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The association between inflammatory indices and mortality in geriatric carbon monoxide poisoning

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Abstract

Carbon monoxide (CO) poisoning poses a significant threat to the geriatric population, who experience disproportionately high mortality rates. This study aimed to evaluate the prognostic utility of systemic inflammatory indices and novel composite biomarkers for predicting mortality in elderly patients with CO poisoning. A retrospective cohort study was conducted on 36 geriatric patients (≥ 65 years) admitted to the emergency department with acute CO poisoning. Demographic, clinical, and laboratory data were collected, including complete blood count, biochemistry, arterial blood gas values, and calculated inflammatory indices (NLR, PLR, SII, SIRI, CAR, MAR, RDW/lactate, COHb/lactate). The primary outcome was in-hospital all-cause mortality. While traditional inflammatory indices (SII, SIRI, NLR, PLR) showed no significant association with mortality, the novel COHb/lactate ratio demonstrated exceptional discriminatory power. Non-survivors exhibited significantly higher median creatinine, WBC, hemoglobin, COHb, and lactate levels, but significantly lower RDW/lactate, pH, HCO_3^-, and COHb/lactate ratios. ROC analysis revealed an AUC of 0.956 ($p = 0.032$) for the COHb/lactate ratio in predicting survival. An optimal cut-off value of < 3.61 was identified, yielding a sensitivity of 94.12% and specificity of 100%. The results indicate that conventional inflammatory indices may lack prognostic specificity in geriatric CO poisoning, likely due to the dominant pathophysiology of acute hypoxic-ischemic injury and age-related alterations in inflammatory response. In contrast, the COHb/lactate ratio, which integrates direct markers of exposure and metabolic consequence, emerges as a superior, highly specific biomarker for risk stratification and mortality prediction in this vulnerable population.

Keywords: Carbon monoxide poisoning, geriatrics, hyperbaric oxygen therapy, inflammatory indices, mortality, prognosis

Introduction

Carbon monoxide (CO) poisoning is a clinical condition caused by the inhalation of a colorless, odorless, and tasteless gas, and it represents a significant global public health issue [1,2]. CO, produced by the incomplete combustion of carbon-based fuels, binds to hemoglobin with an affinity approximately 250 times greater than that of oxygen, forming carboxyhemoglobin [2,3]. This process impairs tissue oxygenation, leading to hypoxic injury and potentially life-threatening clinical manifestations [1-3].

CO poisoning remains one of the leading causes of emergency department (ED) visits and toxicological deaths worldwide [4]. Its insidious onset and nonspecific symptoms often lead to diagnostic delays, thereby increasing mortality [2,4,5]. Clinical presentations vary widely, ranging from nonspecific symptoms such as headache, dizziness, and weakness to severe, life-threatening conditions including coma, convulsions, and cardiac arrest [2,5,6]. Despite early diagnosis and appropriate treatment, mortality rates remain high, particularly among elderly individuals [7].

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According to World Health Organization data, hundreds of thousands of people are exposed to CO poisoning annually, with tens of thousands dying as a result [8]. In the United States, approximately 50,000 individuals visit EDs each year due to CO poisoning, and over a thousand fatalities are reported [4,5]. In Europe and Türkiye, mass poisonings related to the use of stoves, chimneys, charcoal grills, and generators are frequently observed, especially during winter months. In developing countries, inadequate ventilation and the use of solid fuels further exacerbate this problem [9].

Although preventable, CO poisoning continues to cause significant mortality and morbidity. Mortality rates increase with age, pre-existing chronic conditions, and the severity of poisoning [6,9]. Geriatric patients are particularly vulnerable due to reduced cardiopulmonary reserve and a higher burden of comorbidities, which further elevates their risk of mortality [10]. Therefore, early diagnosis of CO poisoning, identification of high-risk groups, and investigation of biochemical and inflammatory markers for predicting mortality are of paramount clinical importance.

Consequently, systemic inflammatory markers, particularly neutrophil-to-lymphocyte ratio (NLR), monocyte-to-lymphocyte ratio (MLR), platelet-to-lymphocyte ratio (PLR), systemic immune-inflammation index (SII), systemic inflammatory response index (SIRI), mean platelet volume (MPV)-to-albumin ratio (MAR), and C-reactive protein (CRP)-to-albumin ratio (CAR), have emerged as potential indirect indicators of inflammation severity. Their ease of measurement in clinical settings makes them promising candidates for predicting mortality and treatment outcomes in patients with acute CO poisoning [11-13].

This study aimed to investigate the prognostic value of inflammatory parameters, with a particular focus on novel composite ratios integrating direct markers of hypoxic insult, such as the Red Cell Distribution Width (RDW) to lactate and the carboxyhemoglobin (COHb) to lactate ratios, in the geriatric population, which demonstrates high mortality rates due to CO poisoning [14,15].

