Association Between Lactate-to-albumin Ratio and 28-day Mortality in Patients with Ventilator-associated Pneumonia

Qi Chen*

School of the First Clinical Medicine, Gannan Medical University, Ganzhou 341000, China

Abstract: *Background:* Ventilator-associated pneumonia (VAP) is a frequent complication for those receiving invasive mechanical ventilation in the ICU, exerts significant impacts on clinical outcomes. We aimed to explore the association between LAR and 28-day mortality in those suffering from VAP. *Methods:* This investigation utilized clinically granular data from MIMIC-IV database. Altogether, 591 patients with VAP were ultimately collected for analysis. Participants were categorized into three groups in accordance with tertiles of LAR. The key clinical endpoint was 28-day all-cause mortality. Univariate Cox Regression, Multivariate Cox Regression, RCS (Restricted cubic spline), Kaplan–Meier curve, and Subgroup analyses were used to examine the association between LAR and 28-day mortality among critical care patients with VAP. *Results:* Of the VAP patients, 22.0% succumbed within the 28-day observational window. According to the multivariable Cox regression analysis, LAR independently influenced the 28-day mortality risk in VAP patients (adjusted HR = 1.22, 95% CI: 1.06~1.39, P = 0.005). Restricted cubic spline analysis revealed a positive correlation between LAR and 28-day mortality. Subgroup analyses confirmed consistent associations across diverse patient characteristics. Kaplan-Meier curves demonstrated that patients in the high-LAR group had significantly lower survival probabilities compared to the low- and medium-LAR groups, suggesting that patients with VAP who have elevated LAR face a greater risk of mortality within 28 days. *Conclusion:* In summary, our study revealed a positive dose-response association between LAR and 28-day mortality in patients with VAP, suggesting that LAR is identified as an independent risk factor for unfavorable clinical outcomes in this population.

Keywords: Lactate-to-albumin Ratio; Ventilator-associated Pneumonia; 28-day All-cause Mortality

DOI: 10.57237/j.mrf.2026.01.001

1 Introduction

VAP is characterized by an infection in the lung parenchyma that appears after 48 hours of invasive mechanical ventilation and is universally regarded as one of the most frequent and consequential infections acquired in hospital settings. [1] Emerging evidence suggests that the incidence of VAP in ICU patients ranges from 5% to 40%, [2] with a mortality rate of 6.3% to 66.9%. [3] Several studies have found that VAP contributes to extended hospitalization and poses a major economic and societal challenge. [2-4] Notwithstanding considerable progress in VAP prevention and therapeutic interventions, the prognosis continues to be unfavorable. [4] To optimize clinical outcomes, it is important to identify patients at high risk for VAP as soon as possible. [5]

In humans, lactic acid is typically maintained at a low concentration under normal conditions, though some severe ill-

*Corresponding author: Qi Chen, chenqi@gmu.edu.cn

Received: 8 December 2025; Accepted: 15 January 2026; Published Online: 20 January 2026 http://www.medresfront.com

nesses can result in higher levels. [6, 7] Conversely, serum albumin levels drop in certain chronic pathological states. [8, 9] Lactate levels can vary swiftly in acute conditions, yet they can not represent chronic pathological states, while albumin fails to promptly reflect acute pathological processes. LAR offers a thorough risk evaluation by combining immediate metabolic conditions with long-term health reserves. [10]

Recent findings have shown that LAR is linked to unfavorable clinical outcomes in patients with severe conditions, such as sepsis, hepatic failure, acute ischemic stroke, chronic obstructive pulmonary disease. [11-14] However, whether LAR associated with mortality in individuals with VAP is not yet explored.

2 Materials and Methods

2.1 Study Design

Employing a retrospective cohort design, the research complied with STROBE standards. [15] The research relied solely on data from the MIMIC-IV (version 2.2) database, an open-access platform dynamically incorporating critical care records. This analysis focused on VAP cases in ICU at Beth Israel Deaconess Medical Center over the period spanning 2008 through 2019. This repository aggregates multidimensional ICU data from 73,181 hospitalizations at Beth Israel Deaconess Medical Center (2008-2019), with structured domains covering physiological monitoring, diagnostic laboratory profiles, comorbidity documentation via ICD codes, and granular therapeutic interventions. Qi Chen (ID: 13278941) completed the online training program and passed the required certification exam administered by the database platform prior to data extraction (completion record ID: 62438361). This study was conducted without requiring informed consent because the MIMIC database provides fully de-identified patient records.

