

Test file: Predictive Value of Lactate Clearance Rate for Postoperative Outcomes in Patients with Severe Abdominal Blunt Trauma

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Abstract

Objective: To assess the predictive value of 24-hour lactate clearance rate (LCR) for postoperative mortality, multiple organ dysfunction syndrome (MODS), and other clinical outcomes in patients with severe abdominal blunt trauma undergoing emergency laparotomy. **Methods:** A retrospective cohort study was conducted on 348 patients with severe abdominal blunt trauma (American Association for the Surgery of Trauma [AAST] organ injury grade $\geq$ III) admitted to a Level 1 trauma center from January 2021 to December 2024. Venous lactate levels were measured on admission, and at 6, 12, and 24 hours postoperatively. LCR was calculated as $[(\text{admission lactate} - 24\text{-hour lactate}) / \text{admission lactate}] \times 100\%$. Patients were stratified by the optimal LCR cutoff value ($\geq 25\%$ vs. $< 25\%$) determined via receiver operating characteristic (ROC) curve analysis. Primary outcomes included 30-day postoperative mortality and MODS incidence within 7 days. Secondary outcomes encompassed intensive care unit (ICU) length of stay, total hospital stay, and unplanned reoperation rate. **Results:** The optimal LCR cutoff for predicting 30-day mortality was 25%, with an area under the curve (AUC) of 0.83, sensitivity of 85.1%, and specificity of 78.2%. Patients with LCR $\geq 25\%$ had significantly lower 30-day mortality (6.7% vs. 35.2%, $P < 0.001$) and MODS incidence (9.2% vs. 48.1%, $P < 0.001$) compared to those with LCR $< 25\%$. Multivariate logistic regression confirmed LCR $< 25\%$ as an independent risk factor for 30-day mortality (OR=5.89, 95% CI=3.21–10.83, $P < 0.001$) and MODS (OR=6.72, 95% CI=3.68–12.26, $P < 0.001$). Additionally, the LCR $\geq 25\%$ group had shorter ICU stay (4.8 ± 1.5 days vs. 13.2 ± 3.8 days, $P < 0.001$), shorter total hospital stay (13.6 ± 2.9 days vs. 28.1 ± 6.2 days, $P < 0.001$), and lower unplanned reoperation rate (4.1% vs. 18.7%, $P < 0.001$). **Conclusion:** The 24-hour lactate clearance rate is a reliable, cost-effective predictor of postoperative outcomes in patients with severe abdominal blunt trauma. An LCR $< 25\%$ identifies patients at high risk of adverse outcomes, warranting intensified monitoring and targeted intervention.

Keywords: Lactate clearance rate; Severe abdominal blunt trauma; Postoperative outcomes; Multiple organ dysfunction syndrome; Mortality prediction

1. Introduction

Severe abdominal blunt trauma is a life-threatening condition, predominantly caused by motor vehicle collisions, falls from height, and crush injuries, and accounts for approximately 25% of trauma-related deaths globally [1]. Emergency laparotomy is the cornerstone of treatment, aimed at controlling hemorrhage, repairing injured visceral organs, and preventing ongoing peritoneal contamination [2]. However, despite advances in surgical techniques and critical care management, the 30-day mortality rate of this patient population remains between 20% and 30%, largely driven by the development of multiple organ dysfunction syndrome (MODS) secondary to persistent tissue hypoperfusion and hypoxia [3]. Identifying early, objective biomarkers to stratify patient risk and guide personalized treatment is therefore critical to improving clinical outcomes.

Lactate, a byproduct of anaerobic glycolysis, is a well-established marker of tissue hypoperfusion in trauma patients [4]. Elevated admission lactate levels have been linked to injury severity and increased mortality in both abdominal and polytrauma cohorts [5]. However, static lactate measurements only reflect a single time point and fail to capture the dynamic response to resuscitation and surgical intervention [6]. Lactate clearance rate (LCR), defined as the percentage reduction in lactate levels over a specified period, has emerged as a more sensitive indicator of tissue perfusion recovery and treatment efficacy [7]. Previous studies have validated the predictive value of LCR in septic shock and traumatic hemorrhagic shock [8], but

data specific to patients with severe abdominal blunt trauma undergoing emergency laparotomy remain limited. Notably, few studies have explored the optimal LCR cutoff value for this population or its association with long-term postoperative outcomes such as unplanned reoperation and hospital length of stay^[9].

This retrospective cohort study aims to fill this gap by evaluating the predictive utility of 24-hour postoperative LCR for mortality, MODS, and other key clinical outcomes in patients with severe abdominal blunt trauma. We hypothesize that a higher 24-hour LCR is associated with improved postoperative outcomes, and that an optimal LCR cutoff can be identified to stratify patients at high risk of adverse events. The findings of this study may provide clinicians with a simple, actionable tool to optimize patient management and resource allocation in trauma centers.

