Original Article

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Determinants of Lactate Clearance and Mortality in Adult Patients with Severe Trauma

Udomsak Tangchaisuriya, M.D.[1], Boriboon Chenthanakij, M.D.[1], Narain Chotirosniramit, M.D.[2], Borwon Wittayachamnankul, M.D., Ph.D.[1], Krongkarn Sutham, M.D.[1]

[1]Department of Emergency Medicine, Faculty of Medicine, Chiang Mai University, Muang, Chiang Mai 50200, Thailand.

[2]Department of Surgery, Faculty of Medicine, Chiang Mai University, Muang, Chiang Mai 50200, Thailand.

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Abstract:

Objective: To evaluate the association between initial blood lactate levels, blood lactate clearance (BLC) at 6 hours, and in-hospital mortality among patients with severe trauma.

Material and Methods: This prospective observational study included 100 adult patients with severe trauma (Revised Trauma Score <6) admitted to a Level-I Trauma Center. Initial and 6-hour venous lactate levels were measured, and BLC was calculated. The endpoint was in-hospital mortality. Logistic regression was used to assess associations with in-hospital mortality and BLC.

Results: The in-hospital mortality rate was 27%. Non-survivors had significantly higher initial lactate levels than survivors (14.2±6.4 vs. 5.7±2.2 mmol/L; p-value<0.01). In multivariate analysis, only initial lactate remained independently associated with mortality (adjusted OR 3.98; 95% CI: 1.30–9.71; p-value<0.001). Patients with low BLC (<10%) had significantly higher mortality than those with high BLC (40.0% vs. 7.9%; p-value=0.030), although no clinical variable independently predicted BLC.

Conclusion: Initial blood lactate is a strong independent predictor of mortality in severe trauma. While BLC ≥10% is associated with improved survival, its determinants remain multifactorial. Serial lactate monitoring should be considered an integral part of early trauma care, especially in resource-limited settings.

Keywords: severe traumatic patients, polytrauma, blood lactate, blood lactate clearance, mortality

Contact: Krongkarn Sutham, M.D.
Department of Emergency Medicine, Faculty of Medicine, Chiang Mai University
E-mail: krongkarn.s@cmu.ac.th

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Introduction

Trauma remains a major cause of death and disability worldwide, particularly among young adults. The increasing incidence of traumatic injuries, most notably from motorcycle accidents, continues to strain healthcare systems. Timely and accurate assessment of trauma severity is crucial to guiding early management and improving survival outcomes. However, in some cases, the patients could be inflicted with cell injuries, possibly leading to occult hypoperfusion. Immediate assessment is only possible once the patients' cell injuries have developed to a higher level with worsening symptoms[1]. As a result, assessment using biomarkers to indicate cell injury serves as a guideline for clinical practice and follow-up, permitting a more efficient evaluation. Several studies have revealed that blood lactate level is an important biomarker that assists in assessing severity and works as a predictor of mortality rate in severe traumatic patients with septicemia and those with injuries[1–4].

In recent years, blood lactate levels have emerged as a valuable biomarker for detecting tissue hypoxia and guiding resuscitation. Elevated lactate levels result from anaerobic metabolism during inadequate tissue perfusion and have been strongly associated with worse outcomes in trauma, sepsis, and critical illness. A normal lactate level is typically below 2.2 mmol/L; levels above 4 mmol/L are often indicative of severe hypoperfusion and correlate with increased mortality[2,3,5]. In elderly patients, even moderately elevated levels (>2.5 mmol/L) can signify a heightened risk[6]. Importantly, blood lactate clearance (BLC), the rate at which lactate levels decline over time—has been proposed as a dynamic indicator of treatment response and a predictor of outcome. Studies have shown that higher lactate clearance, especially within the first 6–12 hours of resuscitation, is associated with improved survival in both sepsis and trauma patients. Conversely, persistently elevated lactate levels reflect ongoing tissue hypoperfusion and cellular damage.

Despite these findings, few studies have explored blood lactate levels and BLC in the context of trauma patients in Southeast Asia. Cultural, environmental, and healthcare system differences may influence prehospital time, resuscitation approaches, and outcomes. This study, therefore, aimed to evaluate the association between blood lactate levels, BLC at 6 hours, and in-hospital mortality, as well as to identify the clinical factors associated with elevated BLC, aiming to improve trauma assessment and guide early interventions in Southeast Asian settings.

