Postoperative infection-related mortality and lymphocyte-to-C-reactive protein ratio in patients undergoing on-pump cardiac surgery: a novel predictor of mortality?

A.A. PALA, A. GÜCÜ, S.A. SÜNBÜL, A. SÜNBÜL, H. ÖZÇELIK, I.B. SEKER, Ü. KARACA, M.T. GÖNCÜ

Department of Cardiovascular Surgery, Bursa Yuksek Ihtisas Training and Research Hospital, Bursa, Turkey

Abstract. – OBJECTIVE: This study aims to investigate the relationship between postoperative infection-related mortality and lymphocyte-to-C-reactive protein ratio (LCR), a newly defined parameter with the combination of inflammatory and immune parameters, in patients undergoing cardiac surgery.

PATIENTS AND METHODS: Between January 2016 and November 2021, 236 patients who underwent on-pomp cardiac surgery with median sternotomy and developed postoperative infection were analyzed retrospectively. Patients were divided into six groups according to the types of postoperative infection. Preoperative, perioperative, and postoperative variables of the patient groups were compared, and factors affecting postoperative mortality were evaluated.

RESULTS: The mortality rate in the patient group we included in the study was 22.9%. Mortality rates did not differ significantly between the infection groups. However, when the LCR value was evaluated between the groups, there was a statistically significant difference ($p<0.001$). The preoperative LCR cut-off value, which predicts postoperative infection-related mortality, was determined as 133.46 (area under the curve (AUC): 0.607, $p=0.017$, 48.1% sensitivity, and 47.8% specificity). In the multivariate analysis, postoperative cerebrovascular event (OR: 78.365, 95% CI: 12.367-496.547, $p<0.001$) and Intensive Care Unit (ICU) stay (odds ratio (OR): 1.136, 95% confidence interval (CI): 1.004-1.284, $p=0.042$) variables were found to be independent predictive factors of postoperative infection-related mortality in the model. There was no positive differentiation of the type of infection in predicting mortality.

CONCLUSIONS: The calculated LCR value is a novel and remarkable parameter in estimating postoperative infection-related mortality in patients undergoing cardiac surgery.

Key Words:
Cardiac surgery, C-reactive protein, Mortality, Infections, Lymphocyte.

Introduction

Evaluation of postoperative mortality and morbidity, which continues as an essential problem despite advances in surgical techniques and cardiac surgery technology, is a complex process[1]. Many evaluation criteria are utilized to predict postoperative outcomes, and the simple and easy to apply scoring systems used in evaluation help clinicians make more immediate decisions. Risk estimation algorithms associated with cardiac surgery and scoring systems created by laboratory parameters can predict the cardiac and metabolic reserves, inflammatory status, nutritional status, susceptibility to morbidity, and mortality of the patients[2,3]. Prognostic nutritional index (PNI), which is one of these scoring systems that is easy to apply, is related to the nutrition of patients and can directly predict mortality[4].

Similarly, more recently defined lymphocyte-to-C-reactive protein ratio (LCR) is evaluated primarily in patients undergoing gastrointestinal surgery for prediction of postoperative mortality and morbidity in many diseases, especially in surgical branches[5-7]. It is also used to predict in-hospital clinical outcomes and mortality in the COVID-19[8,9]. However, to the best of our knowledge, there is no study examining the relationship between cardiac surgery and LCR value, and this deficiency in the literature formed the basis of this study.

Corresponding Author: Arif Gücü, MD; e-mail: dr.arifgucu@gmail.com

Postoperative infections in patients undergoing cardiac surgery are significant complications that affect mortality and morbidity[10]. This study aimed to investigate the relationship between postoperative infection, infection-related mortality, and LCR value obtained from preoperative routine biochemical tests in patients undergoing cardiac surgery.

