricular ejection fraction (NT-proBNP/LVEF) ratio in ACE patients. Elevated NT-proBNP levels are known to be strongly correlated with the risk of MACE. In the present study, the authors propose two new indices, Lp(a)/PA and NT-proBNP/LVEF. The combination of these two indices can be used to comprehensively assess the condition of ACS patients with respect to dyslipidemia and cardiac insufficiency.

Objects and Methods

Research Objectives

A 1:1 matched case-control method was used to retrospectively analyze patients admitted for ACS and who underwent PCI from January 2022 to June 2022, with 1-year follow up for the occurrence of MACE after PCI. Patients who developed MACE were treated as the case group (n = 55), while age- ($\pm$5 years) and gender-matched patients who did not develop MACE were selected as the control group (n = 55). The 110 patients were aged 37–87 years (mean age = 66.3 $\pm$ 10.96 years). The inclusion criteria for patients were: (1) meet the diagnostic criteria for ACS, (2) underwent PCI, and (3) complete clinical data was available. The exclusion criteria were: (1) presence of severe acute infectious diseases immediately before admission, (2) presence of cardiac diseases such as chronic heart failure, rheumatic heart disease, and severe heart valve disease, (3) presence of severe hepatic and renal insufficiency, (4) increased NT-proBNP due to extra-cardiac causes, such as obesity, renal insufficiency, and pulmonary embolism, and (5) presence of malignant tumors.

Data Collection

Information on name, gender, age, body mass index (BMI), previous medical history (hypertension, diabetes, cerebrovascular disease), smoking history, drinking history, pathological status, surgery, and drug use for all patients was collected retrospectively through the medical record system. The SYNTAX score was calculated using syntaxscore.com (https://syntaxscore.org/). Decision criteria for the success of coronary artery stent implantation: After stent implantation, the degree of residual coronary artery stenosis did not exceed 30%, the implanted vessels had good blood flow, there was no myocardial infarction or death, and no further coronary stenting was needed during hospitalization. Related bleeding events were recorded, and involved mainly the bleeding site, hemodynamics, decline in hemoglobin level, hemostasis methods and other dimensions, such as minor bleeding events (normal or decreased hemoglobin concentration $<$30 g/L, minimal intervention-free bleeding), and major bleeding (gastrointestinal bleeding, clinically visible bleeding, including imaging, with a decrease in hemoglobin concentration of $\geq$50 g/L, and intracranial hemorrhage). For slight bleeding, dual antiplatelet therapy (DAPT) was continued with close observation of bleeding. For severe bleeding, the use of DAPT was replaced by single antiplatelet therapy (SAPT) and P2Y12 receptor antagonist. For life-threatening bleeding events, all antithrombotic drugs were immediately stopped. The three patients with serious bleeding in this study were cases with digestive tract hemorrhage, but without apparent intracranial blood. Laboratory tests were performed on the first venous blood sample collected within 2 hours after PCI. These included routine blood tests (white blood cells, hemoglobin) and analyses for biochemical indicators total cholesterol (TC), triglycerides (TG), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), LP(a), eGFR, ALB, PA and NT-proBNP. Fasting hematological indicators were also evaluated if the patient was not fasting. The first cardiac ultrasound was performed within 2 hours of admission, and LVEF values were also obtained. NT-proBNP and LVEF were measured again before discharge, and Lp(a)/PA and NT-proBNP/LVEF were calculated.

Sample Size Calculation

The design of this study was a randomized controlled trial. The sample size for the two groups was calculated by the formula $n = (Z_\alpha + Z_\beta)^2 \cdot 2\sigma^2 / \delta^2$. Based on the results of a literature review and preliminary studies, the difference between the experimental group and the control group was estimated to be 0.6 and the standard deviation 0.86. With the two-sided α set at 0.05, the power of 1-β was 0.9. The ratio of the sample sizes for the experimental and control groups was 1:1. According to the method of Chow *et al.* [8], the sample size for each of the experimental and control groups was 44, as calculated by R language. Taking into account a 10% loss to follow-up and refusal to follow-up, the final requirement was for at least 49 cases in each of the case and control groups, giving a total sample size of 98.

