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Correlation Between Serum Lactate Levels and Mortality in Critically Ill Patients: A Prospective Observational Study

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Abstract: ***Background**: Serum lactate is an important biomarker of tissue hypoxia, impaired perfusion, and disease severity in critically ill patients. Elevated lactate levels have consistently been associated with increased morbidity and mortality in intensive care unit (ICU) patients. Early identification and serial monitoring of hyperlactatemia may facilitate risk stratification and timely intervention. Our aim to evaluate the correlation between serum lactate levels and mortality among critically ill patients admitted to the ICU. **Materials and Methods**: This prospective observational study was conducted in the ICU of a tertiary care teaching hospital over six months. One hundred critically ill adult patients were enrolled. Admission serum lactate was measured through arterial blood gas analysis. Patients were categorised into Group 1 (< 4 mmol/L) and Group 2 (≥4mmol/L). Demographic characteristics, clinical parameters, ventilatory support, ICU stay, and mortality outcomes were recorded. Statistical analysis was performed using SPSS version 25.0; a p-value < 0.05 was considered statistically significant. **Results**: Among 100 patients, 63% were male and 37% were female. Mean serum lactate was significantly higher among non-survivors than survivors (5.6±2.0 vs 2.3±1.1mmol/L; p<0.001). Mortality increased progressively with lactate, reaching 58.3% in patients with lactate > 4 mmol/L. Patients with elevated lactate more frequently required mechanical ventilation (76.3% vs 38.7%; p < 0.001), longer ventilatory support (7.4 ± 3.2 vs 3.8 ± 2.1 days; p < 0.001), and prolonged ICU stay (9.3 ± 4.1 vs 5.8 ± 2.7 days; p < 0.001). Serum lactate correlated significantly with ICU stay (r = 0.54), ventilator days (r = 0.61), and mortality (r = 0.67). ROC analysis showed good predictive performance for mortality (AUC = 0.84). **Conclusion**: Serum lactate is a valuable prognostic biomarker in critically ill patients. Elevated admission lactate and persistent hyper lactatemia are significantly associated with mortality, prolonged ICU stay, and increased ventilator requirement. Early lactate assessment and serial monitoring may improve prognostication and clinical decision-making.*

Keywords: Serumlactate; mortality; critically ill patients; intensive care unit; hyper- lactatemia; prognosis; arterial blood gas.

1. Introduction

Critical illness is frequently accompanied by tissue hypoperfusion, oxygen debt, and metabolic derangements that contribute significantly to morbidity and mortality. Identification of reliable prognostic biomarkers remains essential for risk stratification and optimisation of management strategies in the intensive care unit (ICU). [1, 2]

Serum lactate has emerged as one of the most widely used biomarkers in critical care. Lactate is produced during anaerobic glycolysis when oxygen delivery becomes insufficient to meet tissue metabolic demands. [3, 16] Under normal physiological conditions, production and clearance remain balanced; however, critically ill patients often experience increased production or impaired clearance, leading to hyperlactatemia. [10, 30]

Elevated lactate is commonly observed in sepsis, septic shock, trauma, respiratory failure, cardiogenic shock, and multi- organ dysfunction syndrome. Numerous studies have demonstrated a strong association between hyperlactatemia and adverse outcomes, including prolonged ICU stay, mechanical ventilation, organ failure, and death. [4, 6, 13]

Early work by Broder and Weil linked raised lactate concentrations to the depth of circulatory shock and the likelihood of recovery.[20] Subsequent work by Shapiro et al., Mikkelsen et al., Nichol et al., and Khosravani et al. established lactate as an independent predictor of mortality among critically ill patients[8, 11, 13, 19]

Despite the increasing use of lactate monitoring in critical care, data on its prognostic significance in heterogeneous ICU populations from developing countries remain limited.[12, 15] This study was therefore undertaken to evaluate the correlation between serum lactate levels and mortality among critically ill patients admitted to a tertiary care ICU.