Material and Methods

Study Setting and Design

This retrospective observational cohort study was conducted in the Emergency Department of Kırşehir Ahi Evran University Training and Research Hospital. The study commenced following approval by Kırşehir Ahi Evran University Medical Faculty Ethics Committee (Approval No.: 2025-17/219, date: 04.11.2025) in accordance with the World Medical Association Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. Reporting adheres to the STROBE statement for observational studies, with items pertinent to model performance according to TRIPOD where applicable. The study included 36 geriatric patients (≥65 years) diagnosed with CO poisoning in the emergency department between January 1, 2019, and January 1, 2024.

Measurement of Inflammatory Indices

All indices are calculated using biochemical and complete blood count parameters as follows: NLR: neutrophil count ($\times10^3/\mu L$) / lymphocyte count ($\times10^3/\mu L$); PLR: platelet count ($\times10^3/\mu L$) / lymphocyte count ($\times10^3/\mu L$); MAR: MPV (fL) / serum albumin (g/dL); CAR: CRP (mg/L) / serum albumin (g/dL); SII: platelet count ($\times10^3/\mu L$) × neutrophil count ($\times10^3/\mu L$) / lymphocyte count ($\times10^3/\mu L$); SIRI: neutrophil count ($\times10^3/\mu L$) × monocyte count ($\times10^3/\mu L$) / lymphocyte count ($\times10^3/\mu L$); RDW (%) / lactate (mmol/L); COHb/lactate: COHb (%) / lactate (mmol/L).

Study Population

Inclusion Criteria: A total of 80 geriatric patients (aged ≥ 65 years) admitted to the emergency department with acute CO poisoning were initially screened for this study. However, 44 patients were excluded from the final analysis: 28 due to critically missing laboratory or clinical data, 9 due to a pre-existing history of hematological malignancy, and 7 due to a diagnosed chronic inflammatory disease. Consequently, the final study cohort consisted of 36 patients who met the inclusion criteria of having a confirmed diagnosis, as determined by both clinical presentation and laboratory findings, and with a complete medical record available. This record was required to encompass EKG tracings, ED files, and full laboratory data, including complete blood count, biochemistry, and arterial blood gas parameters.

Exclusion Criteria: Patients under 65 years of age were excluded from the study. Additionally, any geriatric patient (≥65 years) with incomplete or missing data in the hospital's information management system was excluded. Other grounds for exclusion were a documented history of hematological malignancy or a chronic inflammatory disease.

Data Collection

Patient data were retrospectively collected from the hospital's electronic medical record system. As our hospital is the sole healthcare provider in the region, access to patients' complete prior and subsequent medical records was feasible, ensuring comprehensive data collection. Demographic data, including age and gender, as well as vital signs, and clinical features at the time of admission, were retrieved. The following laboratory parameters, obtained at presentation to the ED, were recorded: complete blood count, biochemical parameters (glucose, urea, creatinine, AST, ALT, albumin, CK, CK-MB, troponin), arterial blood gas values (pH, pCO_2, pO_2, HCO_3^-), and inflammatory indices (NLR, PLR, SII, SIRI, CAR, MAR, RDW/lactate ratio, COHb/lactate ratio). Blood samples for COHb and lactate, as key parameters of the study, were drawn during this initial presentation assessment. Furthermore, data regarding comorbidities, all medications used, treatment

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modalities (normobaric oxygen therapy or HBOT), and clinical outcomes (survival or mortality) were documented. Patients with incomplete medical records were excluded from the study.

Outcomes

The primary outcome was in-hospital all-cause mortality. Secondary outcomes included the requirement for HBOT, the association between various inflammatory indices and biochemical markers (including NLR, PLR, SII, CAR, RDW/lactate, and COHb/lactate), and mortality, and an evaluation of their prognostic performance in predicting mortality. Mortality status was ascertained from hospital records and regional health information systems.

Statistical Analysis

Statistical analyses were performed using SPSS 27.0 (Statistical Package for Social Sciences for Windows) and jamovi 2.3 (The jamovi Project, Sydney, Australia). The Shapiro-Wilk test was used to assess the normality of data distribution. Continuous data are presented as mean ± standard deviation or median with interquartile range, and categorical data as counts (percentages), as appropriate. Based on the normality assessment, parametric or non-parametric tests were employed. The specific tests used included the Mann-Whitney U test, the Kruskal-Wallis test, Spearman's correlation analysis, and Receiver Operating Characteristic (ROC) curve analysis. The optimal cut-off value in the ROC analysis was determined by maximizing the area under the curve and Youden's J index. A p-value of less than 0.05 was considered statistically significant.

Results

The mean age of the 36 individuals included in our study was 75.19 ± 6.54 years (range: 65-85). The cohort was equally distributed, with 50% male and 50% female participants. A comparison of participants' biochemical values according to the need for HBOT revealed that patients with higher CK-MB and troponin levels were referred for HBOT significantly more often (Table 1).