Material and Methods

Study design and population

This prospective observational study was conducted at a tertiary-level trauma center. We enrolled 100 adult patients (aged ≥18 years) with severe trauma who presented to the Emergency Department (ED) at Maharaj Nakhon Chiang Mai Hospital, between October 1, 2015 and September 30, 2016, within 24 hours of injury. Severe trauma was defined as having a Revised Trauma Score (RTS) <6 upon arrival. Patients with pre-existing conditions that could affect lactate metabolism (e.g., chronic liver disease, chronic kidney disease, diabetes, cancer, and cardiopulmonary disease), as well as those receiving medications known to alter lactate levels (e.g., metformin, nucleoside reverse transcriptase inhibitors, nitroprusside, and isoniazid), were excluded. Pregnant patients, those with burn injuries, do-not-resuscitate orders, or those transferred from other hospitals without pre-transfer lactate measurements were also excluded. The Institutional Review Board (IRB) of the Faculty of Medicine, Chiang Mai University, approved the study protocol and formally waived the requirement for written informed consent (study code: EME-2558-03363).

Sample size calculation

The sample size was calculated based on previously published data reporting an in-hospital mortality rate of approximately 4.9% among trauma patients (95% CI: 4.5%–5.2%)[7]. Using Cochran's formula for estimating proportions, we assumed a population proportion (p) of 0.05, with a confidence level of 95% (Z=1.96) and a margin of error (d) of 0.05. This resulted in a minimum required sample size of 73 patients (in the Appendix).

Data collection

Baseline demographic and clinical data were collected upon admission, including age, gender, mechanism and location of injury, prehospital time, initial vital signs (systolic blood pressure (BP), heart rate, respiratory rate (RR), temperature, oxygen saturation, Glasgow Coma Scale (GCS)), and RTS. The RTS was calculated using the parameters of GCS, SBP, and RR[8]. Details of resuscitative management, including fluid and blood product administration, use of vasopressors, and emergency surgical intervention, were recorded.

Lactate measurement and BLC

Venous blood lactate levels were measured at 2 timepoints: within one hour of arrival at the ED (defined as BL0), and repeated at 6 hours post-admission (defined as BL6). A 2-mL venous blood sample was collected into sodium chloride-treated ampules to prevent coagulation and immediately sent to the central laboratory. Lactate levels were determined using a colorimetric assay system (Roche COBAS® platform).

BLC is a percentage of change in blood lactate level within a period compared to the initial level. The formula used in the calculation of this study is: BLC (%) = (Blood Lactate at 0 h – Blood Lactate at 6 h)/Blood Lactate at 0 h × 100.

Outcome measures

The primary outcome was in-hospital mortality. Secondary outcomes included initial and BL0, and BLC at 6 hours, and their association with survival. Additionally, we examined factors associated with high BLC to identify predictors of lactate normalization in severe trauma patients.

Data analysis

Descriptive statistics were used to summarize patient characteristics. Categorical variables were compared using the Chi-square test or Fisher's exact test, and continuous variables were analyzed using independent t-tests or Mann–Whitney U tests, depending on data distribution. Univariate logistic regression was used to assess associations between the clinical variables and both in-hospital mortality and BLC. Variables with p-value<0.05 in univariate analysis were included in multivariate logistic regression to identify independent predictors. Adjusted odds ratios (OR) and 95% confidence intervals (CI) were reported. A p-value<0.05 was considered statistically significant. Statistical analyses were performed using SPSS® software version 22.0.

Results

A total of 100 patients were included in the study, of whom 73 survived and 27 died, resulting in an in-hospital mortality rate of 27%. Most patients were male (84%) and aged between 18 and 30 years. Although non-survivors were older on average than survivors (46.7±18.2 vs. 39.8±17.6 years), the difference was not statistically significant (p-value=0.950). Most patients (97%) sustained blunt trauma, and motorcycle accidents were the leading mechanism of injury (80%), particularly among non-survivors (92.6% vs. 75.4% in non-survivors and survivors groups). No deaths were observed among patients with penetrating trauma. The most frequently injured region was the head and neck, with many patients sustaining injuries to multiple body regions.