MACE Follow-Up

The length of postoperative follow-up was 1-year, including in-hospital and out-of-hospital follow-up. This was comprised of a combination of telephone and outpatient follow-up after discharge. MACE included heart failure, cardiovascular death, cardiogenic shock, re-myocardial infarction, and unplanned revascularization. Heart failure was determined by clinical manifestations and signs of heart failure, NT-proBNP $>$125 pg/mL, BNP $>$35 pg/mL, *etc.* cardiogenic shock was defined as systolic blood pressure $<$90 mm Hg for $>$30 min and/or the need for catecholamines, pulmonary congestion, and signs of end-organ

failure [9]. Myocardial infarction was defined as the criteria for the 4th generic definition [10]. Unplanned rebleeding was judged on the basis of repeat coronary angiography.

Statistical Analyses

Data processing was performed with SPSS 26.0 statistical software (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as percentages and compared using the chi-square test or Fishers' exact test. Continuous variables were presented as $\bar{x} \pm s$, or M (P25, P75). ANOVA was used to estimate differences for normally distributed data, and the Kruskal-Wallis H test for non-normally distributed data.

The multiple difference imputation method was used for cases with missing values. Indicators showing statistical significance in univariate analysis were included in the multivariate logistic regression analysis. The fitness information for the model containing the two biomarkers was tested by the likelihood ratio test in multiple logistic regression analysis, with MACEs as dependent variables. Variables with statistically significant differences between MACE and non-MACE groups were used as covariates. ROC curves were applied to determine cut-off values for Lp(a)/PA and NT-proBNP/LVEF, as well as the diagnostic efficacy. ROC curve coordinates and tangent coordinates were used to determine the optimal cut-off points for NT-proBNP/LVEF and Lp(a)/PA, where the vertical axis was sensitivity and the horizontal axis was 1-specificity.

Results

Comparison of Clinical Data between non-MACE and MACE Groups

Of the 110 study subjects, 55 were in the non-MACE group and 55 in the MACE group. As shown in Table 1, statistically significant differences were found between the two groups for the time from onset to PCI, LVEF, NT-proBNP, white blood cell (WBC), Lp(a), PA, Lp(a)/PA, NT-proBNP/LVEF, number of diseased vessels, number of implanted stents, and support diameter (each $p < 0.05$). No statistically significant differences were found for any of the other indicators ($p > 0.05$).

Multi-Factor Logistic Regression Analysis

Variables that were significantly different between the MACE and non-MACE groups in univariate analysis were used as independent variables, and the occurrence of MACE as the dependent variable in multifactorial logistic regression analyses using forward stepwise regression. The equation for model prediction was:

Logit (P) = –11.95 + 0.72 × (WBC) + 1.15 × (Lp(a)/PA) + 0.03 × (NT-proBNP/LVEF) + 0.13 × (Syntax score)

As shown in Table 2, WBC, Syntax score, Lp(a)/PA, and NT-proBNP/LVEF were found to be significant risk factors for the occurrence of MACE ($p < 0.05$).

Predictive Value of Indicators for MACE in Patients Undergoing PCI

The cut-off values for Lp(a)/PA and NT-proBNP/LVEF for the prediction of 1-year postoperative MACE were 1.36 and 61.04, respectively. As shown in Fig. 1 and Table 3, the area under the curve (AUC) for the prediction of MACE by Lp(a)/PA combined with NT-proBNP/LVEF was higher than that of the two tests alone.

