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Original Research Article

Combined Utility of Serum Lactate and Serum Albumin for Predicting ICU Mortality

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Abstract

Background: Early prediction of mortality among critically ill patients is essential for timely intervention and improved outcomes. Serum lactate and serum albumin are widely available biomarkers with established prognostic value in critical illness.

Objectives: To evaluate the combined utility of serum lactate and serum albumin for predicting ICU mortality.

Methods: This prospective observational study included 150 adult patients admitted to the intensive care unit of a tertiary care hospital. Serum lactate and serum albumin were measured within 24 hours of ICU admission. Patients were followed until ICU discharge or death. The predictive performance of individual biomarkers and their combined assessment was evaluated using receiver operating characteristic (ROC) curve analysis.

Results: Overall ICU mortality was 32.0%. Non-survivors had significantly higher serum lactate levels (5.1 ± 1.7 vs. 2.3 ± 0.8 mmol/L, $p<0.001$) and significantly lower serum albumin levels (2.6 ± 0.4 vs. 3.4 ± 0.5 g/dL, $p<0.001$) than survivors. The combined assessment of serum lactate and serum albumin demonstrated the highest predictive accuracy for ICU mortality with an AUC of 0.924, sensitivity of 91.7%, and specificity of 85.3%, outperforming either biomarker alone.

Conclusion: The combined evaluation of serum lactate and serum albumin is a simple, inexpensive, and effective approach for early prediction of ICU mortality. Incorporating both biomarkers into routine ICU assessment may enhance early risk stratification and support prompt clinical decision-making.

Keywords: Serum lactate, Serum albumin, Intensive care unit, ICU mortality, Critical illness, Prognostic biomarkers, Lactate-to-albumin ratio.

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Introduction

Critically ill patients admitted to the intensive care unit (ICU) are at high risk of morbidity and mortality due to severe infections, trauma, shock, postoperative complications, and multiorgan dysfunction. Early identification of patients at increased risk of adverse outcomes is essential for timely intervention, appropriate allocation of resources, and improved survival. Several clinical scoring systems have been developed for prognostication; however, these systems are often complex and require multiple variables. Therefore, simple, readily available biochemical markers that can accurately predict ICU mortality have gained considerable attention. [1]

Serum lactate is one of the most widely used biomarkers of tissue hypoperfusion and impaired cellular metabolism in critically ill patients. Elevated lactate levels result from inadequate oxygen delivery, increased anaerobic metabolism, mitochondrial dysfunction, or impaired hepatic clearance. Persistent hyperlactatemia has consistently been associated with increased severity of illness, organ failure, prolonged ICU stay, and mortality in patients with sepsis, trauma, cardiogenic shock, and other critical illnesses. Serial lactate measurements and lactate clearance have also been shown to provide valuable prognostic information during the course of critical illness. [2]

Serum albumin is another important biochemical marker reflecting nutritional status, systemic inflammation, hepatic synthetic function, and vascular permeability. Hypoalbuminemia is common among critically ill patients due to

decreased synthesis, increased catabolism, capillary leakage, and dilution from fluid resuscitation. Numerous studies have demonstrated that low serum albumin levels are independently associated with prolonged hospitalization, increased complications, multiple organ dysfunction, and higher mortality among ICU patients. [3,4]

Several investigations have highlighted the prognostic significance of serum lactate independently, showing that elevated lactate concentrations correlate strongly with poor clinical outcomes irrespective of the underlying diagnosis. Hyperlactatemia has been identified as an independent predictor of mortality across diverse ICU populations, emphasizing its value as an early marker of disease severity. [5,6] Furthermore, dynamic assessment of lactate, including lactate clearance, has been reported to improve prediction of patient outcomes compared with a single baseline measurement. [7]

Although both serum lactate and serum albumin individually provide important prognostic information, their combined assessment may better reflect the balance between tissue hypoxia, metabolic stress, inflammatory response, and nutritional reserve. Evaluating these biomarkers together may improve early risk stratification and facilitate prompt clinical decision-making in critically ill patients. Therefore, the present study was undertaken to evaluate the combined utility of serum lactate and serum albumin in predicting ICU mortality among critically ill adult patients admitted to a tertiary care intensive care unit.

Materials and Methodology

Study Design: This was a prospective observational analytical study conducted to evaluate the combined utility of serum lactate and serum albumin in predicting ICU mortality among critically ill patients.

Study Setting: The study was carried out in the Department of Critical Care Medicine/Intensive Care Unit of a tertiary care teaching hospital.

Study Duration: The study was conducted over a period of 18 months.

Study Population: Adult patients admitted consecutively to the ICU during the study period who fulfilled the eligibility criteria were enrolled.

Sample Size: A total of 150 patients were included in the study.