Regarding prehospital time, most patients in both groups arrived within 11–30 minutes after injury. Non-survivors had a longer average prehospital time from the onset of injury to hospital arrival compared to survivors (33.7±23.7 min vs. 25.3±19.5 min), although the difference was not statistically significant (p-value=0.362).

Initial vital signs on arrival showed significant differences between the groups. Non-survivors had a significantly lower average systolic blood pressure (80±30 mmHg vs. 120±30 mmHg; p-value<0.001), higher respiratory rate (24±7 bpm vs. 20±4 bpm; p-value=0.020), lower GCS score (5 (4) vs. 10 (9); p-value<0.001), and lower oxygen saturation (85±10% vs. 96±8%; p-value=0.004). No significant differences were observed in pulse rate or body temperature. The RTS was significantly lower in non-survivors (3.1±1.2) than in survivors (5.1±1.0; p-value<0.001).

In terms of emergency management and resuscitation, non-survivors received a higher volume of intravenous crystalloid fluids resuscitation (2,909±1,395 ml vs. 2,053±1,146 ml; p-value=0.040), while colloid administration was similar between the groups. Packed red cell transfusion volume was significantly higher in non-survivors (median (IQR)=4 (3) units vs. 2 (2) units; p-value<0.001), whereas platelet and fresh frozen plasma (FFP) transfusions did not differ significantly. Vasopressor use was markedly higher among non-survivors (44.4%) compared to survivors (2.1%; p-value<0.001). Additionally, a higher proportion of survivors underwent emergency operations (61.1%), such as emergency thoracotomy and emergency laparotomy, compared to non-survivors (37.0%), and this difference was statistically significant, as shown in Table 1.

Patients in the non-survivor group had significantly higher blood lactate levels compared to those who survived, both at initial and at 6 hours. The mean initial lactate level among non-survivors was 14.2±6.4 mmol/L (95% CI: 11.7–16.7), higher than the mean level in survivors, which was 5.7±2.2 mmol/L (95% CI: 5.2–6.2), with a statistically significant difference (p-value<0.01). Similarly, although the average lactate levels decreased over time in both groups, the 6-hour lactate level remained significantly higher in non-survivors, with a mean of 8.4±4.3 mmol/L (95% CI: 6.2–10.5), compared to 4.6±3.1 mmol/L (95% CI: 3.9–5.3) in survivors (p-value<0.01) (Figure 1A).

Among the 88 patients who survived to the 6-hour timepoint and had repeated blood lactate measurements, 78.41% had an elevated BLC, indicating a reduction in lactate levels over time, while 21.59% (n=19) showed increasing lactate levels after 6 hours of treatment. Although the mean percentage of BLC appeared higher in non-survivors than in survivors (27.65±9.60% vs. 13.86±51.54%), this difference was not statistically significant (p-value=0.296). The comparison of BLC between survivors and non-survivors is presented in Figure 1B.

Among the 100 patients with available initial blood lactate measurements, 83 patients (83%) presented with lactate levels ≥4.0 mmol/L. This group had a significantly higher mortality rate of 32.5%, whereas no deaths occurred among patients with initial lactate levels <4.0 mmol/L (n=17). The difference in mortality between the 2 groups was statistically significant (p-value=0.020) (Supplementary Table 1).

At the 6-hour follow-up, blood lactate data were available for 88 patients. Of these, 38 patients (43.2%) had lactate levels that remained ≥4.0 mmol/L. This subgroup exhibited a markedly elevated mortality rate of 39.5% (n=15), in contrast to a 0% mortality rate among patients whose 6-hour lactate levels were <4.0 mmol/L (n=50). The association between 6-hour lactate level and mortality was statistically significant (p-value=0.005) (Supplementary Table 2).

