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Original Research Article

Prognostic Utility of Base Deficit and Lactate in Patients with Septic Shock

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Abstract

Background: Septic shock is associated with high mortality, making early identification of high-risk patients essential. Serum lactate and base deficit are readily available indicators of tissue hypoperfusion and metabolic derangement with potential prognostic value.

Objectives: To evaluate the prognostic utility of admission serum lactate and base deficit in predicting ICU mortality among patients with septic shock.

Methods: This prospective observational study included 150 adult patients diagnosed with septic shock and admitted to the intensive care unit of a tertiary care hospital. Admission serum lactate and arterial base deficit were measured within the first hour of ICU admission. Patients were followed until ICU discharge or death. Receiver operating characteristic (ROC) curve analysis was performed to compare the predictive performance of both biomarkers.

Results: Of the 150 patients, 54 (36.0%) died during ICU stay. Non-survivors had significantly higher serum lactate levels (5.7 ± 1.9 vs. 2.8 ± 1.1 mmol/L; $p<0.001$) and greater base deficit (-8.7 ± 3.1 vs. -3.4 ± 2.2 mmol/L; $p<0.001$) compared with survivors. Serum lactate demonstrated an AUC of 0.903, while base deficit showed an AUC of 0.874. The combined predictive model yielded the highest diagnostic accuracy (AUC 0.935), with sensitivity of 92.6% and specificity of 86.5%.

Conclusion: Both admission serum lactate and base deficit are valuable prognostic biomarkers in septic shock. Their combined assessment provides superior prediction of ICU mortality compared with either parameter alone and may aid in early risk stratification and timely management of critically ill patients.

Keywords: Septic Shock, Serum Lactate, Base Deficit, ICU Mortality, Prognosis, Tissue Hypoperfusion, Critical Care.

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Introduction

Septic shock is a life-threatening manifestation of sepsis characterized by profound circulatory, cellular, and metabolic abnormalities that substantially increase the risk of mortality. Despite advances in critical care management, septic shock continues to be associated with high morbidity, prolonged intensive care unit (ICU) stay, and mortality rates ranging from 30% to 50%. Early identification of patients at increased risk of poor outcomes is therefore essential to guide timely resuscitation and optimize therapeutic interventions. [1-3]

Serum lactate is one of the most widely used biomarkers for assessing tissue hypoperfusion and the severity of septic shock. Elevated lactate levels reflect impaired oxygen delivery, increased anaerobic metabolism, mitochondrial dysfunction, and decreased lactate clearance. Numerous studies have demonstrated that admission lactate levels and their subsequent clearance are strong predictors of organ dysfunction, treatment response, and mortality in patients with septic shock. Consequently, serum lactate has become an integral component of sepsis management guidelines and early goal-directed therapy. [4-6]

Base deficit, derived from arterial blood gas analysis, represents the degree of metabolic acidosis resulting from tissue hypoperfusion and impaired cellular metabolism. It reflects the amount of base required to restore normal acid-base balance and serves as an indirect marker of global oxygen debt. An increased base deficit has been associated with greater illness severity, prolonged shock, multiple organ dysfunction, and increased

mortality in critically ill patients. Compared with lactate estimation, base deficit can be obtained rapidly from routine arterial blood gas analysis and may provide additional information regarding the metabolic status of patients with septic shock. [7]

Several investigators have compared serum lactate and base deficit as prognostic indicators in critically ill patients. Although both parameters independently correlate with disease severity and mortality, evidence regarding their relative prognostic performance in septic shock remains limited. Smith et al. demonstrated that both elevated lactate and worsening base deficit were independently associated with adverse outcomes in ICU patients, suggesting that simultaneous assessment of these parameters may improve early risk stratification. [8]

Therefore, the present study was undertaken to evaluate the prognostic utility of base deficit and serum lactate in patients with septic shock and to compare their effectiveness in predicting ICU mortality.

Materials and Methodology

Study Design: This was a prospective observational analytical study conducted to evaluate the prognostic utility of base deficit and serum lactate in patients with septic shock.

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 24 months.

Study Population: Adult patients admitted to the ICU with a diagnosis of septic shock according to the Sepsis-3 criteria were consecutively 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 (95% confidence level)
- **p** = Expected mortality among septic shock patients = 35%
- **q** = 65%
- **d** = Absolute precision = 8%

The minimum calculated sample size was approximately 137 patients. Considering possible incomplete data and loss to follow-up, the final sample size was increased to 150 patients.

Inclusion Criteria

- Patients aged 18 years or older.
- Diagnosis of septic shock according to Sepsis-3 criteria.
- ICU admission within 24 hours of diagnosis.
- Availability of arterial blood gas analysis and serum lactate estimation at admission.