When inflammatory biomarkers were compared by HBOT status, the RDW/lactate ratio was significantly lower in the treatment group. In contrast, COHb and lactate values were statistically significantly higher (Table 2).

When biochemical and inflammatory parameters were compared by patient outcome (survival), non-survivors had significantly higher median levels of creatinine, WBC, hemoglobin, COHb, and lactate. In contrast, the RDW/lactate ratio, pH, HCO_3^-, and the COHb/lactate ratio were significantly lower in non-survivors compared with survivors (Table 3).

In the ROC analysis evaluating the performance of the COHb/lactate ratio in classifying survival, the area under the curve (AUC=0.956, p=0.032) was found to be significant, indicating that the COHb/lactate ratio is an excellent test for discriminating between survivors and non-survivors (Figure 1).

The optimal cut-off value for the COHb/lactate ratio in our study was 3.61. Values below this cut-off were associated with mortality. For this value, sensitivity was 94.12%, and specificity was 100% (Table 4). Analysis of correlations between COHb and inflammatory indices revealed a moderate negative correlation with the RDW/lactate ratio (Table 5).

Analysis of correlations between lactate and inflammatory indices revealed a moderate positive correlation with SIRI; weak positive correlations with SII, NLR, and PLR; and a strong positive correlation with the RDW/lactate ratio (Table 6).

Table 1. Comparison of biochemical parameters between patients referred and not referred for hyperbaric oxygen therapy

Parameter	HBOT (+) Median (IQR)	HBOT (–) Median (IQR)	p-value
Age (years)	74.0 (24)	75.0 (19)	0.565
Glucose (mg/dL)	152.0 (248)	152.0 (306)	0.943
BUN (mg/dL)	24.0 (31.0)	20.0 (24.0)	0.136
CRP (mg/L)	11.3 (48.7)	6.0 (48.6)	0.667
Albumin (g/dL)	4.1 (0.7)	4.2 (1.1)	0.218
Creatinine (mg/dL)	1.12 (1.08)	1.01 (125.64)	0.565
CK (U/L)	151.0 (5071.0)	110.0 (382.0)	0.168
CK-MB (ng/mL)	5.2 (129.8)	2.8 (19.3)	0.010
Troponin (ng/mL)	68.6 (194.8)	7.2 (111.5)	0.005
ALT (U/L)	14.0 (39.0)	14.0 (91.0)	0.747
AST (U/L)	26,00	23.0 (52.0)	0.830

Values are expressed as median (interquartile range, IQR); p-values calculated using the Mann–Whitney U test. HBOT (+): patients referred for hyperbaric oxygen therapy; HBOT (–): patients not referred. BUN: blood urea nitrogen; CRP: C-reactive protein; ALB: albumin; CK: creatine kinase; CK-MB: creatine kinase-MB; ALT: alanine aminotransferase; AST: aspartate aminotransferase

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Table 2. Comparison of inflammatory biomarkers according to hyperbaric oxygen therapy

Parameter	HBOT (+) Median (IQR)	HBOT (–) Median (IQR)	p-value
WBC (×10⁹/L)	11.30 (10.68)	8.59 (16.49)	0.052
Hb (g/dL)	13.70 (5.50)	13.10 (7.90)	0.247
RDW (%)	13.50 (2.40)	13.30 (6.30)	1.000
Neutrophils (×10⁹/L)	8.31 (11.46)	6.17 (15.94)	0.052
Lymphocytes (×10⁹/L)	0.89 (5.33)	1.79 (3.45)	0.067
Monocytes (×10⁹/L)	0.61 (1.45)	0.54 (0.72)	0.971
Platelets (×10⁹/L)	243.0 (174.0)	238.0 (276.0)	0.641
MPV (fL)	10.20 (1.70)	9.90 (3.10)	0.720
SIRI	5.69 (19.41)	1.86 (17.32)	0.079
SII	2960.76 (4058.35)	692.90 (4489.85)	0.062
NLR	12.18 (17.28)	2.68 (22.23)	0.062
PLR	212.73 (495.08)	144.90 (362.02)	0.117
RDW/Lactate	4.82 (6.27)	6.55 (14.30)	**0.009**
CAR	2.69 (12.18)	1.40 (11.88)	0.541
MAR (MPV/ALB)	2.54 (0.64)	2.39 (0.99)	0.109
COHb (%)	21.30 (31.50)	11.60 (30.70)	**<0.001**
pH	7.34 (0.23)	7.35 (0.57)	0.233
pO2 (mmHg)	30.20 (30.40)	33.00 (69.30)	0.858
pCO2 (mmHg)	47.60 (17.80)	45.50 (54.20)	0.858
$HCO3^-$ (mmol/L)	23.20 (11.30)	24.30 (19.90)	0.136
Lactate (mmol/L)	2.80 (12.30)	2.00 (11.10)	**0.005**

Values are expressed as median (interquartile range, IQR). p-values calculated using the Mann–Whitney U test. Bold values indicate statistical significance ($p < 0.05$). HBOT (+): patients referred for hyperbaric oxygen therapy; HBOT (–): patients not referred. WBC: white blood cell count; Hb: hemoglobin; RDW: red cell distribution width; MPV: mean platelet volume; SIRI: systemic inflammatory response index; SII: systemic immune-inflammation index; NLR: neutrophil-to-lymphocyte ratio; PLR: platelet-to-lymphocyte ratio; CAR: CRP-to-albumin ratio; MAR: MPV-to-albumin ratio; COHb: carboxyhemoglobin.