Table 1 Basic characteristics of the patients studied

Patient data (N=100)		Survivors (N=73)	Non-survivors (N=27)	p-value
Gender	Male	60 (82.2%)	24 (88.9%)	0.320
Age (years)	Mean±S.D.	39.8±17.6	46.7±18.2	0.950
	Range	35.7–43.9	39.6–54.0	
Type of injury	Blunt	70 (95.9%)	27 (100%)	0.050*
	Penetrating	3 (4.1%)	0 (0%)	
Cause of injury	Motorcycle	55 (75.4%)	25 (92.6%)	0.010*
	Car	15 (20.7%)	2 (7.4)	0.460
	Stabbed/shot	2 (2.7%)	0 (0%)	0.100
	Falling	1 (1.4%)	0 (0%)	0.110
Injured parts	Head/Neck	60 (82.2%)	25 (92.6%)	0.160
	Chest	30 (41.1%)	8 (29.6%)	0.210
	Abdomen	24 (32.9%)	11 (40.7%)	0.310
	Pelvis	3 (4.1%)	4 (14.8%)	0.080
	Extremities	27 (37.1%)	11 (40.7%)	0.450
Prehospital time (min)	Mean±S.D.	25.3±19.5	33.7±23.7	0.362
	≤10 min	4 (5.5%)	3 (11.1%)	0.280
	11–30 min	38 (52.1%)	21 (77.8%)	0.020*
	31–60 min	28 (38.3%)	3 (11.1%)	0.010*
	>60 min	3 (4.1%)	0 (0%)	0.380
Initial vital sign:				
SBP (mmHg)	Mean±S.D.	120±30	80±30	<0.001*
PR (bpm)	Mean±S.D.	105±23	104±28	0.780
RR (breaths/min)	Mean±S.D.	20±4	24±7	0.020*
Temperature (°C)	Mean±S.D.	37.2±0.8	36.8±0.5	0.180
Oxygen saturation (%)	Mean±S.D.	96±8	85±10	0.004*
GCS	Median (IQR)	10 (9)	5 (4)	<0.001*
RTS	Mean±S.D.	5.1±1.0	3.1±1.2	<0.001*
Amount of fluid resuscitation: (ml)				
Crystalloid	Mean±S.D.	2,053±1,146	2,909±1,395	0.04*
Colloid	Mean±S.D.	1,017±655	1,320±1,006	0.56
Blood transfusion: (unit)				
Packed red cells	Median (IQR)	2 (2)	4 (3)	<0.001*
Platelets	Median (IQR)	1 (2)	1 (1)	0.860
FFP	Median (IQR)	1 (2)	2 (2)	0.080
Received vasopressor	Yes	2 (2.1%)	12 (44.4%)	<0.001*
Received emergency operation	Yes	45 (61.6%)	10 (37.0%)	0.02*

*with statistical significanc, SBP=systolic blood pressure, PR=pulse rate, RR=respiratory rate, GCS=Glasgow Coma Scale, RTS=Revised Trauma Score, FFP=fresh frozen plasma, S.D.=standard deviation, IQR=interquartile range

BLC at 6 hours was categorized into 2 groups based on the percentage change from the initial lactate level: low BLC (<10%) and high BLC (≥10%). This cutoff was selected based on sensitivity analysis, as detailed in the Appendix Section. Patients with low BLC had a significantly higher mortality rate (40.0%) compared to those with high BLC, who had a mortality rate of approximately 7.9%. A statistically significant difference in mortality across lactate levels was observed (p-value=0.030). (Table 2).