2. Materials and Methods

Study design and setting: Prospective observational study conducted in the ICU of a tertiary care teaching hospital over six months, after approval from the Institutional Ethics Committee.

Sample size: One hundred critically ill adult patients were enrolled, based on prior studies demonstrating a significant association between elevated lactate and ICU mortality. [8, 11]

Inclusion Criteria

- Age≥18 years.
- ICU admission requiring critical care monitoring.

- Requirement of arterial blood gas analysis.
- Informed consent obtained.

Exclusion Criteria
- Age below 18 years.
- Pregnancy.
- Chronic liver failure.
- Inbornerrors of metabolism.
- Death or discharge within one hour of ICU admission.
- Incomplete clinical data.

3. Methodology

After ICU admission, demographic characteristics, diagnosis, vital parameters, laboratory investigations, and lactate levels were recorded. Serum lactate was measured from arterial blood samples at admission and serially during ICU stay. Patients were divided into **Group 1** (serum lactate < 4 mmol/L) and **Group 2** (serum lactate ≥ 4 mmol/L). The primary outcome was the association between serum lactate and ICU mortality; secondary outcomes were mechanical ventilation requirement, duration of ventilation, ICU stay, serial lactate trends, and organ dysfunction.

Statistical Analysis

Continuous variables were expressed as mean ± SD and compared using the unpaired Student's t-test. Categorical variables were analysed using the Chi-square test. Correlations were assessed using Pearson's coefficient, and ROC analysis evaluated predictive accuracy. Multivariate logistic regression identified independent predictors of mortality.[5, 19] A p-value < 0.05 was considered statistically significant. Analyses were performed using SPSS version 25.0.

4. Results

A total of 100 critically ill patients were included; 63 were male and 37 female, with a mean age of 55.9± 13.8 years. Sixty-two patients comprised Group 1 (< 4 mmol/L) and 38 comprised Group 2 (≥ 4 mmol/L). The two groups were comparable in baseline demographic characteristics, with no significant differences in age (54.2±13.4 vs 58.6±14.2 years; p=0.118), sex distribution (p=0.651), or BMI (24.8±3.6 vs 25.5± 4.1kg/m²; p=0.372) (Table1).

Table 1: Demographic characteristics of the study population

Variable	Group1 (<4mmol/L)	Group 2 (≥4mmol/L)	p-value
Number of patients	62	38	—
Age(years)	54.2±13.4	58.6±14.2	0.118
Male (%)	61.3	65.8	0.651
Female (%)	38.7	34.2	0.651
BMI (kg/m²)	24.8±3.6	25.5±4.1	0.372

Sepsis and septic shock were the most common primary diagnoses (32%), followed by respiratory failure (20%) and polytrauma (14%) (Table 2, Figure 1).

Table 2: Distribution of primary diagnoses (n=100)

Diagnosis	n(%)
Sepsis/septic shock	32 (32%)
Respiratory failure	20 (20%)
Polytrauma	14 (14%)
Postoperative cases	12 (12%)
Cardiac illness	9(9%)
Renal failure	7(7%)
Others	6(6%)

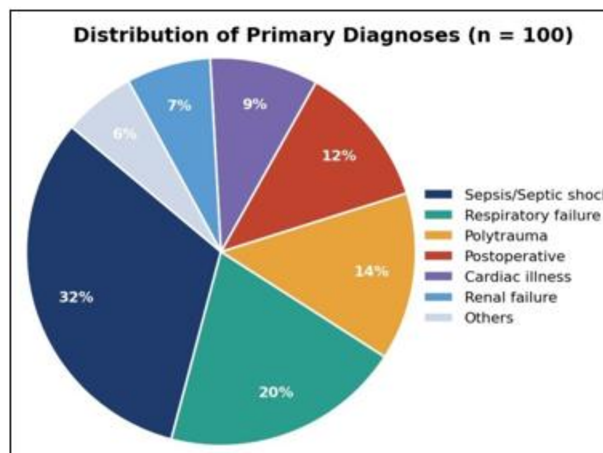

Figure 1: Distribution of primary diagnoses among the study population

Patients with elevated lactate exhibited significantly worse admission physiological parameters, including higher heart rate, lower mean arterial pressure, higher respiratory rate, lower SpO_2, lower Glasgow Coma Scale, and higher temperature (all p ≤ 0.002) (Table 3).