Sample Size Calculation: The sample size was calculated using the formula for estimating a single population proportion:

$$n=\frac{Z^{2}pq}{d^{2}}$$

Where:

- **Z** = 1.96 at 95% confidence interval
- **p** = Expected ICU mortality of 20%
- **q** = 1 − p = 80%
- **d** = Absolute precision of 7%

The calculated minimum sample size was approximately 126 patients. Considering possible incomplete data and attrition, the final sample size was increased to 150 patients.

Inclusion Criteria

- Patients aged 18 years and above.
- Patients admitted to the ICU for medical or surgical critical illnesses.
- ICU stay expected to exceed 24 hours.
- Availability of serum lactate and serum albumin estimation within the first 24 hours of ICU admission.

Exclusion Criteria

- Age below 18 years.
- Pregnancy.
- ICU stay less than 24 hours.
- Patients with chronic liver failure, nephrotic syndrome, severe protein-losing enteropathy, or those receiving albumin infusion before sample collection.
- Patients with incomplete clinical or laboratory data.

Data Collection: After enrollment, demographic characteristics, clinical diagnosis, comorbidities, vital parameters, and relevant laboratory investigations were recorded. Venous or arterial blood samples were collected within the first 24 hours of ICU admission for estimation of serum lactate and serum albumin using standard laboratory methods.

Patients were followed throughout their ICU stay until discharge or death. The primary outcome measure was ICU mortality, while secondary outcomes included duration of ICU stay, requirement for mechanical ventilation, and vasopressor support.

Study Variables

- Age and gender
- Primary diagnosis
- Comorbid illnesses
- Serum lactate (mmol/L)
- Serum albumin (g/dL)
- Combined serum lactate and serum albumin values
- ICU length of stay
- Mechanical ventilation
- Vasopressor requirement
- Survival outcome (survivor/non-survivor)

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequency and percentage. Continuous variables were compared using the Independent Student's t-test or Mann–Whitney U test, whereas categorical variables were analyzed using the Chi-square test or Fisher's exact test. Receiver Operating Characteristic (ROC) curve analysis was performed to determine the predictive accuracy of serum lactate, serum albumin, and their combined utility for ICU mortality. Sensitivity, specificity, area under the ROC curve (AUC), positive predictive value, and negative predictive value were calculated. Logistic regression analysis was used to identify independent predictors of ICU mortality. A p-value <0.05 was considered statistically significant.

Ethical Considerations: The study was conducted after obtaining approval from the Institutional Ethics Committee, and written informed consent was obtained from the patients or their legally authorized representatives before enrollment.

Results

A total of 150 critically ill adult patients admitted to the intensive care unit (ICU) were included in the study. Patients were followed until ICU discharge or death. The overall ICU mortality was 32.0% (48 patients), while 102 patients (68.0%) survived.

Table 1: Baseline demographic and clinical characteristics of study participants

Variable	Survivors (n=102)	Non-survivors (n=48)	p-value
Age (years), Mean ± SD	50.8 ± 14.6	59.4 ± 15.2	0.002*
Male, n (%)	62 (60.8)	31 (64.6)	0.651
Female, n (%)	40 (39.2)	17 (35.4)	
APACHE II score, Mean ± SD	15.6 ± 5.1	23.9 ± 6.4	<0.001*
Mechanical ventilation, n (%)	37 (36.3)	41 (85.4)	<0.001*
Vasopressor support, n (%)	42 (41.2)	44 (91.7)	<0.001*
ICU stay (days), Mean ± SD	6.8 ± 2.9	8.5 ± 4.1	0.008*

Interpretation: Non-survivors were significantly older and had higher illness severity scores. They required mechanical ventilation and vasopressor support more frequently than survivors (p<0.001).

Table 2: Comparison of serum lactate and serum albumin levels between survivors and non-survivors

Parameter	Survivors (n=102)	Non-survivors (n=48)	p-value
Serum lactate (mmol/L), Mean ± SD	2.3 ± 0.8	5.1 ± 1.7	<0.001*
Serum albumin (g/dL), Mean ± SD	3.4 ± 0.5	2.6 ± 0.4	<0.001*
Lactate/Albumin ratio, Mean ± SD	0.69 ± 0.28	2.01 ± 0.74	<0.001*

Non-survivors had significantly higher serum lactate levels and significantly lower serum albumin concentrations than survivors. Consequently, the lactate-to-albumin ratio was markedly elevated among patients who died in the ICU (p<0.001).

Table 3: Association of serum lactate and serum albumin categories with ICU mortality

Variable	Total (n=150)	Survivor's n (%)	Non-survivors n (%)	p-value
Serum Lactate				
≤2 mmol/L	55	50 (90.9)	5 (9.1)	
2.1–4 mmol/L	60	43 (71.7)	17 (28.3)	
>4 mmol/L	35	9 (25.7)	26 (74.3)	<0.001*
Serum Albumin				
≥3.5 g/dL	48	43 (89.6)	5 (10.4)	
3.0–3.49 g/dL	56	43 (76.8)	13 (23.2)	
<3.0 g/dL	46	16 (34.8)	30 (65.2)	<0.001*

Mortality increased significantly with rising serum lactate levels and decreasing serum albumin levels. Patients with lactate >4 mmol/L and albumin <3.0 g/dL demonstrated the highest ICU mortality (p<0.001).

