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Clinical Research

The Neutrophil-to-Lymphocyte Ratio as a Predictor of Postoperative Outcomes in Patients Undergoing Coronary Artery Bypass Grafting

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Background: The neutrophil-to-lymphocyte ratio (NLR) has been suggested as a novel predictive marker of cardiovascular disease. However, its prognostic role in patients undergoing coronary artery bypass grafting (CABG) is unclear. This study aimed to determine the association between the preoperative NLR and early mortality in patients undergoing CABG.
Methods: Cardiac surgery was performed in 2,504 patients at Seoul St. Mary's Hospital from January 2010 to December 2021. This study retrospectively reviewed 920 patients who underwent isolated CABG, excluding those for whom the preoperative NLR was unavailable. The primary endpoints were the 30- and 90-day mortality after isolated CABG. Risk factor analysis was performed using logistic regression analysis. Based on the optimal cut-off value of preoperative NLR on the receiver operating characteristic curve, high and low NLR groups were compared.
Results: The 30- and 90-day mortality rates were 3.8% (n=35) and 7.0% (n=64), respectively. In the multivariable analysis, preoperative NLR was significantly associated with 30-day mortality (odds ratio [OR], 1.28; 95% confidence interval [CI], 1.17–1.39; p<0.001) and 90-day mortality (OR, 1.17; 95% CI, 1.07–1.28; p<0.001). The optimal cut-off value of the preoperative NLR was 3.4. Compared to the low NLR group (<3.4), the high NLR group (≥3.4) showed higher 30- and 90-day mortality rates (1.4% vs. 12.1%, p<0.001; 2.8% vs. 21.3%, p<0.001, respectively).
Conclusion: Preoperative NLR was strongly associated with early mortality after isolated CABG, especially in patients with a high preoperative NLR (≥3.4). Further studies with larger cohorts are necessary to validate these results.

Keywords: Neutrophil to lymphocyte ratio, Coronary artery bypass, Coronary artery disease

Introduction

The neutrophil-to-lymphocyte ratio (NLR) has been suggested as a novel predictive marker for various diseases, from cerebrovascular disease [1] to aortic dissection [2,3]. Not only is the NLR readily accessible, but it also reflects systemic inflammation better than the total white blood cell count or individual neutrophil or lymphocyte counts [4,5]. Since inflammatory reactions are an important process in atherosclerosis, including coronary artery disease (CAD) [6,7], many studies have aimed to elucidate the relationship between NLR and CAD.

According to Papa et al. [8], the NLR is strongly associated with cardiac mortality in patients with stable CAD. An elevated preprocedural NLR was reported to be a significant predictor of long-term outcomes in patients with stable angina, as well as in those with acute CAD requiring percutaneous coronary intervention [7,9,10].

Regarding the prognostic value of the NLR in patients undergoing coronary artery bypass grafting (CABG), some

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studies have reported that an elevated NLR is associated with poorer overall survival [11]. However, the accumulated evidence regarding the preoperative NLR as a predictor of early mortality after CABG remains limited. Our study aimed to determine the association between the preoperative NLR and early mortality in patients undergoing isolated CABG.

Methods

Study population

Cardiac surgery was performed in 2,504 patients at Seoul St. Mary's Hospital from January 2010 to December 2021, of whom 929 patients who underwent isolated CABG were reviewed for inclusion in this study. Nine patients whose preoperative NLR values were missing were excluded. Therefore, a total of 920 participants were finally enrolled and analyzed. This study was approved by the institutional review board of Seoul St. Mary's Hospital (IRB no., KC22RISI0580). Informed consent was waivered.

Outcomes and laboratory analysis

The primary endpoints were 30- and 90-day mortality after isolated CABG during the follow-up period. The preoperative NLR was calculated from peripheral blood samples and the patients had blood samples taken before surgery. The total white blood cell (WBC) and leucocyte subtype counts were assayed using an automated blood cell differential counter (XE-2100; Sysmex Corp., Kobe, Japan). This analyzer, using flow cytometry and fluorescence, showed a low false-negative rate (4%) compared with the manual count of an experienced cytologist [12].