Table 3: Admission clinical parameters

Parameter	Group1	Group2	p-value
Heartrate (beats/min)	96±14	118±18	<0.001
Mean arterial pressure (mmHg)	82±10	68±12	<0.001
Respiratory rate (/min)	22±4	29±5	<0.001
SpO_2 (%)	94±3	89±5	<0.001
Glasgow Coma Scale	12.8±2.1	9.4±2.7	<0.001
Temperature (°C)	37.3±0.8	38.2±1.1	0.002

Serum Lactate and Mortality

Mean admission serum lactate was significantly higher among non-survivors than survivors (5.6 ± 2.0 vs 2.3 ± 1.1 mmol/L; **p < 0.001, statistically significant**; Figure 2). Mortality increased progressively across lactate categories- 11.8% for <2mmol/L, 33.3% for 2–4mmol/L, and 58.3% for > 4mmol/L- a difference that was **statistically significant (χ^2=17.6; p<0.001)** (Table 4, Figure 3). This indicates a clear dose- dependent relationship between lactate and mortality.

Table 4: Serum lactate category and ICU mortality

Lactate level	Mortality (%)	Statistic
<2mmol/L	11.8	χ^2=17.6
2–4mmol/L	33.3	p<0.001
>4mmol/L	58.3	

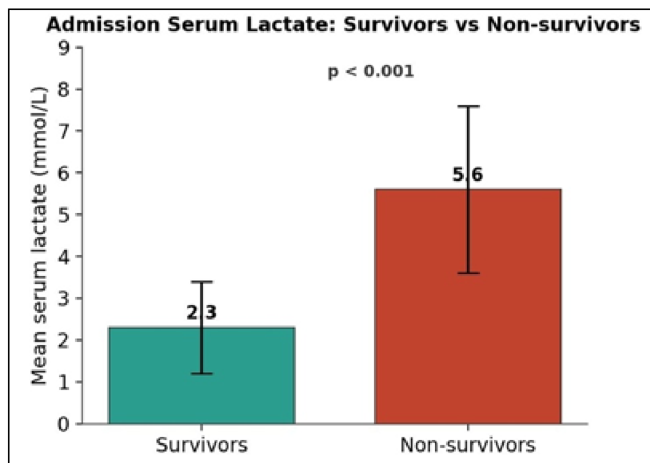

Figure 2: Mean admission serum lactate in survivors versus non- survivors (p<0.001)

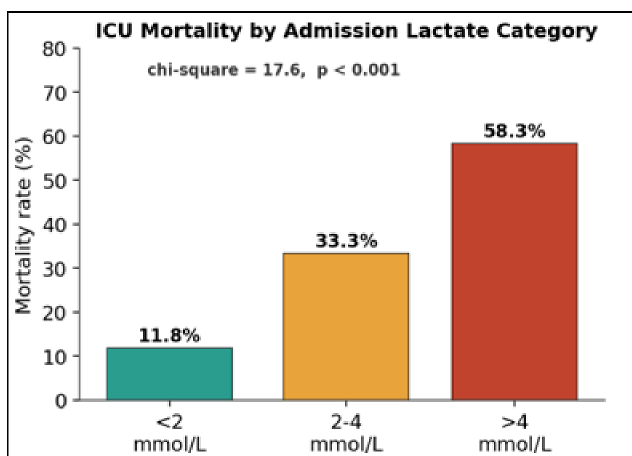

Figure 3: ICU mortality rate by admission lactate category (χ^2=17.6; p<0.001)

Mechanical Ventilation and ICU Stay

Patients in Group 2 required mechanical ventilation significantly more often than those in Group 1 (76.3% vs38.7%; **p<0.001**), and for a longer duration (7.4±3.2vs3.8±2.1days; **p<0.001**). Mean ICU stay was also longer in Group 2 (9.3 ± 4.1 vs 5.8 ± 2.7 days; **p < 0.001**), with a greater proportion staying beyond seven days (63.2% vs 29.0%; **p = 0.001**) (Table 5).