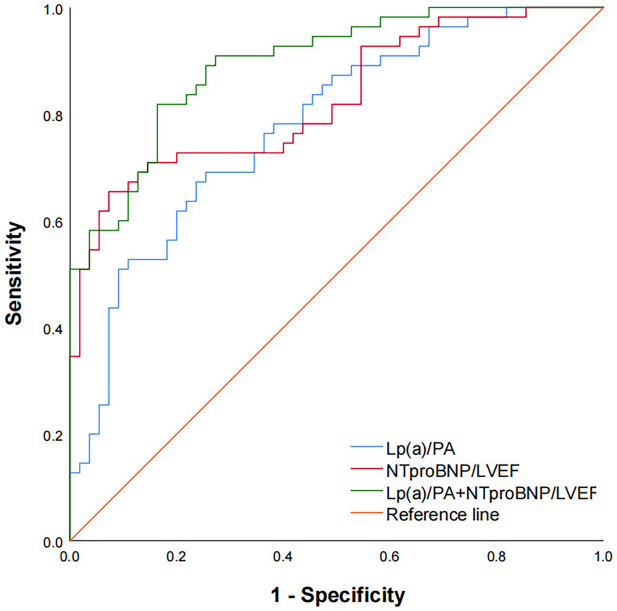

Fig. 1. Receiver operating characteristic (ROC) curve analysis of Lp(a)/PA and NT-proBNP/LVEF for the prediction of MACE. Lp(a), Lipoprotein(a); PA, Prealbumin; NT-proBNP, N-terminal pro-B-type natriuretic peptide; LVEF, Left Ventricular Ejection Fractions; MACE, Major Adverse Cardiovascular Events.

Discussion

The present retrospective study examined whether the combination of Lp(a)/PA and NT-proBNP/LVEF could be used as an early biomarker to predict the occurrence of MACE in ACS patients after PCI. The incidence of MACE was found to increase with increased Lp(a)/PA and NT-proBNP/LVEF ratios, and was also significantly associated with poor prognosis after adjusting for other confounding factors.

LP(a) is a biologically active phospholipid mediator that induces proliferative and morphological changes

Table 1. Comparison of clinical data between non-MACE and MACE groups.

Variable	Non-MACE (n = 55)	MACE (n = 55)	Statistic	*p*
Age, Mean ± SD	65.67 ± 11.42	67.00 ± 10.75	t = –0.628	0.531
BMI, Mean ± SD	25.20 ± 4.77	25.51 ± 4.66	t = –0.344	0.732
Time from onset to PCI (h), Mean ± SD	5.73 ± 1.43	4.89 ± 0.96	t = 3.601	<0.001
LVEF, Mean ± SD	52.05 ± 5.73	41.78 ± 5.51	t = 9.581	<0.001
NT-proBNP, Mean ± SD	1797.85 ± 1205.68	3754.55 ± 1867.44	t = –6.528	<0.001
TC, Mean ± SD	4.68 ± 1.37	5.07 ± 1.49	t = –1.416	0.16
HDL-C, Mean ± SD	0.98 ± 0.56	1.02 ± 0.60	t = –0.406	0.685
LDL-C, Mean ± SD	2.78 ± 0.80	3.04 ± 0.94	t = –1.528	0.13
TG, Mean ± SD	1.66 ± 0.29	1.72 ± 0.30	t = –1.105	0.271
WBC, Mean ± SD	9.39 ± 1.16	10.66 ± 2.29	t = –3.667	<0.001
HGB, Mean ± SD	120.16 ± 20.06	115.11 ± 20.17	t = 1.318	0.19
ALB, Mean ± SD	38.68 ± 5.14	37.90 ± 5.42	t = 0.775	0.44
eGFR, Mean ± SD	91.19 ± 9.09	92.25 ± 11.15	t = –0.545	0.587
Lp a, Mean ± SD	255.41 ± 106.14	339.55 ± 86.60	t = –4.556	<0.001
PA, Mean ± SD	243.71 ± 49.56	209.07 ± 74.50	t = 2.871	0.005
Lp a PA, Mean ± SD	1.10 ± 0.57	1.91 ± 1.15	t = –4.674	<0.001
NT-proBNP LVEF, Mean ± SD	34.76 ± 22.83	91.12 ± 47.02	t = –7.997	<0.001
Syntax score, Mean ± SD	22.49 ± 7.50	28.29 ± 7.46	t = –4.067	<0.001
Gender, n (%)			χ^2 = 2.949	0.086
female	24 (43.64)	33 (60.00)		
male	31 (56.36)	22 (40.00)		
Smoking history, n (%)			χ^2 = 2.961	0.085
no	21 (38.18)	30 (54.55)		
yes	34 (61.82)	25 (45.45)		
History of alcohol consumption, n (%)			χ^2 = 0.037	0.848
no	30 (54.55)	31 (56.36)		
yes	25 (45.45)	24 (43.64)		
Education status, n (%)			χ^2 = 0.350	0.839
below primary school	21 (38.18)	24 (43.64)		
middle school	16 (29.09)	15 (27.27)		
university and above	18 (32.73)	16 (29.09)		
Socioeconomic status, n (%)			χ^2 = 0.842	0.656
poor	17 (30.91)	17 (30.91)		
medium	21 (38.18)	17 (30.91)		
rich	17 (30.91)	21 (38.18)		
Regular physical activity, n (%)			χ^2 = 1.310	0.252
no	31 (56.36)	25 (45.45)		
yes	24 (43.64)	30 (54.55)		
Diabetes, n (%)			χ^2 = 0.587	0.444
no	32 (58.18)	28 (50.91)		
yes	23 (41.82)	27 (49.09)		
Hypertension, n (%)			χ^2 = 2.347	0.126
no	29 (52.73)	21 (38.18)		
yes	26 (47.27)	34 (61.82)		
Coronary heart disease, n (%)			χ^2 = 1.791	0.181
no	22 (40.00)	29 (52.73)		
yes	33 (60.00)	26 (47.27)		
Cerebrovascular diseases, n (%)			χ^2 = 0.148	0.701
no	32 (58.18)	30 (54.55)		
yes	23 (41.82)	25 (45.45)		