Statistical analysis

Data are expressed as median and interquartile range for continuous variables and as number and percentage for categorical variables. Missing data for baseline characteristics were handled using multiple imputations (Supplementary Table 1). A p-value ≤0.05 was considered statistically significant for all comparisons.

Univariable and multivariable analyses were performed for the entire patient cohort using logistic regression to determine the predictors of 30- and 90-day mortality. For the multivariable analyses, variables assessed in the univariable models were included in the final multivariable analyses based on their clinical importance to avoid overfitting if their univariable significance was <0.05. The multicollinearity of variables was assessed separately for 30-day and 90-day mortality by using variance inflation factors (Supplementary Table 2).

The optimal cut-off value of the preoperative NLR value for 30- and 90-day mortality was obtained using receiver operating characteristic (ROC) curves. The patients were

Table 1. Baseline characteristics (n=920)

Characteristic	Value
Age (yr)	66.6±9.64
Sex (male)	683 (74.2)
Body mass index (kg/m^2)	24.4±3.43
Comorbidities	
Hypertension	575 (62.5)
Diabetes mellitus	406 (44.1)
Cerebrovascular accident	36 (3.9)
Chronic obstructive pulmonary disease	7 (0.8)
Chronic renal failure	52 (5.7)
Medication use	
Statin use	530 (57.6)
Aspirin use	549 (59.7)
Laboratory parameters	
White blood count (10^9/L)	7.38±2.94
Neutrophil	60.7±11.1
Lymphocyte	27.7±10.1
Hemoglobin (g/dL)	12.6±1.99
Platelet (10^{12}/L)	216.4±75.26
Creatinine (mg/dL)	1.46±1.95
Total bilirubin (mg/dL)	0.61±2.59
C-reactive protein (mg/dL)	1.06±2.59
Preoperative NLR	2.88±2.49
Left ventricle ejection fraction (%)	53.6±12.4
EuroScore II	2.74±3.52
Emergency	114 (12.4)
No. of bypasses	2.36±0.96
Internal mammary artery used	869 (94.5)
Off-pump procedure	184 (20.0)
Cardiopulmonary bypass time (min)	66.8±105.11
Aortic cross-clamping time (min)	39.3±30.55
Outcomes	
30-Day mortality	35 (3.8)
90-Day mortality	64 (7.0)
Overall mortality	236 (25.7)
Complications	
Bleeding	73 (8.0)
Stroke	15 (1.6)
Extracorporeal membrane oxygenation	16 (1.7)
New renal replacement therapy	26 (2.8)
Infection	27 (2.9)
Ventilator time (min)	19.2±48.07
Hospital stay (day)	11.45±13.25

Variables are presented as mean±standard deviation or frequency (%).
NLR, neutrophil-to-lymphocyte ratio.

divided into 2 groups based on the optimal cut-off value. To reduce the effect of treatment selection bias and potential confounders in this observational study, we performed rigorous adjustment of significant differences in baseline patient characteristics using propensity score matching. A propensity score was generated for each patient using a multivariable logistic regression model based on 19 preoperative characteristic variables shown in Table 1 (age, sex, body mass index, history of hypertension, diabetes mellitus, cerebrovascular accident, chronic obstructive pulmonary disease, chronic renal failure, use of statin or aspirin, hemoglobin, platelet, total bilirubin, C-reactive protein, emergency, left ventricular ejection fraction, number of bypasses, cardiopulmonary bypass time, and aortic cross-clamping time. The low NLR group was then matched to the high NLR group in a 1:1 ratio using the nearest matching method. After matching, we compared the baseline covariates between groups as the standardized mean difference (Supplementary Table 3). For all analyses, values of $p \leq 0.05$ were considered statistically significant. The statistical analyses were performed using SAS ver. 9.3 (SAS Institute Inc., Cary, NC, USA).

Results

As shown in the flow diagram (Fig. 1), we evaluated 920 consecutive patients from a total of 2,504 patients undergoing cardiac surgery during the study period. Patients who received an isolated CABG performed from January 2010 to December 2021 were included. The exclusion criteria were as follows: (1) combined CABG procedures including the valves or aorta and other procedures (n=1,575), and (2) missing preoperative NLR data (n=9).