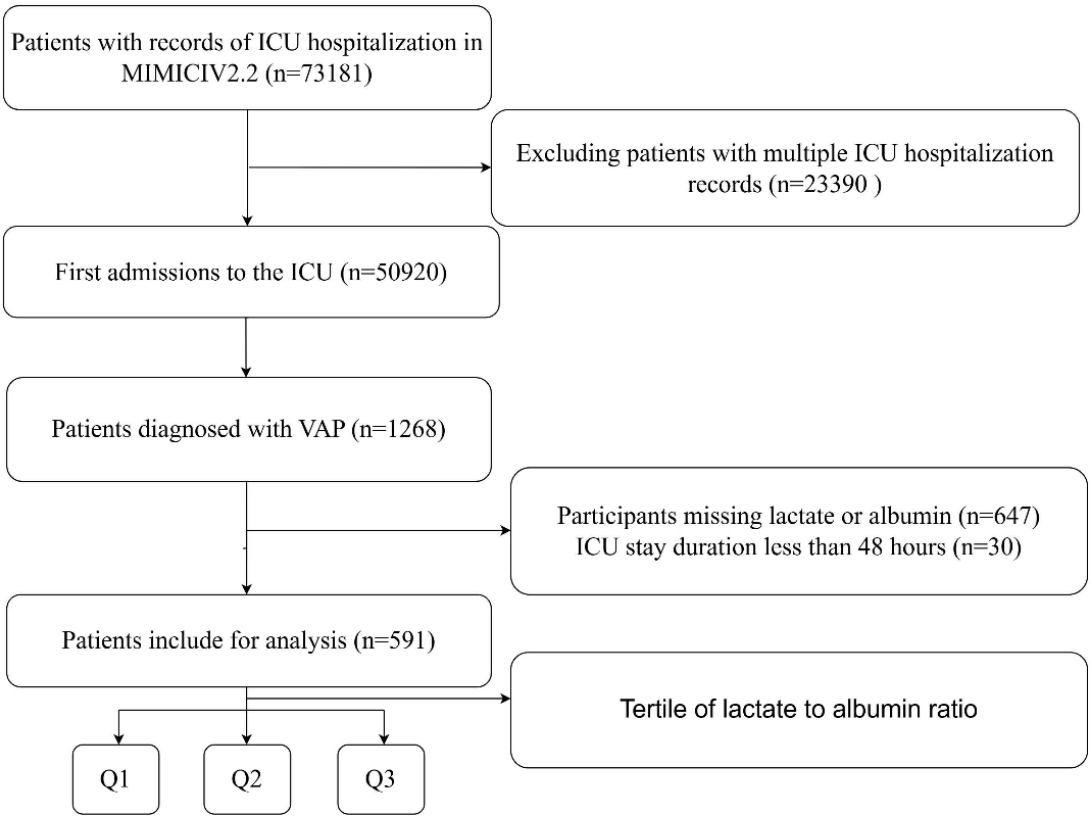

Figure 1 Flowchart of study patients

2.2 Inclusion and Exclusion Criteria

Adult patients (age≥18 years old) who were diagnosed with VAP during their first ICU admission were included in this retrospective cohort analysis. Using ICD-9 (4957, 99731) and ICD-10 (J95851) classification codes from the MIMIC-IV database, we identified 1,268 patients meeting the diagnostic criteria for ventilator-associated pneumonia

(VAP) in the initial screening phase. Exclusions were made for: (1) absence of lactate or albumin measurements within the initial 24-hour period following ICU admission (n=647), and (2) ICU length of stay less than 48 hours (n=30). The remaining 591 VAP cases constituted the study population, as illustrated in Figure 1.

2.3 Data Collection

Data extraction was performed using SQL queries within Navicat Premium (Version 16.3.9). Demographic and clinical variables captured in the study were: age, gender, race, body mass index, mean arterial pressure, respiratory rate, saturation of pulse oxygen, heart rate, lactate, albumin, GCS, SOFA, SAPS II, chronic pulmonary disease, myocardial infarct, sepsis, malignant cancer, diabetes, renal disease, congestive heart failure, liver disease, vasopressor, renal replacement therapy, antibiotics and 28-day all-cause mortality. Data captured within the first 24 hours of ICU admission encompassed vital signs, biomarkers (lactate, albumin), antibiotic prescriptions, and validated scoring systems. Additionally, in cases with multiple laboratory measurements, only the first recorded value within the specified timeframe was retained for analysis.

2.4 Outcome

The main outcome measure was mortality from any cause within 28 days.

2.5 Missing Data

Missing data distributions are cataloged in Table A1. The proportions of missing data for height and weight were 11.34% and 0.85%, respectively. Multiple imputation by chained equations was used to handle missing values. To predict missing values, all gathered variables were used to impute five datasets. We randomly chose an imputed dataset from these for baseline characterization, fitting both univariate and multivariate Cox regression models, and conducting subgroup analyses.

Table 1 Baseline characteristics of the patients according to tertiles of LAR

Variables	Total (n = 591)	LAR<0.50 (n = 195)	0.50≤LAR<0.88 (n = 197)	LAR≥0.88 (n = 199)	P-value
Baseline characteristic					
Age	61.4 ±16.7	61.8 ±15.5	62.5 ±16.2	59.9 ±18.1	0.286
Gender, n (%)					0.086
Female	212 (35.9)	82 (42.1)	66 (33.5)	64 (32.2)	
Male	379 (64.1)	113 (57.9)	131 (66.5)	135 (67.8)	
Race, n (%)					0.291
White	314 (53.1)	114 (58.5)	94 (47.7)	106 (53.3)	
Black	34 (5.8)	11 (5.6)	11 (5.6)	12 (6)	
Other or Unknow	243 (41.1)	70 (35.9)	92 (46.7)	81 (40.7)	
BMI	29.7 ±8.7	30.6 ±9.7	29.3 ±8.2	29.1 ±8.1	0.19
Vital signs					
MAP (mmHg)	84.5 ±21.5	88.0 ±21.2	84.6 ±22.4	80.8 ±20.4	0.004
HR (bpm)	92.5 ±21.5	90.8 ±20.7	90.4 ±20.7	96.3 ±22.5	0.009
RR (Bpm)	20.6 ±6.5	19.9 ±6.0	20.2 ±6.3	21.6 ±7.0	0.023
SpO_2 (%)	96.4 ±5.3	96.8 ±4.1	96.7 ±4.0	95.6 ±7.1	0.039
Scoring systems					
GCS	14.5 ±1.8	14.5 ±1.6	14.5 ±1.6	14.4 ±2.1	0.717
SOFA	3.0 (1.0, 5.0)	2.0 (1.0, 4.0)	3.0 (1.0, 5.0)	4.0 (2.0, 6.0)	< 0.001
SAPS II	44.1 ±15.5	40.3 ±13.5	42.5 ±14.5	49.3 ±16.8	< 0.001
Comorbidities					
Myocardial infarct, n (%)	104 (17.6)	36 (18.5)	29 (14.7)	39 (19.6)	0.412
Congestive heart failure, n (%)	173 (29.3)	64 (32.8)	60 (30.5)	49 (24.6)	0.183
Chronic pulmonary disease, n (%)	161 (27.2)	58 (29.7)	52 (26.4)	51 (25.6)	0.622
Liver disease, n (%)	154 (26.1)	35 (17.9)	50 (25.4)	69 (34.7)	< 0.001
Renal disease, n (%)	125 (21.2)	50 (25.6)	40 (20.3)	35 (17.6)	0.138
Diabetes, n (%)	162 (27.4)	59 (30.3)	56 (28.4)	47 (23.6)	0.311
Sepsis, n (%)	221 (37.4)	58 (29.7)	80 (40.6)	83 (41.7)	0.026