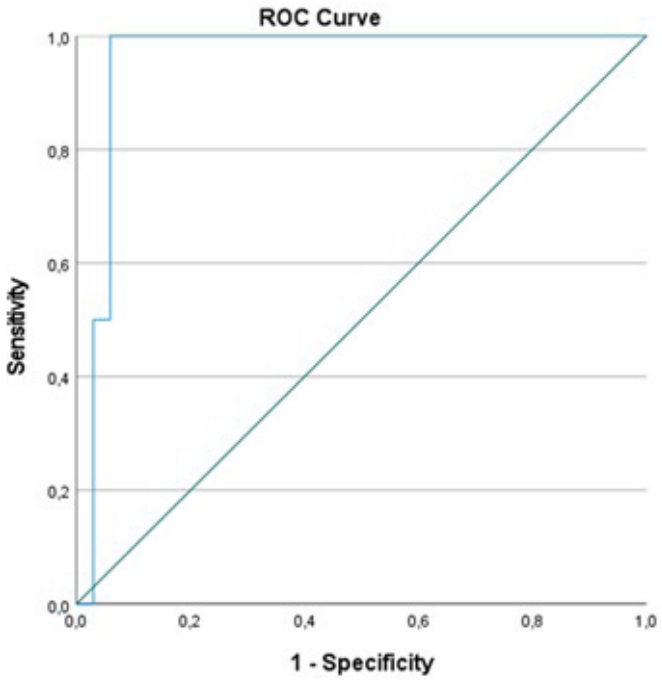

Figure 1. Receiver operating characteristic curve of the COHb/lactate ratio for predicting survival

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Table 3. Comparison of biochemical and inflammatory parameters according to survival status

Parameter	Survivors Median (IQR)	Non-survivors Median (IQR)	p-value
Age (years)	75.0 (24.0)	74.5 (24.0)	0.384
Glucose (mg/dL)	139.5 (312.0)	209.0 (92.0)	0.203
BUN (mg/dL)	21.0 (32.0)	23.4 (13.2)	1.000
CRP (mg/L)	6.5 (48.7)	15.85 (19.7)	0.419
Albumin (g/dL)	4.15 (1.1)	4.25 (0.3)	0.495
Creatinine (mg/dL)	1.01 (1.3)	6.378 (12.44)	**0.006**
CK (U/L)	121.0 (5089.0)	233.0 (360.0)	0.971
CK-MB (ng/mL)	2.93 (131.0)	11.11 (18.7)	0.813
Troponin (ng/mL)	9.15 (194.9)	67.3 (92.6)	0.114
ALT (U/L)	13.5 (91.0)	53.5 (61.0)	0.095
AST (U/L)	22.5 (53.0)	40.5 (23.0)	0.114
WBC ($\times10^9$/L)	8.92 (16.49)	16.46 (2.76)	**0.038**
Hb (g/dL)	13.15 (8.40)	15.85 (1.50)	**0.038**
RDW (%)	13.40 (6.30)	13.70 (1.80)	0.971
Neutrophils ($\times10^9$/L)	6.37 (15.94)	12.95 (5.31)	0.079
Lymphocytes ($\times10^9$/L)	1.47 (5.40)	2.55 (2.58)	0.667
Monocytes ($\times10^9$/L)	0.55 (1.45)	0.84 (0.18)	0.229
Platelets ($\times10^9$/L)	232.5 (313.0)	260.5 (15.0)	0.317
MPV (fL)	10.00 (3.10)	10.00 (0.40)	0.971
SIRI	1.87 (19.50)	6.76 (9.50)	0.286
SII	890.41 (4489.85)	1998.03 (2640.13)	0.667
NLR	3.30 (22.33)	7.53 (9.70)	0.578
PLR	153.84 (495.08)	139.29 (146.81)	0.714
RDW/Lactate	6.38 (14.46)	1.44 (0.73)	**0.013**
CAR	1.48 (12.18)	3.65 (4.38)	0.457
MAR (MPV/ALB)	2.44 (0.99)	2.35 (0.07)	0.384
COHb (%)	12.95 (39.70)	33.00 (8.00)	**0.013**
pH	7.35 (0.39)	7.13 (0.32)	**0.006**
pO_2 (mmHg)	32.80 (35.80)	43.35 (69.30)	1.000
pCO_2 (mmHg)	45.65 (34.50)	63.35 (27.70)	0.051
HCO_3^- (mmol/L)	23.75 (17.10)	11.90 (2.20)	**0.003**
Lactate (mmol/L)	2.10 (13.60)	10.00 (3.80)	**0.013**
COHb/Lactate ratio	6.79 (15.62)	3.34 (0.47)	**0.019**