Patients and Methods

In this retrospective study, 236 patients who underwent on-pomp cardiac surgery in our hospital between January 2016 and November 2021 and who had an infection were evaluated. We defined six types of infections (urinary tract infections, harvest side infections, superficial sternal wound infections, deep sternal wound infections, pneumonia, and sepsis) after cardiac surgery as hospital-acquired infections based on O'Keefe et al[11]. Demographic characteristics, medical records, laboratory findings, and clinical results of the patients in each group were obtained retrospectively from the hospital database. Other recorded data are body surface area (BSA), preoperative left ventricular ejection fraction (LVEF), cardiopulmonary bypass (CPB) time, cross-clamp time, length of stay in the intensive care unit and hospital and use of intra-aortic balloon counterpulsation (IABP). Patients with in-hospital infections were registered in the postoperative period according to the established groups. In addition, cerebrovascular events (CVE) are experienced in transient ischemic attacks or stroke in the early postoperative period. Surgical procedures applied to the patients are classified as aortic valve replacement (AVR), coronary artery bypass graft (CABG), mitral valve replacement (MVR), aortic and mitral valve replacement (AVR+MVR), and combined surgical procedures (Table I).

The study was approved by Bursa Yuksek Ihtisas Training and Research Hospital Clinical Research Ethics Committee with protocol number 2011-KAEK-25 2022/02-21. Due to the retrospective nature of the study, informed consent was not obtained from the patients.

Analysis of Blood Parameters

Peripheral blood samples were acquired from all patients on the first day of hospitalization. Complete blood count was performed with Coulter LH 780 Hematology Analyzer (Beckmann Coulter, Brea, CA, USA). In addition, biochemical measurements were completed using the Cobas 6000 Analyzer (Roche Diagnostic,

Table I. Surgical procedures performed on patients.

Surgical procedures		Number (n)	Percentage (%)
CABG		**147**	**62.3**
	1* CABG	6	2.5
	2* CABG	22	9.3
	3* CABG	67	28.3
	4* CABG	39	16.5
	5* CABG	11	4.7
	6* CABG	2	0.8
AVR		**19**	**8.1**
MVR		**26**	**11**
AVR+CABG		**13**	**5.5**
	AVR+ 1* CABG	3	1.3
	AVR+ 2* CABG	6	2.5
	AVR+ 3* CABG	1	0.4
	AVR+ 4* CABG	3	1.3
MVR+CABG		**15**	**6.4**
	MVR+1* CABG	2	0.8
	MVR+2* CABG	1	0.4
	MVR+3* CABG	8	3.4
	MVR+4* CABG	4	1.7
AVR+MVR		**15**	**6.4**
AVR+MVR+CABG		**1**	**0.4**
Total		**236**	**100**

AVR: Aortic valve replacement; MVR: Mitral valve replacement; CABG: Coronary artery bypass grafting.

Mannheim, Germany). The PNI value used to evaluate the preoperative nutritional status was calculated using [10 × serum albumin (g/dL) + 0.005 × total lymphocyte count ($\times 10^3/\mu L$)] formula[4].

LCR Calculation

LCR value was calculated using [total lymphocyte count ($\times 10^3/\mu L$)/serum C-reactive protein (CRP) (mg/L)] formula.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (min-max), while categorical variables were exemplified as numbers and frequencies. Variance analysis (ANOVA) was utilized to compare groupings in normally distributed data, and Kruskal Wallis analysis was used to compare groups in abnormally distributed data. Multivariate binary logistic regression analysis was calculated to identify predictors for mortality. Patients with postoperative infection were divided into six main groups. Firstly, the parameters of all patients were statistically evaluated. Then, all parameters of each infection group were compared using posthoc tests. In addition, the Bonferonni correction was completed to widen the confidence interval in the posthoc tests. The receiver operating characteristic (ROC) curve analysis was applied to elucidate the effect of the LCR parameter on postoperative mortality. The area under the curve (AUC) was calculated. All calculations were obtained using SPSS for Windows version 25 (SPSS Inc., IBM, Armonk, NY, USA). The statistically significant value was evaluated as $p<0.05$ and $p<0.008$ in post-hoc tests.