Variables	Total (n = 591)	LAR<0.50 (n = 195)	0.50≤LAR<0.88 (n = 197)	LAR≥0.88 (n = 199)	P-value
Malignant cancer, n (%)	54 (9.1)	16 (8.2)	20 (10.2)	18 (9)	0.798
Interventions					
Antibiotic, n (%)	364 (61.6)	109 (55.9)	123 (62.4)	132 (66.3)	0.099
Vasopressor, n (%)	451 (76.3)	132 (67.7)	153 (77.7)	166 (83.4)	0.001
RRT, n (%)	118 (20.0)	33 (16.9)	33 (16.8)	52 (26.1)	0.028
Outcome					
28-day mortality, n (%)	130 (22.0)	30 (15.4)	46 (23.4)	54 (27.1)	0.016

Data are presented as mean ± standard deviation (SD) or median (interquartile range, IQR) for continuous variables, and as counts (proportions) for categorical variables. Abbreviations: MAP, mean arterial pressure, HR, heart rate, RR, Respiratory rate, SpO_2, Peripheral capillary oxygen saturation, GCS, Glasgow Coma Scale, SAPS II, Simplified Acute Physiology Score II, SOFA, Sequential Organ Failure Assessment, RRT, renal replacement therapy.

2.6 Statistical Analysis

When continuous variables followed normal distribution, we reported mean ± standard deviation; otherwise median and interquartile ranges (25th–75th) were applied. Categorical variables were quantified through absolute numbers and relative percentages. To evaluate group differences, one-way ANOVA or the Kruskal-Wallis H test was employed based on the normality of the data, and categorical variables were analyzed using chi-square tests. Using tertile thresholds of LAR, three classifications were made for the patients.: low-LAR group (LAR<0.50, n=195), medium-LAR group (0.50≤LAR<0.88, n=197), and high-LAR group (LAR≥0.88, n=199). The selection of covariates was directed by the following criteria: those with preliminary regression coefficients that fluctuate by more than 10%, guided by earlier studies and comparative analysis of variable incorporation/exclusion patterns between the foundational model and the comprehensive model. The variance inflation factor (VIF) was employed to assess the presence of collinearity. A VIF greater than 2 suggests collinearity. Furthermore, to control for potential confounding factors, three Cox regression models with increasing levels of adjustment were developed: a basic model without any adjustments, Model I which accounted for demographic factors (age, gender, race) and Model II additionally incorporating heart rate, GCS, SAPS II, malignant cancer, myocardial infarct, liver disease, congestive heart failure, renal disease, renal replacement therapy, and antibiotic use. Stratified analyses and interaction tests were performed to assess subgroup heterogeneity in LAR effects, with results visualized through forest plots. Kaplan-Meier survival curves were generated to analyze survival distributions.

Analyses were conducted using R Statistical Software (v4.2.2) and the Free Statistics analysis platform (v2.0). All tests employed a two-tailed method, with significant differences marked by P-values less than 0.05.

3 Results

3.1 Baseline Characteristics

As depicted in Table 1, the baseline clinical profiles and 28-day survival outcomes of the study cohort are detailed. Three groups were derived from LAR tertiles. Participants were aged 61.4 ± 16.7 years, 64.1% of whom identified as male. 22.0% of the study population succumbed to any cause within 28 days. The high-LAR group exhibited significantly elevated values in physiological parameters (HR, RR), severity scores (SOFA, SAPS II), and higher prevalence of comorbidities (liver disease, sepsis). Additionally, this group demonstrated increased utilization of clinical interventions (vasopressors, RRT) and a greater 28-day mortality rate compared to the other two groups ($p < 0.05$). However, MAP and SpO_2 were lower than the other two groups ($p < 0.05$). No significant differences were observed in age, gender, race, BMI, GCS, renal disease, diabetes, chronic pulmonary disease, malignant cancer, congestive heart failure, myocardial infarct and antibiotics among the three groups.

3.2 LAR Is an Independent Risk Factor for 28-day Mortality

Univariate Cox regression analysis identified covariates with potential associations to 28-day survival outcomes (Table A2). Variables that had a p-value less than 0.1 in the univariate analysis were incorporated into the multivariate regression model for adjustment. Key associations identified through multivariable Cox regression are tabulated in Table 2. LAR displayed consistent mortality risk

escalation across progressively adjusted models (Crude model: HR = 1.19, 95% CI: 1.05~1.34; Model I: HR = 1.23, 95% CI: 1.09~1.39; Model II: HR = 1.22, 95% CI: 1.06~1.39). Additionally, sensitivity analyses were conducted by categorizing LAR into tertiles, changing it from a continuous variable to a categorical one. Using the low-LAR group as the reference, the high-LAR group exhibited significantly elevated 28-day mortality risk across all models (Crude model: HR=1.87, 95% CI: 1.20~2.93; Model I: HR=1.91, 95% CI: 1.22~3.00; Model II: HR=2.03, 95% CI: 1.25~3.27). Notably, all three models showned statistically significant trends associated with 28-day mortality (p for trend < 0.05). The findings suggest a dose-response link between LAR and 28-day mortality, where elevated LAR levels correspond to higher hazard ratios. We implemented restricted cubic spline modeling to assess potential nonlinear association. After comprehensive adjustment for confounders, LAR was found to be positively associated with 28-day mortality. (Figure A1).