Values are expressed as median (interquartile range, IQR). p-values were calculated using the Mann–Whitney U test. Bold values indicate statistical significance ($p < 0.05$). BUN, blood urea nitrogen; CRP, C-reactive protein; ALB, albumin; CK, creatine kinase; CK-MB, creatine kinase-MB; ALT, alanine aminotransferase; AST, aspartate aminotransferase; WBC, white blood cell count; Hb, hemoglobin; RDW, red cell distribution width; MPV, mean platelet volume; SIRI, systemic inflammatory response index; SII, systemic immune-inflammation index; NLR, neutrophil-to-lymphocyte ratio; PLR, platelet-to-lymphocyte ratio; CAR, CRP-to-albumin ratio; MAR, MPV-to-albumin ratio; COHb, carboxyhemoglobin

Table 4. Optimal cut-off value of the COHb/Lactate ratio for predicting survival

Cutpoint	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Youden's index	AUC	p
<3.61	94.12	100	100	50	0.941	0.956	0.032

COHb: carboxyhemoglobin; PPV: positive predictive value; NPV: negative predictive value; AUC: area under the curve

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Table 5. Correlations between COHb and inflammatory indices

	COHb	SIRI	SII	NLR	PLR	RDW/ LACTATE	CAR	MAR
COHb	—							
SIRI	0.153	—						
SII	0.155	0.905***	—					
NLR	0.171	0.912***	0.960***	—				
PLR	0.046	0.622***	0.851***	0.796***	—			
RDW/ LACTATE	-0.541***	-0.468**	-0.382*	-0.363*	-0.127	—		
CAR	0.126	0.319	0.306	0.233	0.159	-0.202	—	
MAR	0.122	0.280	0.332*	0.362*	0.393*	0.101	0.259	—

** p < .05, ** p < .01, *** p < .001*; Data presented as Spearman's correlation coefficient (r). COHb: Carboxyhemoglobin; SIRI: Systemic Inflammation Response Index; SII: Systemic Immune-Inflammation Index; NLR: Neutrophil-to-Lymphocyte Ratio; PLR: Platelet-to-Lymphocyte Ratio; RDW: Red Cell Distribution Width; CAR: C-reactive protein-to-Albumin Ratio; MAR: Mean Platelet Volume-to-Albumin Ratio; MPV: Mean Platelet Volume

Table 6. Correlations between lactate and inflammatory indices

	Lactate	SIRI	SII	NLR	PLR	RDW/ LACTATE	CAR	MAR
Lactate (mmol/L)	—							
SIRI	0.525**	—						
SII	0.433**	0.905***	—					
NLR	0.412*	0.912***	0.960***	—				
PLR	0.154	0.622***	0.851***	0.796***	—			
RDW/ Lactate	-0.970***	-0.468**	-0.382*	-0.363*	-0.127	—		
CAR	0.267	0.319	0.306	0.233	0.159	-0.202	—	
MAR	-0.035	0.280	0.332*	0.362*	0.393*	0.101	0.259	—

** p < .05, ** p < .01, *** p < .001*. Data presented as Spearman's correlation coefficient (r). SIRI: Systemic Inflammation Response Index; SII: Systemic Immune-Inflammation Index; NLR: Neutrophil-to-Lymphocyte Ratio; PLR: Platelet-to-Lymphocyte Ratio; RDW: Red Cell Distribution Width; CAR: C-reactive protein-to-Albumin Ratio; MAR: Mean Platelet Volume-to-Albumin Ratio; MPV: Mean Platelet Volume

Discussion

CO poisoning is a serious public health issue, especially for the elderly, who have higher mortality due to diminished physiological reserve and frequent comorbidities [4,6]. This study investigated the prognostic utility of both conventional inflammatory indices and composite biomarkers in geriatric patients with acute CO poisoning. Our primary finding is that the COHb/lactate ratio stood out as a discriminative biomarker, with an AUC of 0.956, showing its potential for identifying high-risk patients in this group.

Moreover, the significantly lower RDW/lactate and COHb/lactate ratios in non-survivors compared to survivors suggest that these novel ratios, which combine hypoxic and metabolic markers, can help predict outcomes [16]. Similarly, direct biomarkers of hypoxia and cellular injury, including WBC, hemoglobin, COHb, and lactate, were significantly elevated in non-survivors, supporting the link between inflammation, hypoxia, and mortality [17]. Lee et al. found that lactate is a key indicator of tissue hypoxia and can predict delayed neurological sequelae [18]. In line with this, a study focusing on geriatric patients found that admission lactate levels were significantly higher in CO poisoning cases than in control group, further showing lactate's role as a marker of hypoxic insult in the elderly [19].