Results

A total of 236 patients was included in our study. The patients were divided into six groups according to their postoperative infections. All of these patients had undergone median sternotomy and on-pomp cardiac surgery. Isolated coronary artery bypass graft (CABG) was performed in 147 patients (62.3%). Isolated valve surgeries were performed on 60 patients (25.5%). 29 patients (12.3%) underwent combined cardiac surgery. Details of surgical procedures are detailed in Table I.

The preoperative demographic values and blood parameters of the patients are shown in Table II. In the variances analysis performed after the patient groups were determined, no statistically significant difference between gender and BSA was ascertained in the patient groups ($p=0.268$ and $p=0.179$, respectively). The frequencies of hypertension and diabetes mellitus in the patient groups did not differ analytically ($p=0.799$ and $p=0.886$, respectively). The mortality of the patients did not deviate significantly between the groups ($p=0.671$). The duration of the cross-clamping and CPB did not vary analytically ($p=0.287$ and $p=0.137$, respectively). There was no differentiation in the analysis of postoperative comorbidities such as a CVE and IABP usage ($p=0.075$ and $p=0.200$, respectively). The preoperative LVEF values did not differ statistically ($p=0.790$). Creatine, ALT, total protein, hemoglobin, hematocrit, platelet count, CRP parameters did not deviate statistically (all p values higher than 0.05). There was a statistically significant difference in age between the patient groups ($p=0.001$). In post-hoc tests, urinary tract infection, superficial sternal wound infection, and pneumonia are statistically more common in elderly patients than sepsis ($p=0.002$, $p=0.003$, and $p=0.001$, respectively). The percentage of neutrophils differed statistically between the groups, and the percentage of neutrophils in patients with urinary tract infection was statistically significant compared to patients with pneumonia ($p=0.008$). BUN, AST, Albumin WBC, Lymphocyte percentage, neutrophil percentage, neutrophil count, and sedimentation values were significant in the analysis of variances, but only neutrophil percentage differed statistically for one group in post-hoc tests. In the evaluation for ICU stay, urinary tract infection was perceived to have a shorter ICU stay than pneumonia ($p=0.001$). Prolonged hospital stays have been demonstrated in patients with superficial sternal wound infections than patients with urinary tract infections and pneumonia ($p<0.001$ for both). When the LCR value, which is the primary goal of our study, was evaluated, there was a statistically significant difference between the patient groups ($p<0.001$). In the posthoc tests, it was revealed that patients with urinary tract infection had a significantly higher LCR value than patients with pneumonia ($p<0.001$). The PNI value also shows a meaningful difference between the infection groups ($p=0.005$). Comparisons between groups are shown in Table III.

Receiver operating characteristic (ROC) curve analysis was performed to recognize the effect of the LCR parameter on postoperative mortality.

Table II. Demographic characteristics, preoperative blood parameters and features of patients.

Preoperative variables		Mean ± S.D. (Min.-Max.)/n (%)
Age (years)		64.67 ± 11.69 (27-86)
Gender, n (%)	Male	148 (62.7%)
	Female	88 (37.3%)
BSA (m^2)		182.41 ± 17.77 (132-244)
Diabetes mellitus		76 (32.2%)
Hypertension		122 (51.7%)
Preoperative LVEF (%)		48.66 ± 9.51 (20-65)
Hemoglobin (g/dL)		12.13 ± 1.94 (7-17.4)
Hematocrit (%)		36.71 ± 5.73 (21.2-56.7)
WBC ($\times 10^6/\mu L$)		10267 ± 4216 (3680-26400)
Neutrophil ($\times 10^6/\mu L$)		7422 ± 3883 (1000-22400)
Lymphocyte ($\times 10^6/\mu L$)		1881 ± 917 (400-8150)
Platelets ($\times 10^3/\mu L$)		256 ± 98.9 (21-632)
BUN (mg/dL)		21.14 ± 9.75 (7-76)
AST (U/L)		41.8 ± 51.85 (11-382)
ALT (U/L)		28.81 ± 51.28 (3.4-657)
Neutrophil (%)		70.31 ± 10.74 (27-93)
Lymphocyte (%)		20.03 ± 9.15 (3-69)
Creatinine (mg/dL)		1.16 ± 1.04 (0.47-11.14)
CRP (mg/L)		42.45 ± 53.78 (2.32-300)
Sedimentation (mm/h)		45.80 ± 31.77 (3-140)
Total Protein (g/dL)		6.65 ± 0.84 (2.64-8.6)
Albumin (g/dL)		3.58 ± 0.53 (1.7-4.78)
PNI		45.29 ± 7.56 (25.6-74.55)
LCR		248.04 ± 300.98 (3.55-1433.3)
Perioperative and postoperative variables		
Cross-clamp time, minute		77.10 ± 34.77 (15-227)
Cardiopulmonary bypass time, minute		107.31 ± 43.41 (25-337)
Cerebrovascular event		62 (26.3%)
IABP usage		40 (16.9%)
ICU stay, days		6.11 ± 6.68 (1-35)
Hospital stay, days		6.92 ± 8.4 (0-90)
Mortality		54 (22.9%)