Table 2 Multivariate COX analysis between LAR and 28-day mortality

Variable	Crude model		Model I		Model II	
	HR (95%CI)	p-value	Adjusted HR (95%CI)	p-value	Adjusted HR (95%CI)	p-value
LAR	1.19 (1.05~1.34)	0.005	1.23 (1.09~1.39)	0.001	1.22 (1.06~1.39)	0.005
0.50<LAR	Reference		Reference		Reference	
0.50≤LAR<0.88	1.57 (0.99~2.48)	0.056	1.49 (0.94~2.37)	0.09	1.69 (1.06~2.71)	0.029
LAR≥0.88	1.87 (1.20~2.93)	0.006	1.91 (1.22~3.00)	0.005	2.03 (1.25~3.27)	0.004
P for trend		0.006		0.005		0.004

Crude model: unadjusted
Model I: adjusted for age, gender, race
Model II: Model I plus HR, GCS, SAPS II, malignant cancer, myocardial infarct, liver disease, congestive heart failure, renal disease, renal replacement therapy, and antibiotic.

3.3 Kaplan–Meier Curve

Using LAR tertiles as cutoff values, participants were classified into three subgroups: high-, medium-, and low-LAR groups. Survival analysis via the Kaplan-Meier method indicated a significant elevation in 28-day mortality risk in the high-LAR subgroup versus the low-LAR subgroup (Log-rank P < 0.05) (Figure 2).

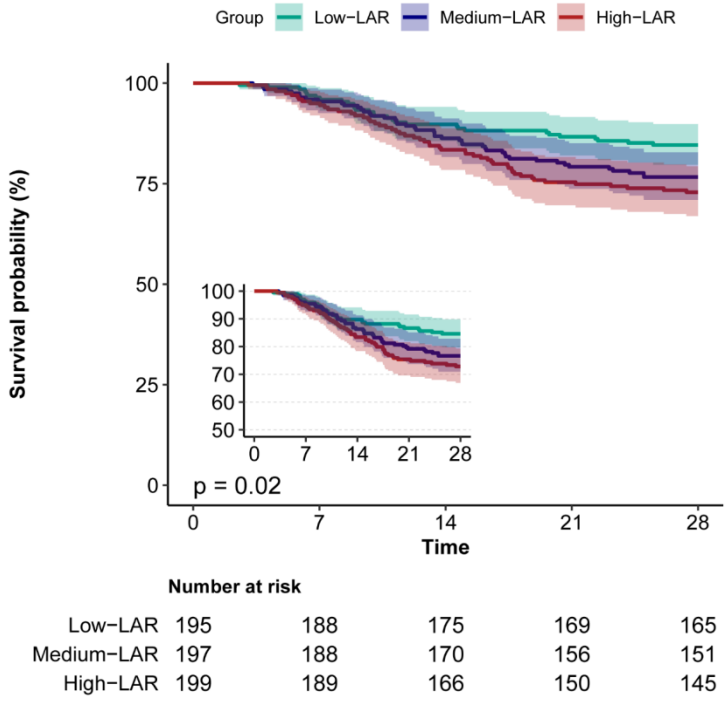

Figure 2 KM survival curves for 28-day mortality in VAP patients

3.4 Subgroup Analysis

We performed stratified analyses among VAP patients to assess potential interaction effects of LAR on 28-day mortality. The concordant outcomes observed across all subgroup stratifications confirmed the stability of the primary results (Figure 3).