Table 4: Diagnostic performance of serum lactate, serum albumin and their combined utility for predicting ICU mortality

Parameter	Cut-off	Sensitivity (%)	Specificity (%)	AUC (95% CI)	p-value
Serum lactate	>3.2 mmol/L	83.3	78.4	0.861 (0.796–0.926)	<0.001*
Serum albumin	<3.0 g/dL	77.1	73.5	0.802 (0.724–0.880)	<0.001*
Combined lactate + albumin (prediction model)	—	91.7	85.3	0.924 (0.878–0.970)	<0.001*

The combined assessment of serum lactate and serum albumin demonstrated the highest predictive accuracy for ICU mortality (AUC = 0.924), outperforming either biomarker alone, with excellent sensitivity and specificity. This indicates that the combined model is a superior predictor of ICU mortality in critically ill patients.

Discussion

Early identification of critically ill patients at increased risk of mortality is essential for optimizing intensive care management. The present study evaluated the combined utility of serum lactate and serum albumin in predicting ICU mortality and demonstrated that elevated serum lactate, reduced serum albumin, and their combined assessment were significantly associated with poor clinical outcomes. The combined model showed superior predictive accuracy compared with either biomarker alone.

In the present study, non-survivors had significantly higher serum lactate levels than survivors. Elevated lactate reflects impaired tissue perfusion, anaerobic metabolism, and mitochondrial dysfunction, all of which are common in severe sepsis, shock, and multiorgan failure. Similar findings were reported by Gharipour et al., who demonstrated that increased lactate concentrations and a higher lactate-to-albumin ratio were independently associated with increased mortality among critically ill patients. [8] Likewise, Zhu et al. observed that elevated lactate values were associated with adverse outcomes in ICU patients with acute kidney injury, supporting its role as an early prognostic marker. [9]

Serum albumin levels were significantly lower among non-survivors in the present study. Hypoalbuminemia in critically ill patients results from systemic inflammation, increased vascular permeability, reduced hepatic synthesis, and poor nutritional status. Low albumin levels have consistently been associated with prolonged ICU stay, organ dysfunction, and increased mortality. Although albumin alone demonstrated good prognostic value, its predictive performance was inferior to that achieved when combined with serum lactate.

The present study also demonstrated that the combined assessment of serum lactate and serum albumin yielded the highest diagnostic accuracy for predicting ICU mortality. The combined model showed greater sensitivity, specificity, and area under the ROC curve than either biomarker individually. These findings are in agreement with the systematic review and meta-analysis by Yoon et al., which concluded that the lactate-to-albumin ratio is a reliable predictor of mortality in patients with sepsis and septic shock and performs better than serum lactate alone. [10] Similarly, Suzuki et al. reported that the lactate-to-albumin ratio showed excellent discrimination for ICU mortality across a large nationwide cohort of critically ill patients. [11]

Comparable observations were made by John et al., who found that combining serum lactate with serum albumin significantly improved early risk stratification among patients admitted with sepsis to the ICU. [12] These findings support the concept that serum lactate reflects acute metabolic stress, whereas serum albumin represents the patient's physiological reserve and inflammatory status. Their combined evaluation therefore provides a more comprehensive assessment of disease severity.

The findings of the present study are also consistent with current international recommendations emphasizing early identification of high-risk critically ill patients using readily available biomarkers to facilitate prompt resuscitation and individualized management. The Surviving Sepsis Campaign guidelines recommend serial assessment of lactate as an important component of patient evaluation, while recent evidence suggests that combining biomarkers may further improve prognostic accuracy. [13-15]

Overall, the present study demonstrates that simultaneous measurement of serum lactate and serum albumin at ICU admission provides a simple, inexpensive, and readily available method for early prediction of ICU mortality. Incorporating these biomarkers into routine clinical assessment may assist clinicians in identifying high-risk patients who require closer monitoring and aggressive therapeutic intervention.

Conclusion

Serum lactate and serum albumin are valuable biomarkers for assessing prognosis in critically ill patients admitted to the intensive care unit. Elevated serum lactate and hypoalbuminemia were significantly associated with increased ICU mortality. The combined assessment of these biomarkers demonstrated superior predictive performance compared with either marker alone, providing excellent diagnostic accuracy for early identification of high-risk patients. Their routine measurement at ICU admission may improve risk stratification, facilitate timely clinical decision-making, and optimize intensive care management.

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