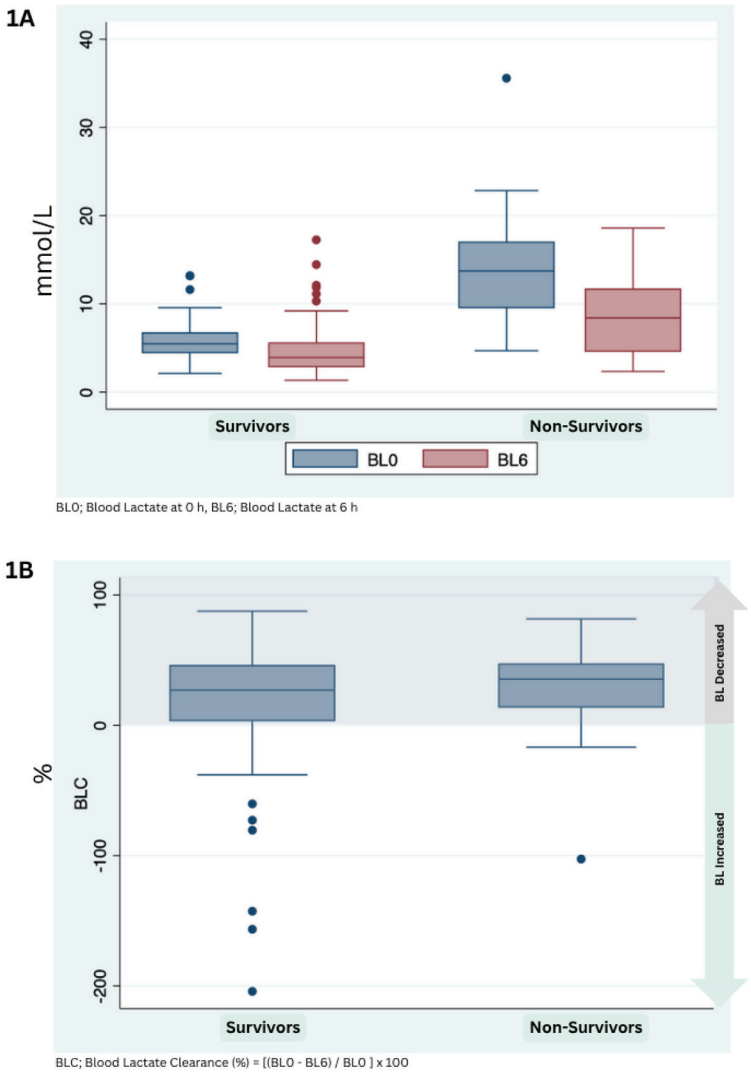

Figure 1 Blood lactate level at 0 and 6 hours and blood lactate clearance in the survivor and non-survivors groups (1A) comparison of initial and 6-hour blood lactate levels (1B) blood lactate clearance at 6 hours

Table 2 Blood lactate clearance at 6 hours and mortality

Blood lactate clearance at 6 hour (%)	Total (n)	Survivors n (%)	Non-survivors n (%)	Mortality rate (%)
<10	25	15 (20.6)	10 (66.7)	40.0
≥10	63	58 (79.4)	5 (33.4)	7.9
Total	88	73 (100.0)	15 (100.0)	17.0

*p-value=0.030 *(Chi-square test)*

In the univariate analysis, age, GCS, RTS, initial blood lactate level, and 6-hour blood lactate level were significantly associated with in-hospital mortality. However, in the multivariate logistic regression model, only the initial blood lactate level remained independently associated with mortality, with an adjusted odds ratio of 3.98 (95% CI: 1.30–9.71; p-value<0.001), as shown in Table 3.

The association of clinical variables with high BLC was analyzed among 88 patients. In the univariate analysis, both prehospital time and GCS score were significantly associated with high BLC. However, in the multivariate logistic regression model, no clinical variable demonstrated an independent association with BLC. The adjusted odds ratios for prehospital time and GCS were 1.03 (95%CI: 1.00–1.05; p-value=0.090) and 1.12 (95% CI: 0.98–1.29; p-value=0.091), respectively (Table 4).

Discussion

This prospective study demonstrates the prognostic utility of initial blood lactate levels and 6-hour blood lactate clearance (BLC) in patients with severe trauma. We found that elevated initial lactate levels were strongly associated with in-hospital mortality, with an adjusted odds ratio of 3.98 (95% CI: 1.30–9.71; p-value<0.001). This supports the

Table 3 Association of clinical variables with mortality: univariate and multivariate analysis results

Variables	Unadjusted OR	95% CI	p-value	Adjusted OR	95% CI	p-value
Age	1.029	1.01–1.05	0.020*	0.996	0.93–1.07	0.913
Prehospital Time	1.000	0.98–1.02	0.942	—	—	—
SBP	1.002	0.998–1.007	0.450	—	—	—
GCS	0.78	0.70–0.89	<0.001*	0.97	0.87–1.09	0.610
RTS	0.61	0.46–0.81	<0.001*	0.87	0.71–1.06	0.099
BL0	3.62	1.93–6.83	<0.001*	3.98	1.30–9.71	<0.001*
BL6	1.24	1.08–1.38	0.002*	1.23	0.75–2.02	0.408
BLC	1.013	0.998–1.029	0.111	—	—	—