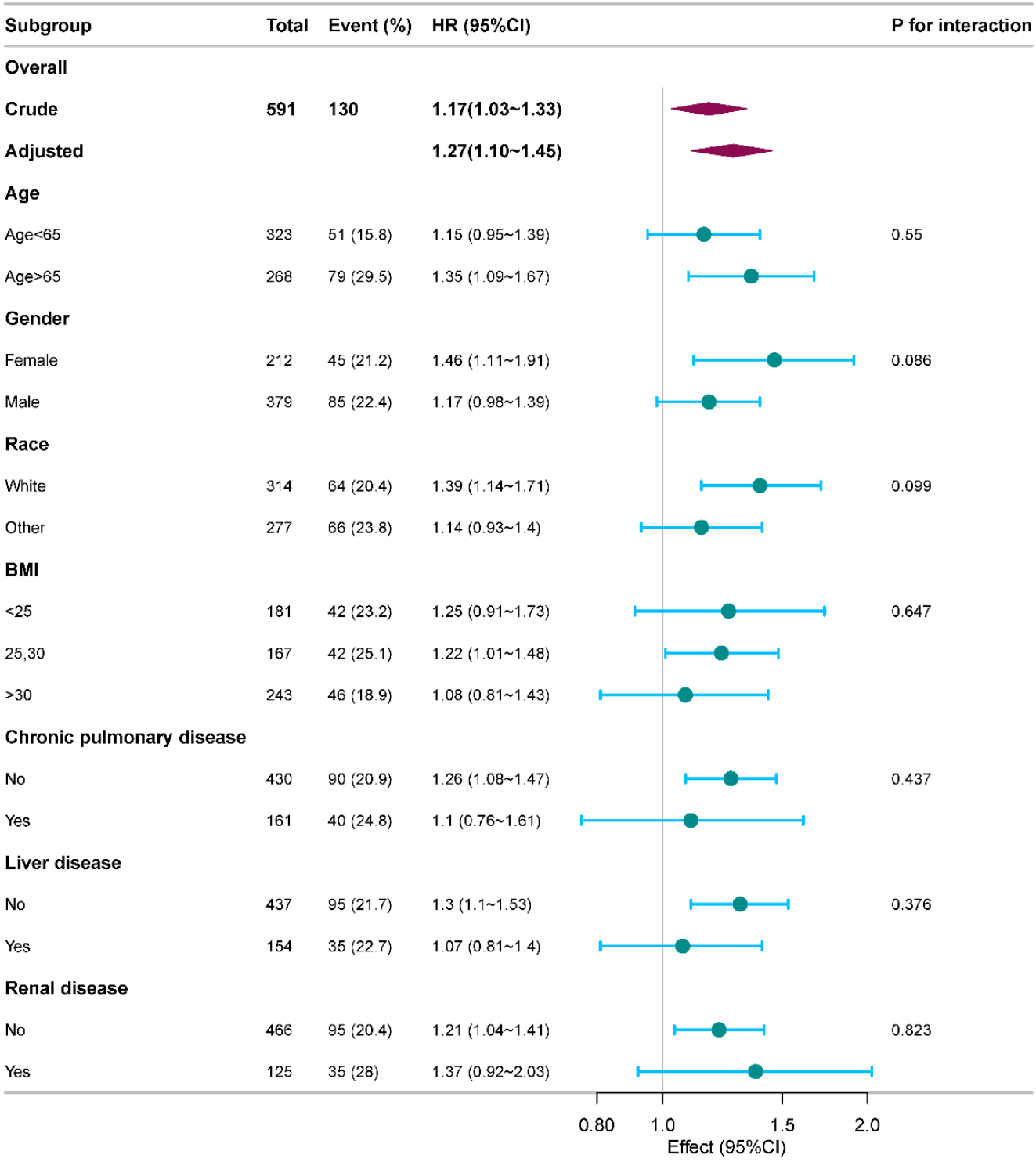

Figure 3 Subgroup analyses of the association between LAR and 28-day all-cause mortality

4 Discussion

In our study, a positive correlation was observed between LAR and 28-day mortality in VAP patients, with increasing LAR levels associated with elevated mortality risk. Kaplan-Meier curves revealed significantly reduced 28-day survival probability in the high-LAR cohort versus comparative groups. Multivariable Cox regression analysis, after comprehensive adjustment for potential confounding variables, consistently revealed that VAP patients with higher LAR had a substantially increased mortality risk.

According to recent studies, LAR is a predictor of the risk of short-term mortality in patients with several critical illnesses, including acute respiratory failure, acute respiratory distress syndrome (ARDS), heart failure and so on. [16-18] Our findings align with prior studies, showing a strong link between increased LAR levels and a higher risk of death (adjusted HR = 1.22, 95% CI: 1.06~1.39, p = 0.005). APACHE II score is a commonly used scoring system to evaluate the severity of illness and forecast mortality risk in ICU patients. [19, 20] The study by Wang et al. showed that LAR had better predictive accuracy for mortality in sepsis patients than the APACHE II score. [21] Acharya et al. found that LAR outperformed albumin and SOFA scores [22] individually in predicting in-hospital mortality for sepsis, acute respiratory failure, and their combination. [23]

Lactate serves as a critical biomarker of tissue oxygenation, [24, 25] hemodynamic perfusion [26], and systemic metabolic status, [27] whereas albumin reflects integrated nutritional reserves [28] and inflammatory burden. [29-31] The seminal study by Broder and Weil established that blood lactate concentrations exceeding 4 mmol/L are associated with adverse clinical outcomes. [32] The study by Dom ńguez de Villota E and Goldwasser P et al. demonstrated that low serum albumin levels are associated with increased risks of infection and mortality. [33, 34] As a predominant complication of mechanical ventilation, VAP ranks as a leading hospital-acquired infection in critical care settings. [35] Accordingly, We hypothesized that the effects of LAR on mortality in patients with VAP might be related to impaired tissue oxygen utilization, metabolic derangements and systemic inflammatory response intensity. The underlying mechanisms require additional investigation to confirm the observed associations.

Arterial blood gas (ABG) analysis and liver function tests (LFTs) are routinely performed in the ICU setting. Their simple analytical procedures, low costs, and freedom from geographical or technical constraints make them accessible in most clinical settings, enabling widespread implementation within compressed timelines. This finding may provide ICU clinicians with a novel clinical tool for the early detection of critically ill patients at high risk, potentially enabling timely intervention.

Our study has several inherent limitations. Firstly, the single-center retrospective cohort design introduces potential selection bias and limits the generalizability of the findings, requiring confirmation via extensive multicenter prospective studies. In addition, our analysis focused solely on the association between baseline LAR at ICU admission and 28-day mortality, precluding evaluation of potential mortality risk modulation through LAR temporal dynamics during critical illness. Finally, the study population was selected from the period between 2008 and 2019. We did not know the exact timing of VAP occurrence, and with the advancement of medical treatments and interventions, there may have been differences in treatment protocols among these patients, which may have introduced certain biases.

5 Conclusion

In summary, our study revealed a positive dose-response association between LAR elevation and 28-day mortality in patients with VAP, suggesting that monitoring LAR might assist in pinpointing high-risk patients and introduces a new biomarker for assessing clinical prognosis. Its generalizability and objectivity need further confirmation in large prospective study conducted across multiple centers.