S.D.: standard deviation; Min.: minimum; Max.: maximum; AST: aspartate aminotransferase; ALT: alanine aminotransferase; BSA: body surface area; BUN: blood urea nitrogen; CRP: C-reactive protein; IABP: intra-aortic balloon pump; ICU: intensive care unit; LCR: lymphocyte to C-reactive protein ratio; LVEF: left ventricle ejection fraction; PNI: prognostic nutritional index; WBC: white blood cell.

In this evaluation, the LCR parameter was assessed notable in predicting mortality (Area Under Curve (AUC): 0.607, 95% confidence interval (CI): 0.523-0.691, p=0.017, cut-off: 133.46, 48.1% sensitivity and 47.8% specificity) (Figure 1).

Multivariate logistic regression was performed to determine the factors affecting mortality. The length of ICU stay was determined as a predictor of mortality (Odds ratio (OR): 1.136, 95% CI: 1.004-1.284, p=0.042). The postoperative hospital stay of the patients negatively predicted mortality (OR: 0.672, 95% CI: 0.525-0.860, p=0.002). The presence of CVE in patients is a strong predictor of mortality (OR: 78.365, 95% CI: 12.367-496.547, p<0.001). Different types of infections were undifferentiated in predicting mortality. (OR: 0.948, 95% CI: 0.805-1.117, p=0.523). Preoperative LVEF values of the patients in the study group were not a predictor for mortality (OR: 0.958, 95% CI: 0.885-1.038, p=0.297). Age, cross-clamp time, IABP usage, and other parameters did not predict mortality for all patients. Some parameters of the regression analysis are presented in Table IV.

When the patients were examined with logistic regression separately according to the infection types, no predictive factor was identified except for the pneumonia subgroup. The length of ICU stay (OR: 1.183, 95% CI: 1.047-1.336, p=0.007) and CVE (OR: 39.438, 95% CI: 4.086-380.675, p=0.001) in the pneumonia subgroup differentiated positively. The length of hospital stay resulted in similar results for the entire patient groups (OR: 0.716, 95% CI: 0.580-0.884, p=0.002).

Table III. Comparisons of classifications according to infection types.