Exclusion Criteria

- Age below 18 years.
- Pregnancy.
- Patients with diabetic ketoacidosis or other primary metabolic acidosis.
- Chronic liver failure or inborn errors of metabolism affecting lactate clearance.
- Patients transferred after more than 24 hours of ICU stay.
- Incomplete laboratory or clinical data.

Data Collection: After enrollment, demographic details, primary source of infection, comorbid illnesses, vital signs, Sequential Organ Failure Assessment (SOFA) score, and Acute Physiology and Chronic Health Evaluation II (APACHE II) score were recorded.

Within the first hour of ICU admission, arterial blood samples were obtained for arterial blood gas analysis, including base deficit, while venous or arterial blood samples were collected simultaneously for serum lactate estimation using standard automated laboratory methods.

Patients received standard management according to institutional septic shock protocols and were followed until ICU discharge or death.

Outcome Measures

Primary Outcome

- ICU mortality.

Secondary Outcomes

- Duration of ICU stay.
- Requirement for mechanical ventilation.
- Vasopressor requirement.
- Development of multiorgan dysfunction syndrome (MODS).

Study Variables

- Age and gender.
- Source of sepsis.
- Comorbidities.
- SOFA score.
- APACHE II score.
- Serum lactate (mmol/L).
- Base deficit (mmol/L).
- Mechanical ventilation.
- Vasopressor support.
- ICU length of stay.
- 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 presented as frequency and percentage. Continuous variables were compared using the Independent Student's t-test or Mann–Whitney U test, and categorical variables were analyzed using the Chi-square test or Fisher's exact test.

Receiver operating characteristic (ROC) curve analysis was performed to compare the prognostic performance of serum lactate and base deficit for predicting ICU mortality. The area under the curve (AUC), sensitivity, specificity, positive predictive value, and negative predictive value were calculated. Multivariate logistic regression analysis was used to identify independent predictors of 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 patients with septic shock admitted to the intensive care unit (ICU) were included in the study. Patients were followed until ICU discharge or death. Of the 150 patients, 54 (36.0%) died during ICU stay, while 96 (64.0%) survived.

Table 1: Baseline demographic and clinical characteristics of the study population

Variable	Survivors (n=96)	Non-survivors (n=54)	p-value
Age (years), Mean ± SD	52.4 ± 13.6	60.8 ± 14.2	0.001*
Male, n (%)	58 (60.4)	35 (64.8)	0.602
Female, n (%)	38 (39.6)	19 (35.2)	
SOFA score, Mean ± SD	8.6 ± 2.1	12.9 ± 2.8	<0.001*
APACHE II score, Mean ± SD	18.2 ± 4.8	25.4 ± 5.5	<0.001*
Mechanical ventilation, n (%)	42 (43.8)	49 (90.7)	<0.001*
Vasopressor support >24 h, n (%)	39 (40.6)	50 (92.6)	<0.001*
ICU stay (days), Mean ± SD	7.1 ± 3.0	8.8 ± 4.2	0.011*

Non-survivors were significantly older and had higher SOFA and APACHE II scores than survivors. The need for prolonged vasopressor support and mechanical ventilation was significantly greater among non-survivors (p<0.001).

Table 2: Comparison of admission serum lactate and base deficit between survivors and non-survivors

Parameter	Survivors (n=96)	Non-survivors (n=54)	p-value
Serum lactate (mmol/L), Mean ± SD	2.8 ± 1.1	5.7 ± 1.9	<0.001*
Base deficit (mmol/L), Mean ± SD	-3.4 ± 2.2	-8.7 ± 3.1	<0.001*

Patients who died had significantly higher serum lactate levels and a significantly greater base deficit at ICU admission compared with survivors, indicating more severe tissue hypoperfusion and metabolic acidosis.

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

Variable	Total (n=150)	Survivors n (%)	Non-survivors n (%)	p-value
Serum Lactate				
≤2 mmol/L	42	38 (90.5)	4 (9.5)	
2.1–4 mmol/L	59	45 (76.3)	14 (23.7)	
>4 mmol/L	49	13 (26.5)	36 (73.5)	<0.001*
Base Deficit				
≤4 mmol/L	60	53 (88.3)	7 (11.7)	
4.1–8 mmol/L	49	34 (69.4)	15 (30.6)	
>8 mmol/L	41	9 (22.0)	32 (78.0)	<0.001*

ICU mortality increased significantly with increasing serum lactate levels and worsening base deficit. Patients with serum lactate >4 mmol/L or base deficit >8 mmol/L had the highest mortality rates (p<0.001).