Availability of Data

Data sets created and analyzed in the present research are accessible through the Medical Information Mart for Intensive Care IV (https://mimic.physionet.org/).

Ethics Approval and Informed Consent

This manuscript involves analysis of pre-existing de-identified data, which was granted exemption status by Massachusetts Institute of Technology Affiliates.

Conflicts of Interest

The authors have no conflicts of interest to declare.

Appendix

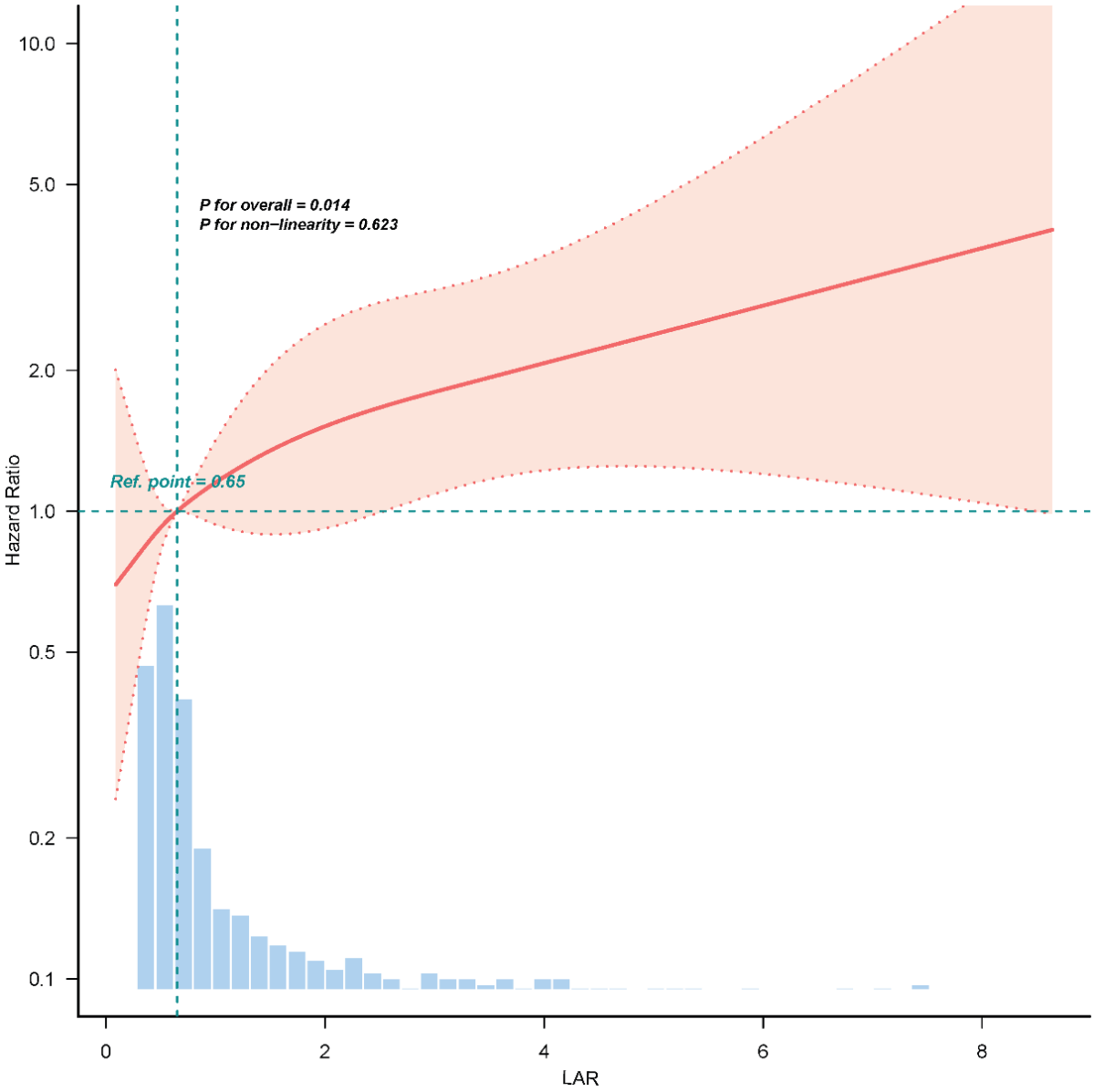

Figure A1 RCS Analyses of the LAR and 28-day mortality in patients with VAP

Table A1 Specific value and percentage of missing variable

Variable	Miss frequency	Miss percentage%
height	67	11.3367
weight	5	0.8460

Table A2 Univariate cox regression analysis

Variables	HR (95%CI)	P-value
Age	1.04 (1.03,1.05)	< 0.001
Gender		
Female	Reference	
Male	1.05 (0.73,1.5)	0.804
Race		

Variables	HR (95%CI)	P-value
White	Reference	
Black	0.28 (0.07,1.14)	0.076
Other or Unknow	1.36 (0.96,1.92)	0.085
BMI	0.99 (0.97,1.01)	0.242
LAR	1.17 (1.03,1.33)	0.012
MAP	0.9967 (0.9889,1.0046)	0.413
Heart rate	0.9908 (0.9826,0.999)	0.028
Respiratory rate	0.9925 (0.9657,1.0201)	0.591
SpO_2	1.01 (0.98,1.05)	0.458
GCS	0.93 (0.86,1.01)	0.08
SOFA	1.03 (0.98,1.09)	0.211
SAPS II	1.02 (1.01,1.03)	0.003
Myocardial infarct	2.24 (1.54,3.27)	< 0.001
Congestive heart failure	1.7 (1.19,2.41)	0.003
Chronic pulmonary disease	1.24 (0.85,1.8)	0.262
Liver disease	1.01 (0.69,1.49)	0.951
Renal disease	1.5 (1.02,2.21)	0.041
Diabetes	1.25 (0.86,1.81)	0.24
Sepsis	1.29 (0.91,1.82)	0.153
Malignant cancer	0.75 (0.39,1.43)	0.378
Antibiotic	0.62 (0.44,0.88)	0.007
Vasopressor	1.26 (0.80,1.98)	0.313
RRT	1.27 (0.86,1.87)	0.231

Abbreviations: MAP, mean arterial pressure, HR, heart rate, RR, Respiratory rate, SpO_2, Peripheral capillary oxygen saturation, GCS, Glasgow Coma Scale, SAPS II, Simplified Acute Physiology Score II, SOFA, Sequential Organ Failure Assessment, RRT, renal replacement therapy.