However, traditional inflammatory markers such as SIRI, SII, NLR, and PLR did not predict mortality in this cohort. This differs from other studies in different patient populations. For instance, Acar et al. and others have reported that SII and similar indices are independent predictors of complication severity and show significant discriminatory power (AUC 0.708-0.746) in broader adult populations with CO poisoning [12,20]. Furthermore, a recent study focusing on elderly patients with severe CO poisoning showed that SII was a significant predictor of in-hospital cardiovascular adverse events (AUC 0.828) [21]. Similarly, other research also found that SII and MHR are valuable early predictors of myocardial injury in general adult

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patients with acute CO poisoning [22]. Additionally, Duyan and Vural showed that SII, along with NLR, MLR, and the RDW-lymphocyte ratio (RLR), could predict troponin elevation (AUC 0.71-0.77) in adult CO poisoning patients, further validating the role of these indices in identifying specific cardiac injury [23]. The divergence in our results may be attributed to fundamental differences in study populations and primary endpoints. While these studies focused on predicting specific complications, such as cardiovascular events and poisoning severity, our study focused on all-cause mortality in a geriatric population [21-24].

This distinction is important. While inflammatory indices can predict certain complications, they appear less reliable for overall mortality in frail elderly patients, where death typically results from a cascade of hypoxic injury, metabolic acidosis, and multi-organ failure. This is supported by a geriatric study, which found that the NLR was not a reliable marker for CO poisoning cases, as it changes with age and is usually elevated in the elderly, which limits its discriminative power [19]. The geriatric study similarly noted that COHb level alone is inadequate for predicting prognosis, showing the need for more markers. Our COHb/lactate ratio seems to fill this gap for predicting death risk [24].

The pathophysiology of CO poisoning, centered on acute hypoxic-ischemic damage rather than a pure systemic inflammatory response, may be disproportionately amplified in the elderly. This age group exhibits a reduced cardiopulmonary reserve, a high burden of comorbidities, immunosenescence, and inflammaging. These factors collectively diminish immune cell functionality and create a dysregulated inflammatory baseline. Consequently, in the context of acute hypoxic injury, conventional hematological ratios likely become a non-specific marker of stress, incapable of distinguishing the profound metabolic failure that leads to death from the inflammatory response to severe complications [25]. This concept of a diminished and nonspecific inflammatory response in the elderly is consistent with the observation that all systemic inflammatory parameters (WBC, NLR, RDW) were significantly elevated in geriatric patients with moderate-severe CO poisoning, likely representing a maximal, non-specific stress response rather than a precise indicator of fatal outcome [24]. This concept is further supported by the pediatric study, which also found no prognostic value for SII, suggesting that the very young and the very old may represent unique physiological differences where these indices lose utility [26]. Therefore, while systemic inflammation plays a role, its reflection through these conventional ratios may be insufficient or too nonspecific for mortality risk stratification in acute geriatric CO poisoning. This shows the need for more specific biomarkers that directly reflect the hypoxic insult, such as the COHb/lactate ratio, which performed well in our study (AUC = 0.956) and offers a direct assessment of the balance between toxic exposure and its metabolic consequences. Our findings are supported by Cervellin et al., who demonstrated a significant correlation between initial blood lactate and COHb levels ($r = 0.54$, $p < 0.001$) and identified lactate as the only independent predictor of hospital admission in CO-poisoned patients (AUC 0.850) [27].

The behavior of individual components of these ratios provides further understanding. RDW, recognized as an inflammatory parameter, does not increase immediately following acute events such as sudden blood loss, hemolysis, hypoxia, or acute inflammation. The production of new erythrocytes (reflected by an increase in reticulocytes and the release of variable-sized red blood cells into circulation) typically requires approximately 3-5 days. Hence, RDW usually becomes elevated only after several days [28,29]. In our study, cases of CO poisoning were admitted to our hospital at the time of diagnosis or upon suspicion of exposure. Although RDW levels were generally low in the overall cohort, non-survivors had higher RDW levels than survivors. This may indicate chronic exposure to CO or the presence of an underlying condition that chronically elevates RDW. This is consistent with the findings of Uzunosmanoglu et al., who reported significantly higher RDW levels in geriatric patients with moderate-severe CO poisoning compared to mild cases (16.10% vs. 13.85%, $p < 0.001$), suggesting RDW may show the severity of the acute insult and/or chronic burden [24]. Importantly, the significantly lower RDW/lactate ratio in non-survivors, even though their RDW was higher, shows that the quick rise in lactate is more important than the slower RDW response in fatal cases. In contrast, lactate levels rise rapidly (within hours) in critically ill patients [30,31]. In our study, lactate levels were significantly elevated in patients with moderate to severe poisoning. This explains that the lower RDW/lactate ratio, particularly in patients referred for HBOT, is attributable to the delayed increase in RDW coupled with the rapid rise in lactate levels [30,31].