*with statistical significance, SBP=systolic blood pressure, GCS=glasgow coma score, RTS=revised trauma score, BL0=blood lactate level at 0 hours, BL6=blood lactate level at 6 hours, BLC=blood lactate clearance at 6 hours, 95% CI=95% confidence interval, OR=odd ratio

Table 4 Association of clinical variables with lactate clearance: univariate and multivariate analysis results (N=88)

Variables	Unadjusted OR	95% CI	p-value	Adjusted OR	95% CI	p-value
Age	0.98	0.96 – 1.01	0.235	–	–	–
Prehospital Time	1.02	1.00 – 1.05	0.018*	1.03	1.00 – 1.05	0.090
SBP	0.99	0.97 – 1.01	0.270	–	–	–
GCS	1.04	0.93 – 1.17	0.046*	1.12	0.98 – 1.29	0.091
RTS	0.81	0.36 – 1.83	0.613	–	–	–
Crystalloid	1.00	0.99 – 1.00	0.208	–	–	–

*with statistical significance, SBP=systolic blood pressure, GCS=glasgow coma score, RTS=revised trauma score, BL0=blood lactate level at 0 hours, BL6=blood lactate level at 6 hours, BLC=blood lactate clearance at 6 hours, 95% CI=95% confidence interval, OR=odd ratio

role of initial lactate as a robust early biomarker reflecting systemic hypoperfusion and metabolic stress. Our findings align with a recent systematic review in adult trauma, which affirmed the association between elevated lactate and mortality risk[2]. Early lactate values, such as those measured at 2 hours, have also been associated with poor outcomes in trauma and sepsis[9]. However, a multi-center trauma registry study found that while initial lactate was related to ICU admission and need for mechanical ventilation, it was not an independent predictor of in-hospital mortality after adjustment (adjusted OR 1.7; p-value=0.06)[10]. These findings suggest that early identification of patients with markedly elevated lactate upon ED arrival could support timely escalation of care, including aggressive resuscitation, damage control surgery, and ICU admission planning.

We also examined the prognostic value of lactate clearance over time. Despite previous studies reporting that high BLC is associated with improved outcomes, our multivariate logistic regression analysis did not identify BLC or other clinical variables, such as age, SBP, GCS, RTS, or prehospital time, as independent predictors of mortality. This is in line with the findings by Dekker et al., who found no additional predictive value of BLC over a single initial lactate measurement in trauma patients[11].

Nevertheless, other studies have demonstrated that poor BLC strongly predicts adverse outcomes. For example, Dezman et al. reported a 24-hour mortality rate significantly higher in patients who failed to reduce lactate to <2 mmol/L, with non-clearance being one of the strongest predictors of death (OR 7.4)[12]. Odom et al. also found that in trauma patients with initially elevated lactate (≥4.0 mmol/L), lower clearance at 6 hours independently predicted mortality[5]. While our multivariate findings did not highlight these, our stratified analysis of BLC using a 10% cutoff offers important insights.

We categorized BLC into low BLC (<10%) and high BLC (≥10%) groups based on prior evidence, including sepsis trials that demonstrated non-inferiority of lactate-guided resuscitation compared to central venous oxygen saturation ($ScvO_2$)-guided therapy[4,5]. We found that adult trauma patients with low BLC had significantly higher mortality than those with high BLC (40.0% vs. 7.9%; p-value=0.030), suggesting that failure to clear lactate within 6 hours may indicate a higher risk of death. This is consistent with both the trauma and sepsis literature, where early lactate clearance ≥10% is associated with improved survival[13–15].

The initial lactate levels in our study ranged from 2.41 to 35.58 mmol/L, with significantly higher values among non-survivors (14.2±6.4 vs. 5.7±2.2 mmol/L; p-value<0.01). These levels are higher than those reported in some previous studies[3,8,13,16]. This reflects the high burden of severe trauma in our cohort, which included a large proportion of Southeast Asian patients injured in motorcycle accidents.