References

[1] Ranzani OT, Niederman MS, Torres A. Ventilator-associated pneumonia. Intensive Care Med. 2022 Sep; 48(9): 1222-1226. https://doi.org/10.1007/s00134-022-06773-3

[2] Papazian L, Klompas M, Luyt CE. Ventilator-associated pneumonia in adults: a narrative review. Intensive Care Med. 2020 May; 46(5): 888-906. https://doi.org/10.1007/s00134-020-05980-0

[3] Mumtaz H, Saqib M, Khan W, Ismail SM, Sohail H, Muneeb M, Sheikh SS. Ventilator associated pneumonia in intensive care unit patients: a systematic review. Ann Med Surg (Lond). 2023 May 12; 85(6): 2932-2939. https://doi.org/10.1097/MS9.0000000000000836

[4] Duszynska W, Idziak M, Smardz K, Burkot A, Grotowska M, Rojek S. Frequency, etiology, mortality, cost, and prevention of respiratory tract infections-prospective, one center study. J Clin Med. 2022; 11(13): 3764. https://doi.org/10.3390/jcm11133764

[5] Fernando SM, Tran A, Cheng W, et al. Diagnosis of ventilatorassociated pneumonia in critically ill adult patients—a systematic review and meta-analysis. Intensive Care Med. 2020; 46(6): 1170-1179. https://doi.org/10.1007/s00134-020-06036-z

[6] Revelly JP, Tappy L, Martinez A, Bollmann M, Cayeux MC, Berger MM, Chioléro RL. Lactate and glucose metabolism in severe sepsis and cardiogenic shock. Crit Care Med. 2005 Oct; 33(10): 2235-40. https://doi.org/10.1097/01.ccm.0000181525.99295.8f

[7] Smuszkiewicz P, Jawień N, Szrama J, Lubarska M, Kusza K, Guzik P. Admission Lactate Concentration, Base Excess, and Alactic Base Excess Predict the 28-Day Inward Mortality in Shock Patients. J Clin Med. 2022 Oct 18; 11(20): 6125. https://doi.org/10.3390/jcm11206125

[8] Don BR, Kaysen G. Serum albumin: relationship to inflammation and nutrition. Semin Dial. 2004 Nov-Dec; 17(6): 432-7. https://doi.org/10.1111/j.0894-0959.2004.17603.x

[9] Soeters PB, Wolfe RR, Shenkin A. Hypoalbuminemia: Pathogenesis and Clinical Significance. JPEN J Parenter Enteral Nutr. 2019 Feb; 43(2): 181-193. https://doi.org/10.1002/jpen.1451

[10] Gharipour A, Razavi R, Gharipour M, Mukasa D. Lactate/albumin ratio: An early prognostic marker in critically ill patients. Am J Emerg Med. 2020 Oct; 38(10): 2088-2095. https://doi.org/10.1016/j.ajem.2020.06.067

[11] Yoon SH, Choi B, Eun S, Bae GE, Koo CM, Kim MK. Using the lactate-to-albumin ratio to predict mortality in patients with sepsis or septic shock: a systematic review and meta-analysis. Eur Rev Med Pharmacol Sci. 2022 Mar; 26(5): 1743-1752. https://doi.org/10.26355/eurrev_202203_28244

[12] Wu H, Wu L, Luo L, Li HY, Zhang BF. Association between lactate-to-albumin ratio and mortality in hepatic failure: a retrospective cohort study. BMC Infect Dis. 2025 Mar 28; 25(1): 433. https://doi.org/10.1186/s12879-025-10783-z

[13] Zhang S, Chen N, Ma L. Lactate-to-albumin ratio: A promising predictor of 28-day all-cause mortality in critically Ill patients with acute ischemic stroke. J Stroke Cerebrovasc Dis. 2024 Jun; 33(6): 107536. https://doi.org/10.1016/j.jstrokecerebrovasdis.2023.107536

[14] Xie J, Liu H, He Q, Li C. Relationship between lactate-to-albumin ratio and 28-day mortality in patients with exacerbation of chronic obstructive pulmonary disease admitted to the Intensive Care Unit. Eur J Med Res. 2024 Apr 30; 29(1): 258. https://doi.org/10.1186/s40001-024-01867-8

[15] Elm EV, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. BMJ. 2007; 335: 806–8. https://doi.org/10.1136/bmj.39335.541782.AD

[16] Dong Y, Shi X, Wang C, Hu Y, Li J, Luo H, Zhu M, Hu F, Chu Q. The impact of the lactate-to-albumin ratio on long-term mortality risk in patients with severe heart failure and type 2 diabetes. BMC Cardiovasc Disord. 2025 Mar 29; 25(1): 234. https://doi.org/10.1186/s12872-025-04612-z