Table 1 summarizes the patients' baseline and operative characteristics. The median age was 66.6±9.6 years, and 683 men (74.2%) were enrolled. The median number of bypassed grafts was 2.36±0.96. The median cardiopulmonary bypass time was 66.8±105.11 minutes. The median preoperative NLR was 2.88±2.49. As other inflammatory markers, the WBC count and C-reactive protein level were 7.38±2.94 $\times 10^9$/L and 1.46±1.95 mg/dL, respectively. Furthermore, 30-day mortality occurred in 35 patients (3.8%) versus 90-day mortality in 64 patients (7%).

Preoperative neutrophil-to-lymphocyte ratio and 30-day mortality

The univariable analysis identified preoperative NLR as an independent predictor of 30-day mortality (odds ratio [OR], 1.31; 95% confidence interval [CI], 1.20–1.42; $p<0.001$). Old age (OR, 1.05; 95% CI, 1.01–1.09; p=0.001) was associated with higher 30-day mortality. Male sex (OR, 0.31; 95% CI, 0.15–0.64; p=0.002) and high ejection fraction (OR, 0.92; 95% CI, 0.19–1.35; $p<0.001$) were associated with significantly lower risks of death. In terms of comorbidities, patients diagnosed with chronic renal failure had a higher mortality rate (OR, 7.72; 95% CI, 3.35–17.80; $p<0.001$).

Multivariable analysis showed that preoperative NLR was strongly associated with 30-day (OR, 1.28; 95% CI, 1.17–1.39; $p<0.001$). Old age and left ventricular ejection fraction were strong predictors for 30-day mortality, as was preoperative NLR (OR, 1.05; 95% CI, 1.00–1.09; $p<0.03$; OR, 0.93; 95% CI, 0.90–0.95; $p<0.001$, respectively). These findings are summarized in Table 2.

Preoperative neutrophil-to-lymphocyte ratio and 90-day mortality

In the multivariable analysis, an elevated preoperative NLR was associated with 90-day mortality (OR, 1.17; 95% CI, 1.07–1.28; $p<0.001$). Other than preoperative NLR, old age (OR, 1.05; 95% CI, 1.01–1.08; p=0.005) and male sex (OR, 0.46; 95% CI, 0.27–0.78; p=0.004) were associated with 90-day mortality. The preoperative creatinine level and undergoing an emergency operation were also identi-

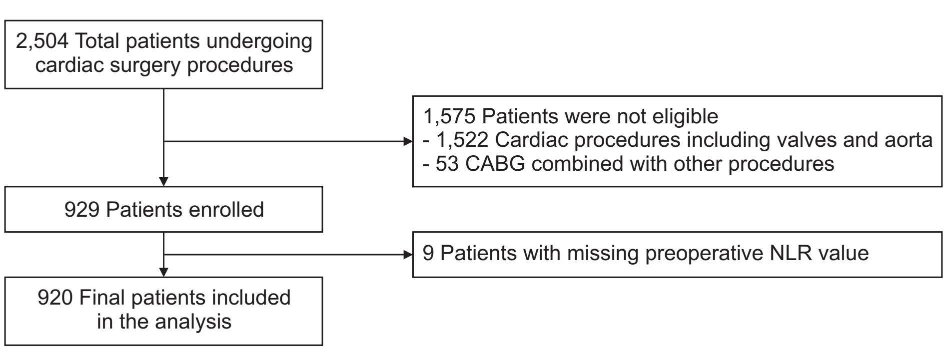

Fig. 1. The study demographics. CABG, coronary artery bypass grafting; NLR, neutrophil-to-lymphocyte ratio.

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Table 2. Neutrophil-to-lymphocyte ratios and 30-day mortality