Variables	Urinary tract Infections n = 84 (35.6%) Mean ± S.D. (Min.-Max.)/n (%)	Harvest side Infections n = 30 (12.7%) Mean ± S.D. (Min.-Max.)/n (%)	Superficial sternal wound infections n = 12 (5.1%) Mean ± S.D. (Min.-Max.)/n (%)	Deep sternal wound infections n = 11 (4.7%) Mean ± S.D. (Min.-Max.)/n (%)	Pneumonia n = 91 (38.6%) Mean ± S.D. (Min.-Max.)/n (%)	Sepsis n = 8 (3.4%) Mean ± S.D. (Min.-Max.)/n (%)	*p*-value
Age, years	64.96 ± 10.75 (38-86)	64.10 ± 7.19 (47-75)	68.25 ± 15.82 (37-82)	59.55 ± 11.93 (33-71)	66.11 ± 11.26 (27-85)	48.88 ± 19.84 (27-79)	0.001*
Preoperative LVEF (%)	49.14 ± 10.56 (20-65)	49.67 ± 9.46 (25-65)	45.42 ± 3.96 (40-50)	47.27 ± 8.76 (30-60)	48.35 ± 9.43 (25-65)	50 ± 5.97 (45-60)	0.790
WBC (×10^6/μL)	9564 ± 3857 (3800-26400)	9765 ± 3499 (3680-19400)	10845 ± 4332 (6500-20660)	8040 ± 3149 (4900-13900)	0936 ± 442 18 (3700-25300)	14131 ± 15965 (5200-21300)	0.090
Neutrophil (%)	66.5 ± 10.02 (42-87)	72.67 ± 8) (55-89	74.17 ± 9.02 (58-91)	71.18 ± 9.59) (61-93	72.08 ± 11.63 (27-92)	74.25 ± 11.46 (59-89)	0.004*
Lymphocyte (%)	23.11 ± 8.41 (3-43)	18.47 ± 7.90 (5-37)	16.5 ± 6.23 (4-27)	18.45 ± 8.04 (5-32)	18.64 ± 10.03 (3-69)	17 ± 8.91 (6-29)	0.007*
Neutrophil (×10^6/μL)	6501 ± 3454 (1700-22440)	7203 ± 3176 (2700-16600)	8306 ± 4335 (4300-18790)	5924 ± 3090 (3000-12500)	8090 ± 4043 (1000-20500)	11043 ± 5790 (3200-17900)	0.004*
Lymphocyte (×10^6/μL)	2080 ± 854 (570-4420)	1709 ± 758 (520-3200)	1590 ± 584 (760-2630)	1350 ± 536 (600-1200)	1848 ± 1068 (400-8150)	1975 ± 615 (1100-2780)	0.071
BUN (mg/dL)	19.67 ± 7.6 (9-46.17)	19.65 ± 7.68 (8-47.38)	21.84 ± 4.21 (14-26.17)	27.74 ± 175.62 (11-76)	22.56 ± 11.14 (10-71)	16 ± 6.23 (7-28)	0.035*
AST (U/L)	33 ± 35.47 (11-297)	27.01 ± 12.46 (11-66)	35.04 ± 16.07 (14-58)	61.27 ± 91.64 (13-319)	53.66 ± 67.05 (11-382)	38.16 ± 10.20 (21-55.6)	0.042*
Sedimentation (mm/h)	40.2 ± 30.07 (8-133)	53.4 ± 27.21 (9-110)	48.16 ± 31.82 (3-102)	56 ± 31 (7-107)	49.46 ± 34.22 (7.3-140)	17 ± 10.25 (6-33)	0.019*
CRP (mg/L)	30.32 ± 38.25 (2.32-169)	42.97 ± 47.89 (3.11-181)	39.62 ± 58.58 (3.02-188)	65.82 ± 57.49 (3.03-188)	52.02 ± 64.64 (3.02-300)	31.11 ± 49.19 (3-115)	0.085
Albumin (g/dL)	3.71 ± 0.52 (2.4-4.7)	3.60 ± 0.49 (1.7-4.28)	3.67 ± 0.47 (2.94-4.38)	3.44 ± 0.68 (2.24-4.5)	3.46 ± 0.51 (1.96-4.78)	3.73 ± 0.57 (2.9-4.5)	0.043*
PNI	47.53 ± 7.23 (29.5-68.5)	44.57 ± 6.13 (26-54.3)	44.73 ± 5.51 (34.95-52.15)	41.16 ± 8.22 (25.9-50.67)	43.87 ± 7.97 (25.6-74.55)	47.17 ± 7.77 (35.5-54.9)	0.005*
LCR	365 ± 365.45 (3-1433)	199.01 ± 251.3 (3.9-791)	216 ± 229.44 (7.45-675.24)	140 ± 226.72 (7.45-693.07)	112 ± 213.44 (3.97-1008.89)	435 ± 333.87 (9.57-893.89)	< 0.001*
Cerebrovascular event	18 (7.6%)	6 (2.5%)	4 (1.7%)	1 (0.7%)	28 (11.9%)	5 (2.1%)	0.075
IABP usage	11 (4.7%)	6 (2.5%)	2 (0.8%)	2 (0.8%)	15 (6.4%)	4 (1.7%)	0.200
ICU stay, days	3.45 ± 2.5 (1-17)	6.57 ± 7.51 (2-33)	9.08 ± 9.63 (1-35)	5.36 ± 3.5 (2-13)	7.95 ± 8.16 (2-35)	8 ± 4.17 (2-15)	< 0.001*
Hospital stay, days	5.19 ± 5.03 (0-41)	9.37 ± 8.18 (0-31)	16.17 ± 25.22 (0-90)	9.45 ± 6.30 (2-24)	6.21 ± 5.57 (0-30)	6.63 ± 10.66 (0-27)	< 0.001*
Mortality	18 (7.6%)	6 (2.5%)	4 (1.7%)	1 (0.7%)	22 (9.3%)	3 (1.3%)	0.671