Supporting the role of end-organ hypoxic injury, patients referred for HBOT had significantly higher levels of CK-MB and troponin. This finding suggests that CO exposure induces hypoxic damage in cardiac myocytes and that cardiac biomarkers play an important role in determining prognosis [7,32]. Similarly, Henry et al. reported that myocardial injury following moderate to severe CO poisoning is associated with long-term mortality [32]. This cardiac involvement is common, as demonstrated by Cervellin et al., who found that 66% of CO-poisoned patients had detectable troponin levels, with a significant correlation between lactate and troponin ($r = 0.44$, $p = 0.001$) [27]. Our results are consistent with this literature and highlight the importance of using cardiac biomarkers in clinical decision-making. Additionally, patients referred for HBOT had elevated COHb and lactate levels, as expected, since high COHb levels and the presence of clinical symptoms are considered among the indications for HBOT, with elevated lactate serving as an early indicator of tissue hypoxia [30,31].

Huang et al. found that severe CO poisoning raises the risk of kidney problems by 3.77 times and is associated with poor prognosis [33]. Our findings similarly showed significantly higher creatinine levels in non-survivors, supporting the link between renal impairment and mortality. This result shows the

impact of comorbidities on prognosis, especially in geriatric patients.

This study has several limitations due to its retrospective, single-center design. The small sample size limits the statistical power and generalizability of our findings; consequently, the promising results for the COHb/lactate ratio should be interpreted as preliminary and hypothesis-generating, requiring validation in larger, prospective, multi-center cohorts. The absence of a control group further complicates the assessment of biomarker specificity. As inflammatory indices and key biomarkers were measured only at a single time point upon admission, dynamic changes reflecting disease progression or response to therapy could not be captured. Finally, due to the observational nature of the study, variations in HBOT protocols that may influence outcomes could not be fully controlled.

Conclusion

In conclusion, this study suggests that conventional inflammatory indices (SIRI, SII, NLR, and PLR) may lack prognostic specificity for mortality in geriatric CO poisoning. In contrast, composite biomarkers that integrate hypoxic and metabolic markers, particularly the COHb/lactate ratio, demonstrated discriminatory power, with the RDW/lactate ratio also showing prognostic value. Elevated creatinine, WBC, hemoglobin, and cardiac biomarkers (CK-MB and troponin) further correlated with poor outcomes. These preliminary findings highlight the potential utility of readily available biomarker ratios in identifying high-risk elderly patients, though validation in larger prospective studies is warranted.

Ethical Approval
This study was approved by the Ethics Committee of Kırşehir Ahi Evran University Faculty of Medicine (Approval No: 2025-17/219, Date: 04/11/2025).

Patient Consent
Not necessary for this manuscript due to the retrospective nature of the study.

Conflict of Interest
The authors confirm the absence of any conflicts associated with this work.