Variable	Outcome: 30-day mortality			
	Univariable analysis		Multivariable analysis	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Age	1.05 (1.01–1.09)	0.001		
Sex (male)	0.31 (0.15–0.64)	0.002		
Body mass index	0.95 (0.86–1.05)	0.37		
Comorbidities				
Hypertension	1.08 (0.51–2.28)	0.84		
Diabetes mellitus	0.92 (0.44–1.91)	0.84		
Cerebrovascular accident	0.84 (0.11–6.41)	0.87		
Chronic renal failure	7.75 (3.35–17.80)	<0.001	6.14 (2.63–14.35)	<0.001
Medication use				
Statin use	0.61 (0.31–1.20)	0.15		
Aspirin use	1.01 (0.51–2.02)	0.97		
Laboratory				
White blood cell count	1.17 (1.08–1.27)	<0.001		
Neutrophil count	1.09 (1.06–1.13)	<0.001		
Lymphocyte count	0.88 (0.84–0.92)	<0.001		
Hemoglobin	0.69 (0.57–0.82)	<0.001		
Platelet	0.99 (0.98–1.00)	0.07		
Preoperative NLR	1.31 (1.20–1.42)	<0.001	1.23 (1.12–1.35)	<0.001
C-reactive protein	1.20 (1.12–1.29)	<0.001		
Creatinine	1.21 (1.10–1.33)	<0.001		
Left ventricular ejection fraction	0.92 (0.89–0.94)	<0.001		
EuroScore II	1.27 (1.19–1.35)	<0.001		
Emergency	7.77 (3.71–16.30)	<0.001	3.04 (1.33–7.00)	0.008
No. of bypasses	0.88 (0.63–1.26)	0.51		
Internal mammary artery used	1.52 (0.66–4.23)	0.26		
Off-pump procedure	0.92 (0.41–1.52)	0.36		
Cardiopulmonary bypass time	1.00 (1.00–1.00)	0.09		
Aortic cross-clamp time	1.01 (0.99–1.02)	0.09		

OR, odds ratio; CI, confidence interval; NLR, neutrophil-to-lymphocyte ratio.

fied as risk factors for 90-day mortality (OR, 1.11; 95% CI, 1.01–1.23; p=0.03, and OR, 2.04; 95% CI, 2.04–4.02; p=0.04). These findings are summarized in Table 3.

Comparison of outcomes between neutrophil-to-lymphocyte ratio groups according to the optimal cut-off value

The optimal cut-off preoperative NLR value was 3.4 on the ROC curves for 30- and 90-day mortality (Fig. 2). Based on the optimal value, the high NLR group (≥3.4) showed higher 30- and 90-day mortality rates than the low NLR group (<3.4; 1.4% versus 12.1%, p<0.001; 2.8% versus 21.3%, p≤0.001, respectively). Using propensity score matching, 171 subjects were assigned to the low or high NLR group. In the matched cohort, as in the previous unmatched analysis, the incidence of death at 30 and 90 days postoperative was higher in the high NLR group. The results from the unmatched and matched cohorts are summarized in Table 4.

Discussion

The present study investigated the association between preoperative NLR and early mortality after CABG. The multivariable analysis showed that a high preoperative NLR was a strong predictor for 30- and 90-day mortality. Furthermore, our results suggest that the optimal cut-off preoperative NLR value is 3.4.

Since NLR is reportedly a stronger predictor for increased cardiovascular risk than the total WBC or differential leukocyte counts [4], many studies have investigated the prognostic role of NLR in cardiovascular surgery. Silberman et al. [13] showed that an elevated preoperative NLR was associated with a higher incidence of operative mortality among patients undergoing cardiac surgery. Sev-