Timing may also influence the prognostic utility of BLC. While several studies have demonstrated better survival with BLC assessed at 6, 12, 24, and 48 hours, others such as Regnier et al. found no significant association at 2 hours[16]. Our findings thus support the 6-hour window as a meaningful timepoint for assessing early physiological response in trauma.

Age-related differences in lactate clearance have been described previously, with younger patients showing more effective clearance due to a greater physiological reserve[16–18]. In our subgroup analysis, patients aged ≥70 years had a higher, though not statistically significant, mortality rate compared to younger patients (37.5% vs. 26.1%; p-value=0.48).

Additionally, we further explored factors associated with achieving high BLC (≥10%). Univariate analysis indicated that shorter prehospital time and higher GCS were associated with improved clearance, but neither remained significant in multivariate analysis (adjusted ORs:

prehospital time 1.03 (1.00–1.05); GCS 1.12 (0.98–1.29). This underscores the complexity of lactate metabolism, likely involving multiple physiological and treatment-related factors, and is consistent with other studies reporting no single clinical variable that independently predicts lactate clearance[16,19].

Current trauma management emphasizes rapid, structured care based on the ATLS principles (XBCDE), along with strategies like damage control resuscitation, permissive hypotension, and staged surgery to address life-threatening injuries. Physiologic markers such as lactate are central to early risk stratification and monitoring resuscitation response[20,21]. Our findings support this framework, highlighting the value of lactate measurements in identifying severely injured patients at a higher risk of mortality.

From a clinical perspective, these findings are highly relevant. The Committee on Trauma recommends resuscitation strategies—including damage control surgery, permissive hypotension, and hemostatic resuscitation—guided by serial lactate monitoring, targeting a reduction to ≤4 mmol/L[20]. Our results support incorporating lactate and BLC monitoring into trauma protocols, particularly in resource-limited settings such as Southeast Asia, where access to invasive monitoring is constrained. Serial lactate assessments could serve as a rapid, practical indicator of treatment response and help identify patients at increased risk for deterioration.

Limitations

This study has several limitations. First, blood lactate levels could not be measured at the prehospital scene, as our hospital relies on centralized laboratory analyzers. This process can take up to an hour, limiting its utility in guiding rapid resuscitation. The use of point-of-care lactate testing could enhance timeliness and clinical applicability in emergency settings and should be considered in future implementations. Second, the study included only adult patients with severe trauma. Broader inclusion of pediatric and geriatric populations in future studies is needed to improve generalizability and to investigate age-related differences in lactate metabolism and clearance. Third, although we assessed BLC at the 6-hour timepoint, which was commonly used in most previous studies, additional serial measurements (e.g., at 12, 24, or 48 hours) may provide more detailed insights into lactate kinetics and their association with clinical outcomes. Furthermore, the lack of a comparator or intervention group limits the ability to draw causal conclusions. Fourth, the observed in-hospital mortality rate in our cohort was notably higher (27%) than the 5% rate used in the initial sample size calculation. This discrepancy suggests that while our study had sufficient power to estimate proportions, a larger sample may be necessary to improve the precision and power of future multivariable analyses, especially if the aim is to identify independent predictors of lactate clearance or mortality more robustly. Fifth, the use of RTS as the trauma severity score instead of more widely validated systems such as TRISS or ISS, due to the study's aim to use a simpler and more objective assessment[22]. Sixth, this study focused primarily on lactate as a resuscitation marker. Other routine parameters of laboratory or radiologic investigations, including blood glucose, hemoglobin (Hb) concentration, renal function, acid-base status, bedside ultrasound or imaging, were not determined in our study. Some parameters, like blood glucose or Hb, in particular, may serve as a useful and rapidly obtainable adjunct in settings where lactate testing is delayed. Future studies should explore the combined predictive value of these simple bedside tests alongside lactate dynamics to inform comprehensive trauma care. Seventh, serum lactate levels are known to influence surgical decision-making

in polytrauma, particularly the choice between early total care and damage control strategies. This study did not distinguish between these operative approaches. Future studies incorporating timing, extent, and type of surgical intervention would be valuable to better understand how lactate-guided strategies influence outcomes. Lastly, this study did not assess the impact of potential second-hit phenomena, such as surgical procedures or secondary insults, on lactate levels or clearance. Future research should investigate how such exposures modulate the physiological response in polytrauma patients, especially in relation to metabolic biomarkers like lactate.