Table 1. Continued.

Variable	Non-MACE (n = 55)	MACE (n = 55)	Statistic	*p*
Hyperlipidemias, n (%)			$\chi^2 = 0.587$	0.444
no	28 (50.91)	32 (58.18)		
yes	27 (49.09)	23 (41.82)		
Atrial fibrillation, n (%)			$\chi^2 = 0.038$	0.846
no	32 (58.18)	33 (60.00)		
yes	23 (41.82)	22 (40.00)		
Location of vascular lesion, n (%)			$\chi^2 = 2.425$	0.297
Anterior descending branch	28 (50.91)	31 (56.36)		
Branch of cyclotron	15 (27.27)	18 (32.73)		
Right coronary artery	12 (21.82)	6 (10.91)		
Clopidogrel Ticagrelor, n (%)			$\chi^2 = 1.371$	0.242
no	0 (0.00)	3 (5.45)		
yes	55 (100.00)	52 (94.55)		
Aspirin, n (%)			$\chi^2 = 0.000$	1
no	1 (1.82)	2 (3.64)		
yes	54 (98.18)	53 (96.36)		
ACEI ARB ARNI, n (%)			$\chi^2 = 0.587$	0.444
no	27 (49.09)	23 (41.82)		
yes	28 (50.91)	32 (58.18)		
B Blocker, n (%)			$\chi^2 = 0.920$	0.337
no	27 (49.09)	22 (40.00)		
yes	28 (50.91)	33 (60.00)		
Statins, n (%)			$\chi^2 = 0.146$	0.703
no	29 (52.73)	27 (49.09)		
yes	26 (47.27)	28 (50.91)		
Successful stent implantation, n (%)			$\chi^2 = 0.000$	1
no	1 (1.82)	1 (1.82)		
yes	54 (98.18)	54 (98.18)		
No reflow occurred during surgery, n (%)			$\chi^2 = 0.509$	0.475
no	55 (100.00)	53 (96.36)		
yes	0 (0.00)	2 (3.64)		
Minor bleeding during surgery, n (%)			$\chi^2 = 0.000$	1
no	52 (94.55)	53 (96.36)		
yes	3 (5.45)	2 (3.64)		
Severe bleeding during surgery, n (%)			$\chi^2 = 0.000$	1
no	54 (98.18)	54 (98.18)		
yes	1 (1.82)	1 (1.82)		

MACE, major adverse cardiovascular events; BMI, body mass index; PCI, percutaneous coronary intervention; LVEF, left ventricular ejection fraction; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides; WBC, white blood cell; HGB, hemoglobin; ALB, albumin ; eGFR, estimated glomerular filtration rate.