Table 3. Neutrophil-to-lymphocyte ratios and 90-day mortality

Variable	Outcome: 90-day mortality			
	Univariable analysis		Multivariable analysis	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Age	1.05 (1.02–1.08)	<0.001	1.04 (1.01–1.08)	0.005
Sex (male)	0.46 (0.27–0.78)	0.004		
Body mass index	0.95 (0.86–1.05)	0.37		
Comorbidities				
Hypertension	1.01 (0.59–1.74)	0.94		
Diabetes mellitus	1.16 (0.69–1.95)	0.57		
Cerebrovascular accident	0.45 (0.62–3.27)	0.43		
Chronic renal failure	3.7 (1.9–7.4)	<0.001	2.38 (1.07–5.32)	0.03
Statin	0.85 (0.50–1.43)	0.54		
Aspirin	1.02 (0.60–1.74)	0.82		
Laboratory				
White blood cell count	1.13 (1.08–1.18)	<0.001		
Neutrophil	1.10 (1.08–1.13)	<0.001		
Lymphocyte	0.88 (0.85–0.91)	<0.001		
Hemoglobin	0.69 (0.62–0.78)	<0.001	0.84 (0.75–0.95)	0.007
Platelet	0.99 (0.99–1.00)	0.17		
Preoperative NLR	1.35 (1.25–1.47)	<0.001	1.19 (1.04–1.15)	<0.001
C-reactive protein	1.18 (1.15–1.23)	<0.001		
Creatinine	1.14 (1.06–1.22)	<0.001		
Left ventricle ejection fraction	0.95 (0.93–0.96)	<0.001	0.96 (0.94–0.98)	<0.001
EuroScore II	1.17 (1.13–1.20)	<0.001		
Emergency	4.7 (2.76–8.10)	<0.001	2.12 (1.17–3.86)	0.014
No. of bypasses	1.01 (0.78–1.32)	0.92		
Internal mammary artery used	1.64 (0.46–5.42)	0.26		
Off-pump procedure	0.89 (0.37–1.82)	0.42		
Cardiopulmonary bypass time	1.00 (1.00–1.00)	0.08		
Aortic cross-clamp time	1.01 (0.99–1.01)	0.13		

OR, odds ratio; CI, confidence interval; NLR, neutrophil-to-lymphocyte ratio.

eral studies have suggested preoperative NLR as an emerging prognostic factor for worse postoperative outcomes after heart surgery [14-16].

Although those studies also reported the usefulness of preoperative NLR, they were limited by their heterogeneous patient groups involving various cardiac operations. Many studies have examined the prognostic role of NLR in relation to inflammation in CAD [7-9,17]. Therefore, it was necessary to study the significance and usefulness of NLR by limiting the patient sample to those undergoing CABG, and we increased the homogeneity by focusing solely on those patients. Few studies have reported the association between preoperative NLR and postoperative clinical outcomes after CABG [11,18,19].

Azab et al. [18] attempted to determine the relationship between prognostic predictions of preoperative NLR and mortality of CABG-operated patients and compare the differences between the sternotomy and minimal-incision ap-

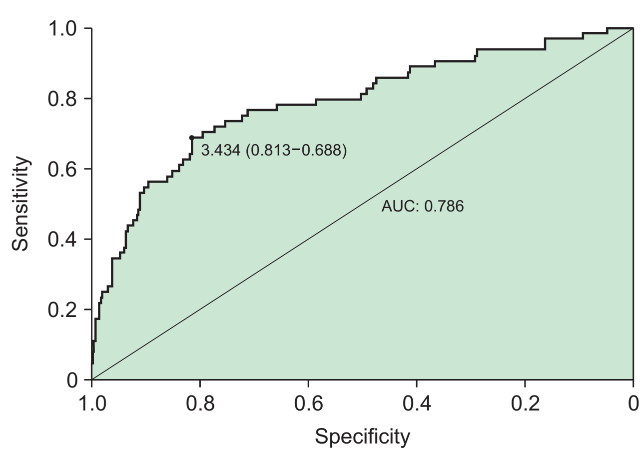

Fig. 2. The receiver operating characteristic curve of the preoperative neutrophil-to-lymphocyte ratio for 90-day mortality. AUC, area under the curve.

Table 4. Comparison of outcomes between NLR groups according to the optimal cut-off value