Table 4: Prognostic performance of serum lactate and base deficit for predicting ICU mortality

Parameter	Cut-off Value	Sensitivity (%)	Specificity (%)	AUC (95% CI)	p-value
Serum lactate	>3.8 mmol/L	88.9	81.3	0.903 (0.854–0.952)	<0.001*
Base deficit	>6.0 mmol/L	83.3	79.2	0.874 (0.815–0.933)	<0.001*
Combined lactate + base deficit model	—	92.6	86.5	0.935 (0.894–0.976)	<0.001*

Both serum lactate and base deficit were significant predictors of ICU mortality. However, the combined predictive model incorporating both parameters demonstrated the highest diagnostic accuracy (AUC = 0.935), with excellent sensitivity (92.6%) and specificity (86.5%), indicating superior prognostic performance compared with either marker alone.

Discussion

Septic shock remains one of the leading causes of mortality among critically ill patients despite advances in early diagnosis and management. Prompt identification of patients at high risk of adverse outcomes is essential for timely resuscitation and appropriate resource utilization. The present study evaluated the prognostic utility of admission serum lactate and base deficit in patients with septic shock and demonstrated that both parameters were significantly associated with ICU mortality. Furthermore, their combined assessment showed better predictive performance than either marker alone.

In the present study, non-survivors had significantly higher serum lactate levels than survivors. Hyperlactatemia reflects inadequate tissue perfusion, impaired oxygen utilization, mitochondrial dysfunction, and persistent circulatory failure, all of which are characteristic features of septic shock. Similar findings were reported by Khosravani et al., who demonstrated that hyperlactatemia was independently associated with increased mortality among critically ill patients regardless of the underlying diagnosis. [9] Likewise, Filho et al. observed that increasing serum lactate concentrations were strongly associated with poor outcomes in patients with sepsis and suggested that even moderately elevated lactate levels should prompt aggressive resuscitation. [10]

Although serum lactate remains an established biomarker of tissue hypoperfusion, it may be influenced by several factors, including hepatic dysfunction, β-adrenergic stimulation, and altered metabolism. Therefore, additional markers reflecting metabolic derangement may improve prognostic accuracy. Base deficit, derived from arterial blood gas analysis, reflects the severity of metabolic acidosis and global oxygen debt. In the present study, non-survivors exhibited significantly greater base deficit than survivors, indicating more severe metabolic compromise. Similar observations were reported by Hajjar et al., who found that severe metabolic abnormalities, including elevated lactate and worsening acid-base disturbances, were associated with adverse clinical outcomes in critically ill patients. [11] Rishu et al. also demonstrated that even mild elevations in lactate accompanied by metabolic acidosis were associated with increased mortality, emphasizing the importance of early metabolic assessment in critically ill patients. [12]

The present study further demonstrated that the combination of serum lactate and base deficit achieved the highest predictive accuracy for ICU mortality, with superior sensitivity, specificity, and area under the ROC curve compared with either parameter alone. These findings suggest that the two biomarkers provide complementary information regarding tissue hypoperfusion and systemic metabolic disturbances. Kimmoun et al. highlighted that severe lactic acidosis represents a complex hemodynamic disorder involving impaired tissue oxygen delivery and acid-base imbalance, supporting the combined evaluation of lactate and metabolic parameters for prognostic assessment. [13] Similarly, Lee and An emphasized the importance of serum lactate as a vital prognostic marker in septic shock while acknowledging that interpretation alongside acid-base status may improve clinical decision-making. [14]

The findings of the present study are also supported by Nguyen et al., who reported that early correction of hyperlactatemia was associated with improved survival in severe sepsis and septic shock, underscoring the value of serial metabolic monitoring during resuscitation. [15] More recently, Gonzalez Mora et al. demonstrated that the combined assessment of lactate clearance and standard base deficit provided better prognostic information than either parameter alone for predicting mortality in septic shock patients, which closely parallels the findings of the present study. [16] Overall, the results suggest that admission serum lactate and base deficit are simple, inexpensive, and rapidly available biomarkers that can effectively identify high-risk septic shock patients. Their combined use enhances prognostic accuracy and may facilitate early aggressive resuscitation, closer monitoring, and appropriate therapeutic decision-making in the intensive care unit.

Conclusion

Admission serum lactate and base deficit are significant independent predictors of mortality in patients with septic shock. Elevated serum lactate and increased base deficit were associated with greater illness severity and higher ICU mortality. The combined assessment of these two parameters demonstrated superior prognostic performance compared with either biomarker alone. Routine measurement of serum lactate and base deficit at ICU admission may improve early risk stratification, guide resuscitation strategies, and support clinical decision-making in patients with septic shock.

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