Table 5: Mechanical ventilation and ICU stay by group

Variable	Group 1	Group 2	p- value
Ventilator requirement (%)	38.7	76.3	<0.001
Ventilator days (mean ± SD)	3.8±2.1	7.4±3.2	<0.001
Mean ICU stay (days)	5.8±2.7	9.3±4.1	<0.001
ICU stay > 7 days (%)	29.0	63.2	0.001

Mortality and Serial Lactate Trends

Overall mortality was significantly higher in Group 2 than Group 1 (57.9% vs 16.1%; **p < 0.001**). Serial monitoring showed that survivors predominantly demonstrated a decreasing lactate trend (76.5%), whereas non-survivors more often showed persistent elevation (50.0%) or rising lactate (37.5%); this association was **statistically significant (p<0.001)** (Table 6, Figure 4). Lactate clearance was thus strongly associated with survival.

Table 6: Serial lactate trends and outcome.

Serial lactate trend	Survivors (%)	Non-survivors (%)	p- value
Decreasing trend	76.5	12.5	<0.001
Persistent elevation	17.6	50.0	
Rising lactate	5.9	37.5	

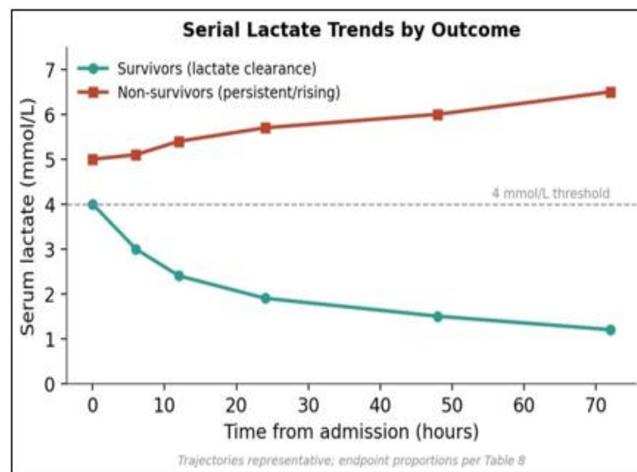

Figure 4: Serial serum lactate trends in survivors and non-survivors.

Correlation, ROC, and Regression Analyses

Pearson's analysis showed significant positive correlations between serum lactate and ICU stay (r=0.54), ventilator days(r=0.61), and mortality (r=0.67) (all **p<0.001**; Table7). ROC analysis demonstrated good predictive performance for mortality, with an area under the curve of 0.84 (95% CI0.76–0.91; **p<0.001**). The optimal cut-off of 3.8 mmol/L yielded a sensitivity of 81.3% and specificity of 78.4% (Figure 5). On multivariate logistic regression, lactate> 4mmol/L in dependently predicted mortality (adjusted OR=5.8; 95% CI 2.4–13.9; **p < 0.001**).