Variable	Unmatched cohort			Matched cohort		
	Low NLR (NLR <3.4, n=713)	High NLR (NLR ≥3.4, n=207)	p-value	Low NLR (NLR <3.4, n=171)	High NLR (NLR ≥3.4, n=171)	p-value
Age (yr)	66.5±9.2	67.2±10.7	0.40	67.4±9.0	67.5±10.7	0.91
Sex (male)	501 (74.3)	128 (73.1)	0.77	131 (76.6)	128 (74.9)	0.80
Body mass index (kg/m^2)	24.6±3.3	23.4±3.61	<0.01	23.4±3.0	23.3±3.6	0.78
Comorbidities						
Hypertension	439 (61.6)	136 (65.7)	0.38	115 (67.3)	110 (64.3)	>0.99
Diabetes mellitus	303 (42.5)	103 (49.7)	0.07	82 (48.0)	83 (48.5)	0.83
Cerebrovascular accident	26 (3.6)	10 (5.1)	0.27	7 (4.1)	7 (4.1)	>0.99
Chronic obstructive pulmonary disease	5 (0.7)	2 (1.1)	0.63	2 (1.2)	2 (1.1)	>0.99
Chronic renal failure	27 (3.8)	25 (13.1)	<0.01	19 (11.1)	24 (14.0)	0.51
Statin	412 (57.8)	118 (57.1)	0.79	96 (56.1)	98 (57.3)	0.91
Aspirin	432 (60.6)	117 (56.6)	0.19	93 (54.4)	98 (57.3)	0.66
Laboratory						
White blood cell count (10^9/L)	6.70±1.81	9.73±4.47	<0.01	6.7±2.0	9.5±3.9	<0.01
Hemoglobin (g/dL)	12.8±1.84	11.6±2.28	<0.01	11.9±2.0	11.6±2.3	0.26
Platelet (10^9/L)	216.0±64.0	217.8±105.2	0.76	213.2±71.8	205.0±71.2	0.28
Creatinine (mg/dL)	1.27±1.62	2.30±2.94	<0.01	1.8±2.6	2.4±3.1	0.08
Total bilirubin (mg/dL)	0.58±0.27	0.66±0.38	<0.01	0.6±0.4	0.7±0.4	0.41
C-reactive protein (mg/dL)	0.57±1.31	2.89±4.76	<0.01	1.4±2.1	2.8±4.6	<0.001
Preoperative NLR	1.92±0.65	6.10±3.50	<0.01	2.0±0.7	6.1±3.3	<0.001
Left ventricle ejection fraction (%)	55.3±11.6	48.6±13.0	<0.01	49.6±13.4	48.2±13.1	0.32
EuroScore II	2.13±2.32	4.83±5.58	<0.01	3.2±3.4	4.9±5.5	0.001
Emergency	55 (7.7)	59 (28.5)	<0.01	27 (15.8)	51 (29.8)	0.06
No. of bypasses	2.35±0.96	2.40±0.98	0.52	2.35±0.96	2.40±0.98	0.83
Cardiopulmonary bypass time (min)	66.1±119.7	69.6±46.0	0.70	65.6±42.9	70.0±45.7	0.36
Aortic cross-clamp time (min)	39.2±30.7	39.6±29.1	0.49	40.5±30.3	41.4±28.7	0.77
Outcomes						
30-Day mortality	10 (1.4)	25 (12.1)	<0.01	7 (4.1)	21 (12.3)	0.01
90-Day mortality	20 (2.8)	44 (21.3)	<0.01	14 (8.2)	35 (20.5)	0.02
Complications						
Bleeding	50 (7.0)	23 (11.2)	0.06	16 (9.4)	20 (11.7)	0.59
Stroke	10 (1.4)	5 (2.4)	0.47	3 (1.8)	5 (2.9)	0.72
Extracorporeal membrane oxygenation	4 (0.6)	12 (5.8)	<0.01	2 (1.2)	11 (6.4)	0.02
New renal replacement therapy	14 (2.0)	12 (5.8)	0.01	5 (2.9)	10 (5.8)	0.29
Infection	16 (2.2)	11 (5.3)	0.03	6 (3.5)	8 (4.7)	0.78
Ventilator time (min)	14.9±38.6	34.1±69.7	<0.01	15.1±20.7	33.1±68.0	0.001
Hospital stay (day)	10.6±12.7	14.6±16.1	<0.01	11.7±9.6	14.7±16.3	0.04

Variables are presented as mean±standard deviation or frequency (%).
NLR, neutrophil-to-lymphocyte ratio.

proaches. In their study, regardless of the approach, the preoperative NLR was an independent predictor of postoperative mortality in patients who underwent CABG.

Gurbuz et al. [19] aimed to evaluate whether an elevated preoperative NLR was associated with the risk of long-term cardiovascular events in patients undergoing CABG, similar to our study. In their univariable analysis, as in our study, an elevated preoperative NLR and high preoperative EuroScore were independent predictors of the outcomes.