Conclusion

In summary, initial blood lactate levels are a strong independent predictor of in-hospital mortality in severe trauma patients. Although no clinical predictors of BLC were identified, achieving ≥10% clearance within 6 hours was significantly associated with improved outcomes. Serial lactate monitoring may thus play an important role in early trauma care decision-making. But the factors influencing BLC need further study.

Author contributions

UT contributed to the conceptualization, methodology, investigation, data curation, writing – original draft, writing – review and editing, and visualization.

BC contributed to the conceptualization, methodology, formal analysis, investigation, data curation, writing – original draft, writing – review, and editing.

NC contributed to the conceptualization, data curation, writing – the original draft, writing – review, and editing.

BW writing – original draft, writing – review and editing.

KS contributed to the conceptualization, methodology, formal analysis, investigation, resources, writing – original draft, writing – review and editing, supervision, and project administration.

This manuscript has been read and finally approved by all the authors.

Patient and public involvement

Patient and Public Involvement (PPI) was integral to the design, execution, and dissemination of this study. Recognizing the importance of incorporating patient perspectives and ensuring the relevance of our research, we engaged with patients and members of the public at multiple stages of the research process.

Ethics approval

The Research Ethics Committee of the Faculty of Medicine, Chiang Mai University, approved the research protocol (STUDY CODE: EME-2558-03363).

Consent for publication

Written informed consent was obtained from the patients for publication of this case report and any accompanying images. A copy of the consent is available for review upon request.

Data availability

The datasets are available from the corresponding author upon reasonable request.

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Conflict of interest

None.

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Appendix

Sample size estimation calculation

The sample size was calculated using Cochran's formula for estimating proportions in a population with a specified level of precision. The formula is:

$$N = \frac{p\,(1-p)\,z^2}{d^2}$$

Where:

- N = Required sample size
- Z = Z-value for the 95% CI
- p = Estimated proportion of the population (0.05) (7)
- d = Acceptable margin of error (0.05)

Substituting the values:

$$N = \frac{0.05\,(1-0.05)\,1.96^2}{1.96^2} = 73$$

This resulted in a minimum required sample size of 73 patients.

Analysis and Results of Sensitivity Analysis Using Different Lactate Clearance Cutoffs

Based on our sensitivity analysis, a 10% lactate clearance cutoff provided the strongest discrimination for mortality risk compared to those with clearance ≥10%. This cutoff is consistent with the prior trauma and sepsis literature; we found that the 10% cutoff provided the strongest discriminatory ability for mortality risk. Patients with lactate clearance <10% had an odds ratio of 3.91 for mortality (OR 3.91 (95%CI 0.79–37.50), indicating a trend toward increased mortality, although this did not reach statistical significance (p-value=0.068).

Supplementary Table 1 Initial blood lactate levels (BL0) vs. mortality rate

BL0 (mmol/L)	Total (n)	Survivors n (%)	Non-survivors n (%)	Mortality rate (%)
<2.5	1	1 (100.0)	0 (0.0)	0.0
2.5–3.9	16	16 (100.0)	0 (0.0)	0.0
≥4.0	83	56 (67.5)	27 (32.5)	32.5
Total	100	73 (73.0)	27 (27.0)	27.0

Supplementary Table 2 6-hour blood lactate levels (BL6) vs. mortality rate

BL6 (mmol/L)	Total (n)	Survivors n (%)	Non-Survivors n (%)	Mortality rate (%)
<2.5	15	15 (100.0)	0 (0.0)	0.0
2.5–3.9	35	35 (100.0)	0 (0.0)	0.0
≥4.0	38	23 (60.5)	15 (39.5)	39.5
Total	88	73 (83.0)	15 (17.0)	17.0

p-value=0.005 (Fisher's exact test)

Supplementary Table 3 Sensitivity analysis of odds ratio (OR) for mortality using different blood lactate clearance (BLC) cutoffs

BLC cutoffs (%)	OR	95% CI	p-value
<10	3.91	0.79–37.50	0.068
<30	1.57	0.49–5.17	0.393
<50	0.87	0.14–3.81	0.852