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References

1. Dolanbay T, Vural A. Is asymptomatic low-dose carbon monoxide poisoning harmless at emergency department presentation. Eurasian J Emerg Med. 2024;23:203-8.
2. Ernst A, Zibrak JD. Carbon monoxide poisoning. N Engl J Med. 1998;339:1603-8.
3. İncekaya Y, Feyizi H, Bayraktar S, et al. Carbon monoxide poisoning and hyperbaric oxygen therapy. Okmeydanı Tıp Derg. 2017;33:114-8.
4. Sönmez FT, Güneş H, Saritaş A, Kandiş H. Carbon monoxide poisoning: clinical manifestations, consequences, monitoring, diagnosis and treatment of toxicity. Konuralp Med J. 2015;7:192-8.
5. Can G, Sayılı U, Sayman OA, et al. Mapping of carbon monoxide related death risk in Turkey: a ten-year analysis based on news agency records. BMC Public Health. 2019;19:9.
6. Vural A, Dolanbay T. Early and late adverse clinical outcomes of severe carbon monoxide intoxication: a cross-sectional retrospective study. PLoS One. 2024;19:e0301399.
7. Henry CR, Satran D, Lindgren B, et al. Myocardial injury and long-term mortality following moderate to severe carbon monoxide poisoning. JAMA. 2006;295:398-402.
8. GBD 2021 Carbon Monoxide Poisoning Collaborators. Global, regional, and national mortality due to unintentional carbon monoxide poisoning, 2000-2021: results from the Global Burden of Disease Study 2021. Lancet Public Health. 2023;8:e839-49.
9. Yurtseven S, Arslan A, Eryigit U, et al. Carbon monoxide poisoning in Turkey: analysis of 552 cases. J Emerg Med. 2009;36:269-73.
10. Ernst A, Zibrak JD. Clinical manifestations of carbon monoxide poisoning. UpToDate. https://www.uptodate.com access date 01.09.2025.
11. Henry CR, Satran D, Lindgren B, et al. Cardiovascular manifestations of moderate to severe carbon monoxide poisoning. J Am Coll Cardiol. 2005;45:1513-6.
12. Acar T, Ertekin B. The role of SII and SIRI values in predicting the severity of CO poisoning in the emergency department. Phoenix Med J. 2023;5:23-31.
13. Dimitrijević J, Čalamać M, Đurmez O, Stojanović M. Mean platelet volume-to-albumin ratio as a predictor of mortality in patients with febrile neutropenia: an observational study. Medicina (Kaunas). 2025;61:601.
14. Oh TK, Song IA, Lee JH. Clinical usefulness of C-reactive protein to albumin ratio in predicting 30-day mortality in critically ill patients: a retrospective analysis. Sci Rep. 2018;8:14977.
15. Yčas JW. Toward a blood-borne biomarker of chronic hypoxemia: red cell distribution width and respiratory disease. Adv Clin Chem. 2017;82:105-97.
16. Moon JM, Shin MH, Chun BJ. The value of initial lactate in patients with carbon monoxide intoxication: in the emergency department. Hum Exp Toxicol. 2011;30:836-43.
17. Hampson NB, Piantadosi CA, Thom SR, Weaver LK. Carbon monoxide poisoning: pathogenesis, management, and future directions of therapy. Am J Respir Crit Care Med. 2012;186:1095-101.
18. Lee H, Oh J, Kang H, et al. Association between early phase serum lactate levels and occurrence of delayed neuropsychiatric sequelae in adult patients with acute carbon monoxide poisoning: a systematic review and meta-analysis. J Pers Med. 2022;12:651.
19. Doğruyol S, Akbaş I, Tekin E, Doğruyol MT. Carbon monoxide intoxication in geriatric patients: how important are lactate values at admission?. Hum Exp Toxicol. 2020;39:848-54.
20. Li J, Qi HN, Gong P, et al. Prognostic value of systemic immune-inflammation index and monocyte-to-HDL-cholesterol ratio in early cardio-cerebral complications in elderly patients with acute severe carbon monoxide poisoning. Drug Chem Toxicol. 2024;47:381-5.
21. Li J, Qi H, Gong P, et al. Correlation of blood SII and MHR with nosocomial cardiovascular adverse events in elderly patients with severe carbon monoxide poisoning. J Clin Emerg. 2023;24:292-6.
22. Qi H, Li J, Kong F, et al. Role of systemic immune-inflammation index combined with monocyte to high density lipoprotein-cholesterol ratio in predicting myocardial injury after acute carbon monoxide poisoning. Academic Journal of Naval Medical University. 2023;44:646-50.
23. Duyan M, Vural N. Diagnostic value of systemic immune-inflammation index and red cell distribution width-lymphocyte ratio in predicting troponin elevation in carbon monoxide poisoning. Cukurova Med J. 2022;47:1584-90.

DOI: 10.5455/medscience.2025.12.356

24. Uzunosmanoğlu H, Dağar S, Çorbacıoğlu ŞK, et al. Evaluation of geriatric patients with carbon monoxide ıntoxication presenting to the emergency department. Eur J Clin Anal Med. 2021;9:1-5.

25. Goyani P, Christodoulou R, Vassiliou E. Immunosenescence: aging and immune system decline. Vaccines (Basel). 2024;12:1314.

26. Özdemir Kaçer E. The prognostic value of systemic immune inflammation index in children with carbon monoxide poisoning. J Contemp Med. 2023;13:879-84.

27. Cervellin G, Comelli I, Rastelli G, et al. Initial blood lactate correlates with carboxyhemoglobin and clinical severity in carbon monoxide poisoned patients. Clin Biochem. 2014;47:298-301.

28. Kim CH, Park JT, Kim EJ, et al. An increase in red blood cell distribution width from baseline predicts mortality in patients with severe sepsis or septic shock. Crit Care. 2013;17:R282.

29. Urben T, Amacher AS, Becker C, et al. Red blood cell distribution width for the prediction of outcomes after cardiac arrest. Sci Rep. 2023;13:15081.

30. Kaldirim U, Yolcu U, Arziman I, et al. The relationship between blood lactate, carboxy-hemoglobin and clinical status in CO poisoning. Eur Rev Med Pharmacol Sci. 2014;18:2777-82.

31. Bakker J, Nijsten MW, Jansen TC. Clinical use of lactate monitoring in critically ill patients. Ann Intensive Care. 2013;3:12.

32. Dağar S, Emektar E, Uzunosmanoğlu H et al. Clinical uses of lactate and lactate clearance in carbon monoxide poisoning. Istanbul Med J. 2019;20:519-23.

33. Huang TL, Tung MC, Lin CL, Chang KH. Risk of acute kidney injury among patients with carbon monoxide poisoning. Medicine (Baltimore). 2021;100:e27239.