Gibson et al. [11] proposed that preoperative NLR has strong predictive power for a high mortality risk in patients with CABG. In particular, when patients were divided into quartiles of preoperative NLR values, the risk of death was significantly greater in the subjects in the highest quartile and the reference quartile had an NLR of 3.36, similar to the cut-off value of our study. This study set the primary outcome as overall mortality. We also analyzed the relationship between overall mortality and preoperative NLR by using a Cox proportional hazard model. It showed marginally significant association in the multivariable analysis (hazard ratio, 1.04; 95% CI, 0.98–1.09; p=0.08) (Supplementary Table 4), suggesting that preoperative NLR is more strongly associated with early mortality than with late mortality.

Another study revealed that elevated postoperative NLR values, rather than preoperative NLR, were associated with significantly higher mortality rates among patients undergoing cardiac surgery [20]. The postoperative NLR may be affected by multiple factors, such as cardiopulmonary bypass time, postoperative infection, or inflammatory responses to surgical insult. Therefore, it is considered difficult to identify the predictive role of the NLR for postoperative outcomes. In addition, this paper did not present a comparison of predictive power between the preoperative NLR and postoperative NLR, and the postoperative NLR cannot be considered a superior index to the preoperative NLR in predicting the incidence of postoperative death.

One analysis compared the association of preoperative and postoperative NLR with complications after cardiac surgery [21]. The preoperative NLR and postoperative day (POD) 2 NLR were associated with a higher incidence of postoperative atrial fibrillation, whereas the POD 1 NLR was not. When the correlation with postoperative AKI was evaluated, the preoperative NLR had a lower relevance, while the POD 1 NLR and the POD 2 NLR were statistically significant. Accordingly, the authors argued that the postoperative NLR was a superior surrogate marker for postoperative complications to the preoperative NLR. However, these data did not demonstrate an association between NLR and mortality. Further studies are necessary to determine which NLR value (preoperative or postoperative) is a better surrogate marker of postoperative clinical outcomes.

The reasons for the association between a high preoperative NLR and worse early outcomes are not fully understood, but some potential mechanisms have been identified. An association between leukocytosis and increased morbidity and mortality in patients with ischemic vascular disease has long been observed. Both an elevated neutrophil count and depressed lymphocytes are associated with worse outcomes [22]. That is, a higher NLR ratio is indicative of a worse outcome. Specifically, neutrophil infiltration is associated with secondary damage after myocardial ischemia and is implicated in reperfusion injury through both direct toxic effects on the myocardium and vascular endothelium and leucocyte plugging in the microvasculature [6,23]. Furthermore, lymphocytopenia is an indicator of the general state of immunosuppression, and diminished immune system function adversely affects survival [24]. Elevation of the NLR may reflect a chronic background inflammatory state. Although neutrophils play a limited role in atherogenesis, they have a major role in the disruption of atherosclerotic plaques that affect the progression of atherosclerosis and the risk of acute complications [25].

There are several limitations of this study. First, it was a retrospective analysis, which involves inherent selection bias and confounding variables. Second, a relatively small sample was collected from a single institution. Third, our analysis did not compare the superiority of the preoperative and postoperative NLR. Fourth, there were limitations in objectifying and quantifying the preoperative condition of infection and inflammation, although we presented preoperative C-reactive protein levels as an indicator of these conditions. Finally, The potential mechanisms underlying the association between a high preoperative NLR and early mortality are not fully understood, even though several hypotheses are widely accepted regarding this issue. Thus, further well-designed prospective studies are necessary to establish more evidence in patients undergoing CABG.

In conclusion, a high preoperative NLR was strongly associated with early mortality after CABG. Moreover, an elevated preoperative NLR (≥3.4) was correlated with a higher early mortality rate. Based on these results, the preoperative NLR can be used clinically as an inexpensive and easily accessible predictor of mortality among patients who are about to undergo CABG. However, further studies with large cohorts are necessary to validate these results.

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Conflict of interest

No potential conflict of interest relevant to this article was reported.

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Supplementary materials

Supplementary materials can be found via https://doi.org/10.5090/jcs.22.082. **Supplementary Table 1.** Descriptive statics of data for multiple imputations. **Supplementary Table 2.** Assessment of multicollinearity of variables for 30-day and 90-day mortality. **Supplementary Table 3.** Baseline covariates between low NLR group and high NLR group. **Supplementary Table 4.** Risk factor analysis for overall mortality.

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