in cells that can promote platelet aggregation and lead to thrombosis [11]. Previous studies [12,13] reported that LP(a) induces the expression of inflammatory cytokines and increases the expression of adhesion molecules on the surface of endothelial cells, thereby promoting the formation of atherosclerotic plaques. Several previous studies also reported that elevated Lp(a) levels were significantly associated with adverse clinical outcomes and could be used to predict the risk of MACE [14–17]. PA is a negative acute phase response protein synthesized mainly in the liver and with a short half-life of approximately 2 d. The synthesis of PA is inhibited in an acute inflammatory environment where cytokines stimulate the liver to produce acute phase proteins (e.g., CRP). Increased vascular permeability and protein leakage during acute inflammatory conditions can also lead to decreased PA levels. Therefore, PA in the acute phase can reflect not only the inflammatory condition, but also the nutritional status of the patient. Because of its short half-life, PA is more sensitive than albumin in the assessment of malnutrition [18]. It has also been reported that low

Table 2. Multi-factor logistic regression analysis.

Variable	Beta	S.E	Z	*p*	OR (95% CI)
Syntax score	0.13	0.05	2.68	0.007	1.14 (1.04–1.26)
WBC	0.72	0.27	2.73	0.006	2.06 (1.23–3.47)
Lp(a)/PA	1.15	0.50	2.29	0.022	3.14 (1.18–8.38)
NT-proBNP/LVEF	0.03	0.01	3.52	<0.001	1.03 (1.01–1.04)
Time from onset to PCI	–0.33	0.26	–1.26	0.207	0.72 (0.43–1.20)

Table 3. ROC values for Lp(a)/PA, NT-proBNP/LVEF, and the two indicators combined.

Variable	Cut-off value	Sensitivity (%)	Specificity (%)	Youden index	AUC (95% CI)
Lp(a)/PA	1.36	69.1	74.5	0.436	0.779 (0.693–0.864)
NT-proBNP/LVEF	61.04	65.5	92.7	0.582	0.827 (0.75–0.904)
Lp(a)/PA + NT-proBNP/LVEF	0.39	81.8	81.8	0.636	0.895 (0.838–0.951)

serum PA levels upon admission of ACS patients can independently predict MACE after hospitalization [19]. The ratio of Lp(a) to PA is an indicator of the balance between Lp(a) and PA in the body, and can also be used to assess the inflammatory and nutritional status of the patient. When the value of either Lp(a) or PA changes, the ratio changes accordingly, thereby providing greater sensitivity than either marker alone.

Several mechanisms may cause elevated peripheral blood NT-proBNP following myocardial infarction. ACS leads to rapid activation of the cardiac natriuretic peptide system and results in increased production of NT-proBNP [20]. This is associated with myocardial strain due to ventricular diastolic insufficiency. LVEF and NT-proBNP are direct indicators of cardiac pump function. Previous studies have shown that cardiac insufficiency, especially LVEF <30%, significantly increases the risk of sudden cardiac death in patients with myocardial infarction [21]. NT-proBNP release can also be stimulated by the increased inflammatory response triggered by plaque rupture and the release of inflammatory factors. The present study confirms that elevated NT-proBNP levels have strong predictive value for MACE after ACS [22–24]. Severe coronary artery disease may lead to an increased infarct size and damaged myocardium, resulting in myocardial diastolic dysfunction, increased release of NT-proBNP stimulated by inflammatory factors, and severe cardiac insufficiency.