Table 7: Correlation between serum lactate and clinical outcomes

Variable	Correlation coefficient (r)	p- value
Serum lactate vs ICU stay	0.54	<0.001
Serum lactate vs ventilator days	0.61	<0.001
Serum lactate vs mortality	0.67	<0.001

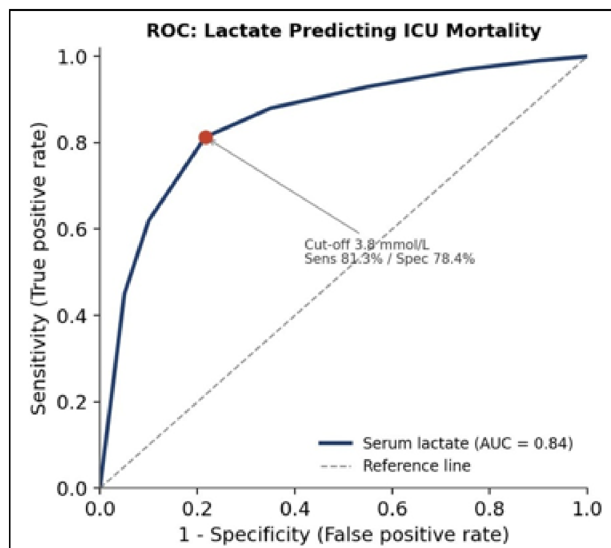

Figure 5: ROC curve for serum lactate predicting ICU mortality (AUC=0.84).

5. Discussion

This study demonstrated a strong association between elevated serum lactate and mortality among critically ill patients. Non- survivors had significantly higher admission lactate than survivors, and mortality increased progressively across lactate categories, indicating a dose-dependent relationship. [4, 8]

These findings are consistent with the work of Mikkelsen et al., who found that higher lactate levels predicted death in severe sepsis even after accounting for the presence of shock and organ dysfunction. [8]Khosravani et al. similarly demonstrated that hyperlactatemia independently predicts adverse outcomes in critically ill patients, [13] and Shapiroetal. And Nicholetal. Confirmed lactate as an independent mortality predictor across large cohorts. [11, 19]

The mortality of 57.9% among patients with lactate > 4mmol/L in the present study is broadly comparable to, though somewhat higher than, the 44–46% reported by Mikkelsen and Khosravani (Table 8). [8, 13] This difference may be attributable to a greater proportion of patients with septic shock and multiorgan dysfunction in our cohort, as well as differences in resource setting and case mix in a developing- country tertiary ICU.

Serial lactate monitoring proved particularly informative. Survivors demonstrated progressive lactate clearance, whereas non-survivors showed persistent or rising lactate. These observations align with Nguyen et al., Arnold et al., and Jones et al., who identified early lactate clearance as an important therapeutic target and predictor of survival, [7, 26, 27] and with Bakker et al., who linked serial lactate to the Development of multiple organ failure.[4] The interpretation of clearance must none the less account for the observation by Hernandez et al. and Suetrong and Walley that raised lactate can arise through mechanisms other than oxygen deprivation. [14, 28]

The ROC AUC of 0.84 indicates good discriminative performance and aligns with previously reported values of 0.78–0.87.[12, 19] The independent predictive value on regression (adjusted OR 5.8) reinforces its prognostic utility and is concordant with early goal-directed and lactate-guided resuscitation strategies.[18, 23]

Table 8: Comparison with previous studies

Study	Sample size	Mortality
Mikkelsen et al.	830	46%
Khosravani et al.	1247	44%
Shapiro et al.	1278	28%
Nicholetal.	7145	Significant increase
Present study	100	57.9% (lactate> 4mmol/L)

Strengths

- Prospective study design.
- Serial lactate monitoring in addition to admission values.
- Inclusion of a heterogeneous ICU population.
- Evaluation of both admission lactate and lactate trends.
- ROC and multivariate regression analyses performed.

Limitations

- Single-centre study.
- Relatively small sample size.
- Heterogeneous disease population.
- Lack of long-term follow-up.

6. Conclusion

Serum lactate is a valuable and readily available prognostic biomarker in critically ill patients. Elevated admission lactate and persistent hyperlactatemia are strongly associated with increased mortality, prolonged ICU stay, and greater ventilator requirement. Lactate > 4 mmol/L independently predicts mortality. Early measurement and serial monitoring of serum lactate should be incorporated into routine ICU assessment to facilitate risk stratification and guide therapeutic interventions.

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