S.D.: standard deviation; Min.: minimum; Max.: maximum; AST: aspartate aminotransferase; BUN: blood urea nitrogen; CRP: C-reactive protein; IABP: intra-aortic balloon pump; ICU: intensive care unit; LCR: lymphocyte to C-reactive protein ratio; LVEF: left ventricle ejection fraction; PNI: prognostic nutritional index; WBC: white blood cell.

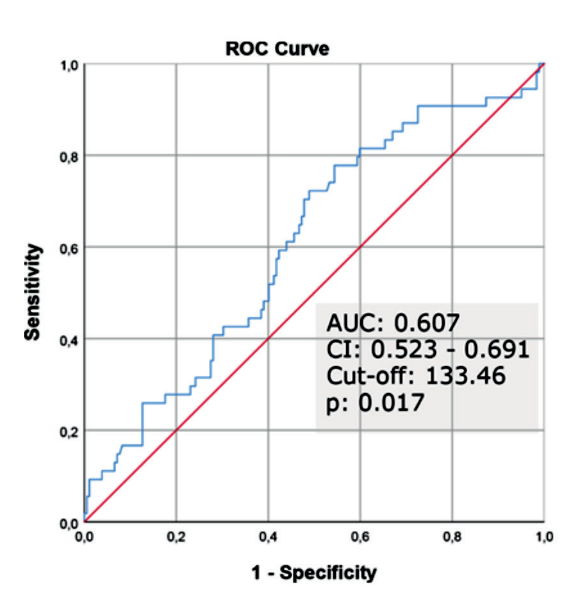

Figure 1. Data figure of the area under the curve (AUC), confidence interval (CI), and cut-off values in receiver-operating characteristic (ROC) curve analysis for established lymphocyte to C-reactive protein ratio.

Discussion

Postoperative infection is a significant and severe complication after cardiac surgery. Despite all the developments in cardiac surgery, the incidence of postoperative infection is >10%, and infections are responsible for 17% of mortality after cardiac surgery[10-12]. This study examines the relationship between postoperative infection-related mortality and a newly defined parameter, LCR, in patients who underwent on-pomp cardiac surgery. The first time in the literature, we determine that the LCR value is a remarkable parameter in the estimation of mortality in patients who developed an infection after cardiac surgery. The postoperative infection, ICU stay, and postoperative CVE variables are independent predictive factors of mortality.