While both Lp(a)/PA and NT-proBNP/LVEF are strong predictors of MACE, the present study found that a combination of the two has even better efficacy. ROC curve analysis showed that the area under the curve (AUC) of Lp(a)/PA for predicting MACE was 0.723 (0.629–0.817), with a cut-off value of 1.4, a sensitivity of 60%, and a specificity of 76.4%. For NT-proBNP/LVEF, the AUC for predicting MACE was 0.871 (0.808–0.935), with a cut-off value of 40.15, a sensitivity of 60%, and a specificity of 76.4%. For the combination of these two biomarkers, the AUC was 0.889 (0.830–0.947), the cut-off value was 0.37, the sensitivity was 81.8%, and the specificity was 83.6%. Lipoprotein(a)/PA and NT-proBNP/LVEF values are simple to obtain, with the tests being easy to perform and inexpensive. Moreover, the NT-proBNP and Lp(a)/PA values can be used to evaluate the degree of myocardial function damage. Higher NT-proBNP/LVEF ratios are associated with more severe myocardial damage. This can help clinicians to determine whether further therapeutic interventions, such as coronary recanalization, are needed [23]. Elevated NT-proBNP/LVEF and Lp(a)/PA ratios are also associated with an increased risk of adverse outcomes in ACS patients. High NT-proBNP/LVEF ratios suggest that patients have an elevated risk of mortality, recurrent myocardial infarction, or other adverse events [22]. Lp(a) can be secondary to thrombosis and unstable plaque rupture, leading to continuous and complete occlusion of the coronary artery, which is closely related to myocardial infarction [25]. PA is involved in several arterial vascular inflammatory mechanisms, and serum inflammatory factors are always involved at each stage of atherosclerotic plaque formation [19]. Therefore, reducing the Lp(a)/PA index is valuable for the prediction of cardiovascular events in patients with ACS. Currently, there are several types of drugs for Lp(a) treatment, including niacin and estrogen that target apoA synthesis, and anti-sense oligonucleotides and microsomal triglyceride transfer protein inhibitors that target apoB. Proprotein convertase subtilisin/kexin type 9 (PCSK9) shows good efficacy at reducing Lp(a). The monitoring of combined indicators can also help physicians to adjust treatment based on the individual condition of the patient, as well as to changes in their condition. When NT-proBNP/LVEF is low, it is not advisable to treat only NT-proBNP/LVEF. Therefore, clinicians need to identify the cause of disease in patients to treat. The treatment principles for patients with heart failure are cardiotonic, diuretic and vasodilator. Diuretic, inotropic drugs, positive inotropic drugs and vasodilator drugs can improve the patient condition after heart failure. If the condition is serious and the blood pressure continues to decrease, treatment with intra-aortic balloon pump, mechanical ventilation support, or ventricular assist devices can be used. For patients with recurrent myocardial infarction, medical and surgical treatment is required. Drug therapy involves mainly the use of coronary artery dilation drugs (nitroglycerin, *etc.*), in-

travenous drip, drugs that reduce myocardial oxygen consumption (metoprolol, *etc.*), and thrombolytic drugs (urokinase, *etc.*) used in accordance with the thrombolytic indications. Surgical treatment is the first choice for patients with myocardial infarction. PCI and stent implantation can directly relieve coronary artery obstruction. Higher NT-proBNP and Lp(a)/PA ratios may be associated with a longer hospital stay and increased risks of recurrent cardiovascular events and mortality. Hence, this combined index can also be used as a prognostic indicator for ACS patients to help with early disease assessment and allow non-invasive risk management.

The present study had several limitations. Firstly, it was a single-centre retrospective study with a small sample size and limited representativeness, thus restricting the ability to extrapolate the results. Multi-center and prospective clinical studies with a larger sample size are needed to confirm the results. Secondly, the long-term risk for MACE was not investigated in this study and requires a longer follow-up time than this and earlier studies. Thirdly, Lp(a) and PA levels were only assessed at baseline, and a relatively high prevalence of elevated Lp(a) was observed in our study. Given these biomarkers may be predictors of MACE after PCI, continuous dynamic measurements could allow more accurate prediction of risk. Fourth, the observational design of the study means there may have been inadequate adjustment for potential confounders. Finally, the interaction analyses should be considered exploratory, given the limited statistical power of the study.

Conclusion

This study explored the relationship between Lp(a)/PA and NT-proBNP/LVEF and the occurrence of MACE after PCI in patients with ACS. The combination of these two indicators offers a more rapid and accurate assessment of the risk of MACE after PCI in ACS patients, thus allowing the identification of high-risk patients.

Availability of Data and Materials

Data available on request from the authors.

Author Contributions

YZ contributed to the concept and designed the research study. YZ and FS performed the research. YZ and FS provided help and advice on the experiments. YZ and FS contributed to the analysis and interpretation of the data. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study has been exempted the ethics by the institution.

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Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

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