[17] Ren J, Kang Q, Wang F, Yu W. Association of lactate/albumin ratio with in-hospital mortality in ICU patients with acute respiratory failure: A retrospective analysis based on MIMIC-IV database. Medicine (Baltimore). 2023; 102(39): e35410. https://doi.org/10.1097/MD.0000000000035410

[18] Wang HX, Huang XH, Ma LQ, Yang ZJ, Wang HL, Xu B, Luo MQ. Association between lactate-to-albumin ratio and short-time mortality in patients with acute respiratory distress syndrome. J Clin Anesth. 2024 Dec; 99: 111632. https://doi.org/10.1016/j.jclinane.2024.111632

[19] Knaus WA, Zimmerman JE, Wagner DP, Draper EA, Lawrence DE. APACHE-acute physiology and chronic health evaluation: a physiologically based classification system. Crit Care Med. 1981 Aug; 9(8): 591-7. https://doi.org/10.1097/00003246-198108000-00008

[20] Markgraf R, Deutschinoff G, Pientka L, Scholten T. Comparison of acute physiology and chronic health evaluations II and III and simplified acute physiology score II: a prospective cohort study evaluating these methods to predict outcome in a German interdisciplinary intensive care unit. Crit Care Med. 2000 Jan; 28(1): 26-33. https://doi.org/10.1097/00003246-200001000-00005

[21] Wang B, Chen G, Cao Y, Xue J, Li J, Wu Y. Correlation of lactate/albumin ratio level to organ failure and mortality in severe sepsis and septic shock. J Crit Care. 2015 Apr; 30(2): 271-5. https://doi.org/10.1016/j.jcrc.2014.10.030

[22] Vincent JL, de Mendonça A, Cantraine F, Moreno R, Takala J, Suter PM, Sprung CL, Colardyn F, Blecher S. Use of the SOFA score to assess the incidence of organ dysfunction/failure in intensive care units: results of a multicenter, prospective study. Working group on "sepsis-related problems" of the European Society of Intensive Care Medicine. Crit Care Med. 1998 Nov; 26(11): 1793-800. https://doi.org/10.1097/00003246-199811000-00016

[23] Acharya CP, Yadav A, Pokhrel S, Bastola S, Jha S. Prognostic significance of lactate/albumin ratio in respiratory failure and sepsis. Ann Med. 2025; 57(1): 2482024. https://doi.org/10.1080/07853890.2025.2482024

[24] Brooks GA. Lactate as a fulcrum of metabolism. Redox Biol. 2020; 35: 101454. https://doi.org/10.1016/j.redox.2020.101454

[25] Kamel KS, Oh MS, Halperin ML. L-lactic acidosis: pathophysiology, classification, and causes; emphasis on biochemical and metabolic basis. Kidney Int. 2020 Jan; 97(1): 75-88. https://doi.org/10.1016/j.kint.2019.08.023

[26] Vincent JL, Quintairos E Silva A, Couto L Jr, Taccone FS. The value of blood lactate kinetics in critically ill patients: a systematic review. Crit Care. 2016 Aug 13; 20(1): 257. https://doi.org/10.1186/s13054-016-1403-5

[27] Gou Y, Li A, Dong X, Hao A, Li J, Xiang H, Rahaman S, He TC, Fan J. Lactate transporter MCT4 regulates the hub genes for lipid metabolism and inflammation to attenuate intracellular lipid accumulation in non-alcoholic fatty liver disease. Genes Dis. 2025 Feb 15; 12(4): 101554. https://doi.org/10.1016/j.gendis.2025.101554

[28] Eckart A, Struja T, Kutz A, Baumgartner A, Baumgartner T, Zurfluh S, et al. Relationship of nutritional status, inflammation, and serum albumin levels during acute illness. A prospective study. Am. J. Med. 2020; 133: 713–22. https://doi.org/10.1016/j.amjmed.2019.10.031

[29] Akkiz H, Carr BI, Bag HG, Karaogullarindan U, Yalcin K, Ekin N, et al. Serum levels of inflammatory markers CRP, ESR and albumin in relation to survival for patients with hepatocellular carcinoma. Int. J. Clin. Pract. 2021; 75: e13593. https://doi.org/10.1111/ijcp.13593

[30] Wiedermann, Christian J. MD. Anti-inflammatory activity of albumin. Critical Care Medicine 35(3): p 981-982, March 2007. https://doi.org/10.1097/01.ccm.0000257234.87784.91

[31] Quinlan, Gregory J. PhD; Mumby, Sharon BSc; Martin, Greg S. MD; Bernard, Gordon R. MD; Gutteridge, John M. C. DSc; Evans, Timothy W. MD. Albumin influences total plasma antioxidant capacity favorably in patients with acute lung injury. Critical Care Medicine 32(3): p 755-759, March 2004. https://doi.org/10.1097/01.ccm.0000114574.18641.5d

[32] Broder G, WEIL MH. Excess lactate: an index of reversibility of shock in human patients. Science. 1964 Mar 27; 143(3613): 1457-9. https://doi.org/10.1126/science.143.3613.1457

[33] Dom ńguez de Villota E, Mosquera JM, Rubio JJ, Galdos P, D éz Balda V, de la Serna JL, Tom ás MI. Association of a low serum albumin with infection and increased mortality in critically ill patients. Intensive Care Med. 1980 Nov; 7(1): 19-22. https://doi.org/10.1007/BF01692917

[34] Goldwasser P, Feldman J. Association of serum albumin and mortality risk. J Clin Epidemiol. 1997 Jun; 50(6): 693-703. https://doi.org/10.1016/s0895-4356(97)00015-2

[35] Ring BJ. 2024 Year in Review: Ventilator-Associated Pneumonia. Respir Care. 2025 May 19. https://doi.org/10.1089/respcare.13102