Perioperative surgical stress and acute inflammatory response due to CPB, preoperative systemic inflammatory status and immune-nutritional status play a significant role in the pathogenesis of postoperative infections in cardiac surgery[4,10,13]. Inflammatory, nutritional and immune markers and their various combinations are defined and investigated as a predictor of postoperative infection in the literature. CRP is a nonspecific acute-phase protein that reflects the inflammatory state and is widely used in clinical practice. High preoperative CRP levels are associated with poor prognosis after cardiac surgery. Cappabianca et al[14] reported a relationship between preoperative CRP levels and postoperative infection and in-hospital mortality. Vitartaitė et al[15] found that preoperative CRP level is an independent risk factor for the development of sternal wound infection. Lymphocytes play an essential role in the immune response, reflect the immune-nutrition status, and are affected by physiological stress[7]. In inflammatory conditions, lymphocyte apoptosis accelerates, and lymphopenia indicates a poor prognosis[16]. Based on this information, the LCR parameter is defined as a new parameter combining these systemic inflammatory and immune parameters. Okugawa et al[17] defined the LCR parameter as a clinically appropriate nutrition-inflammation marker in their study that analyzed gastric cancer patients. Ou et al[18] reported that preoperative LCR has a better predictive value than other inflammatory

Table IV. Some parameters whose effects were investigated on mortality in multivariate logistic regression analysis.

Variables	Multivariate analysis		
	p-value	OR	95% CI Lower-Upper
Age (years)	0.608	1.024	0.963-1.120
Preoperative LVEF	0.297	0.958	0.885-1.038
Cross-clamp time	0.669	1.012	0.957-1.070
IABP usage n (%)	0.944	0.935	0.141-6.200
ICU stay, days	0.042*	1.136	1.004-1.284
Hospital stay, days	0.002*	0.672	0.525-0.860
Cerebrovascular event	< 0.001*	78.365	12.367-496.547
Types of infection	0.523	0.948	0.805-1.117

OR: odds ratio; CI: confidence interval; IABP: intra-aortic balloon pump; ICU: intensive care unit; LVEF: left ventricle ejection fraction.

indices defined as prognostic markers in patients with non-metastatic colorectal cancer. He et al[19] defined pretreatment LCR as a promising biomarker in predicting prognosis in their study that included patients with lung cancer. This parameter is also examined in the COVID-19 pandemic. Ullah et al[8] reported decreased LCR value as a predictor of in-hospital mortality in COVID-19. Similarly, Asghar et al[20] found the LCR value associated with disease severity and mortality in COVID-19 patients.

In the light of this information in the literature, we designed a hypothesis that claims postoperative infection-related mortality after cardiac surgery should be associated with LCR, an immune-based parameter. Patients with postoperative infection were divided into six groups. Firstly, in the descriptive statistics, the averages of parameters such as BSA and the frequencies of hypertension, diabetes mellitus, and mortality parameters are homologous. Similarly, in the previous LCR evaluation in the literature, there was no differentiation in the frequencies of diabetes and hypertension in Covid patients[8]. In another study, the descriptive statistical data were not similar[17]. In our study, the absence of diversity in the intraoperative values of cross-clamp time and CPB time suggests that the risks of extracorporeal circulation are equally distributed in all groups. In addition, the undifferentiated preoperative LVEF and the use of IABP do not show variation. The incidence of CVE is not statistically different between patient groups.

In comparisons between infection groups, the mean age of the groups is differed analytically. In the study of Okugawa et al[17], they used LCR evaluation to predict short- and long-term outcomes in gastric cancer patients, similar results were obtained regarding the mean age variable. Urinary tract infection, superficial sternal wound infection, and pneumonia are more common in older people than sepsis. This may be associated with the lack of self-care with advanced age. The percentage of neutrophils are higher in patients with urinary tract infection than in patients with pneumonia. In one of the recent studies, Park et al[21] reported that a high neutrophil ratio is an independent risk factor for mortality in urinary tract infections. Lalueza et al[22] reported that high neutrophil count was a predictor of the development of bacteremic urinary tract infection in emergency departments. This situation coincides with the positive differentiation of the percentage of neutrophils in urinary tract infections in our study. The length of stay in ICU is shorter in urinary tract infections than in pneumonia. This suggests that urinary infection after cardiac surgery is managed more easily than pneumonia. We observe that patients with superficial infections have longer hospital stays than those with urinary tract infections and pneumonia; this situation is more challenging, especially for the health economics. The differentiation of the PNI in the patients between the groups indicates that the immune nutrition is different between the groups. The nutrition of patients may have little effect on the development of urinary tract infections; however, it has an essential effect on the development and prognosis of deep sternal wound infections, pneumonia, and sepsis[23].

Preoperative LCR value are statistically significantly different between the infection groups, and it is remarkable that the mean LCR values are lower in the pneumonia subgroup. Also, ROC analysis describing the effect of LCR value on mortality in patients with infection after cardiac surgery in our study is shown in Figure 1. AUC value is similar to previous studies performed outside of cardiac surgery[5]. The occurrence of similar AUC values in different patient populations can indicate the universality of the LCR value. In our logistic regression analysis, prolonged ICU stay positively predicts mortality for all patients. The results of a publication by Lingsma et al[24] showed the effects of prolonged ICU stay on mortality. Prolongation of postoperative hospitalizations predicts mortality negatively. We think this situation occurs with adequate patient care in hospital conditions. Another remarkable finding in our analysis is postoperative CVE alone is a strong predictor of mortality. In parallel with this finding, in a nationally representative study by Mohamed et al[25], postoperative stroke in patients undergoing coronary artery bypass grafting was associated with high in-hospital mortality rates. It was discerned that the type of infection does not have a differential effect on mortality. Regardless of the source of immune-based responses in the body, this phenomenon affects mortality without differentiation. In the regression analysis completed in patient subgroups according to infection, only the pneumonia subgroup is differentiated due to the frequency of pneumonia. However, ICU stays, and CVE are predictive factors in predicting mortality in the pneumonia group, similar to all patients in the study.

The retrospective design of the study and relatively small sample size are stand out as its main limitations. In addition, external validation should be performed for the reliability and generalizability of the results since it is single-center. For this reason, multicenter, prospective studies should be planned.

Conclusions

According to the findings of our study, the preoperative LCR value is a new and remarkable parameter in the estimation of postoperative infection-related mortality after cardiac surgery. In addition, in the analyzes we performe, ICU stay, and postoperative CVE variables are independent predictive factors of postoperative infection-related mortality. Therefore, we believe these findings will benefit the management of early therapeutic and preventive interventions to reduce the risk of postoperative death from infection.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Authors' Contribution

Conceptualization, A.G., S.A.S. and A.A.P.; methodology, A.G., S.A.S. and A.A.P.; software, A.S. and H.O.; validation, A.G., S.A.S. and M.T.G.; formal analysis, A.G., I.B.S., and S.A.S.; investigation, A.G., A.S., H.O.; resources, A.G., S.A.S. and A.A.P.; data curation, A.G., S.A.S. and A.A.P.; writing original draft preparation, A.G., S.A.S., A.A.P., A.S., H.O., I.B.S. and M.T.G; writing review and editing, A.G., S.A.S., A.A.P., A.S., H.O., I.B.S. and M.T.G; supervision, A.G., S.A.S and M.T.G.; project administration, A.G., S.A.S and A.A.P. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and the local institutional review board (University of Health Sciences, Bursa Yuksek Ihtisas Education and Research Hospital, Bursa) approved the study protocol (number of approval: 2011-KAEK-25 2022/02-21).

Informed Consent Statement

Due to the retrospective nature of the study, informed consent was not obtained from the patients.

Data Availability Statement

All data are available by the corresponding author upon reasonable request.

ORCID ID

Arda Aybars Pala: https://orcid.org/0000-0001-7056-9313; Arif Gücü: https://orcid.org/0000-0002-7464-3362; Sadık Ahmet Sünbül: https://orcid.org/0000-0002-9981-1932; Ayşe Sünbül: https://orcid.org/0000-0003-1985-5132; Hakan Özçelik: https://orcid.org/0000-0002-2474-8246; Ümran Karaca: https://orcid.org/0000-0001-5922-2300; İbrahim Burak Şeker: https://orcid.org/0000-0002-5145-4921; Mehmet Tuğrul Göncü: https://orcid.org/0000-0002-3666-8673.

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