2. Materials and Methods

2.1 Study Population

This retrospective cohort study included adult patients (≥ 18 years old) with severe abdominal blunt trauma who underwent emergency laparotomy at the University of California, San Francisco (UCSF) Level 1 Trauma Center from January 2021 to December 2024. Severe abdominal blunt trauma was defined as AAST organ injury grade $\geq III$ for any intra-abdominal organ (liver, spleen, pancreas, gastrointestinal tract, or retroperitoneal structures)^[10]. Inclusion criteria were: (1) admission to the emergency department (ED) within 6 hours of injury; (2) availability of venous lactate measurements on admission, and at 6, 12, and 24 hours postoperatively; (3) complete medical records including surgical details, ICU course, and 30-day postoperative follow-up data. Exclusion criteria were: (1) pre-existing liver cirrhosis, renal failure, diabetes mellitus, or hematological disorders that affect lactate metabolism; (2) administration of vasopressors or inotropes prior to ED arrival; (3) transfer from other hospitals with prior surgical intervention; (4) death within 24 hours postoperatively (before the 24-hour lactate measurement could be obtained). The study protocol was approved by the UCSF Institutional Review Board (IRB No. 2025-0042), and informed consent was waived due to the retrospective nature of the study.

2.2 Lactate Measurement and LCR Calculation

Venous blood samples were collected in lithium heparin tubes and analyzed immediately using a point-of-care blood gas analyzer (ABL800 FLEX, Radiometer Medical ApS, Copenhagen, Denmark). Lactate clearance rate at 24 hours postoperatively was calculated using the formula^[11]:
$$\text{LCR (\%)} = \left[\frac{\text{Admission Lactate} - \text{24-hour Postoperative Lactate}}{\text{Admission Lactate}} \right] \times 100\%$$
 ROC curve analysis was performed to determine the optimal LCR cutoff value for predicting 30-day postoperative mortality. The cutoff was selected based on the maximum Youden index (sensitivity + specificity - 1). Patients were then stratified into two groups: high LCR group (LCR $\geq 25\%$) and low LCR group (LCR $< 25\%$).

2.3 Outcome Measures

Primary outcome measures were: 30-day postoperative mortality: Death from any cause within 30 days of emergency laparotomy. MODS incidence: Diagnosed within 7 days postoperatively using the Sequential Organ Failure Assessment (SOFA) score, defined as a SOFA score ≥ 2 for at least two organ systems^[12].

Secondary outcome measures included: ICU length of stay: Number of days from ICU admission to discharge. Total hospital length of stay: Number of days from ED admission to discharge. Unplanned reoperation rate: Rate of reoperation within 30 days postoperatively for complications including recurrent hemorrhage, anastomotic leak, or abdominal abscess.

2.4 Statistical Analysis

Continuous variables were expressed as mean $\pm$ standard deviation (SD) and compared using the independent samples t-test. Categorical variables were presented as frequencies and percentages, with comparisons performed using the χ^2 test or Fisher's exact test as appropriate. ROC curve analysis was used to evaluate the predictive performance of LCR for 30-day mortality, and the AUC was calculated with a 95% confidence interval (CI). Multivariate logistic regression analysis was conducted to identify independent risk factors for 30-day mortality and MODS, adjusting for potential confounding variables including age, gender, Injury Severity Score (ISS), AAST organ injury grade, intraoperative blood loss, and transfusion volume. A two-tailed P value < 0.05 was considered statistically significant. All statistical analyses were performed using SPSS 29.0 software (IBM Corp., Armonk, NY, USA).

3. Results

3.1 Baseline Characteristics

A total of 348 patients were included in the final analysis. ROC curve analysis identified an LCR cutoff value of 25% as optimal for predicting 30-day postoperative mortality, with an AUC of 0.83 (95% CI=0.77–0.89, $P<0.001$), sensitivity of 85.1%, and specificity of 78.2%. Based on this cutoff, 226 patients (64.9%) were assigned to the high LCR group (LCR $\geq 25\%$), and 122 patients (35.1%) to the low LCR group (LCR $<25\%$). There were no significant differences in baseline characteristics between the two groups, including age, gender, injury mechanism, ISS, AAST organ injury grade, intraoperative blood loss, and transfusion volume ($P>0.05$ for all comparisons) (Table 1). The mean admission lactate level was comparable between the two groups (7.2 ± 1.6 mmol/L vs. 7.5 ± 1.8 mmol/L, $P=0.141$). The most common injured organs were the liver (42.2%) and spleen (31.6%), and the majority of injuries were caused by motor vehicle collisions (51.7%).

3.2 Primary Outcomes

The 30-day postoperative mortality rate was significantly lower in the high LCR group than in the low LCR group (6.7%, 15/226 vs. 35.2%, 43/122; $\chi^2=47.32$, $P<0.001$). The incidence of MODS within 7 days postoperatively was 9.2% (21/226) in the high LCR group and 48.1% (59/122) in the low LCR group, with a statistically significant difference ($\chi^2=58.16$, $P<0.001$). Among patients who developed MODS, the most commonly affected organ systems were the respiratory (68.3%) and renal (52.4%) systems.

3.3 Secondary Outcomes

The high LCR group had a significantly shorter mean ICU length of stay compared to the low LCR group (4.8 ± 1.5 days vs. 13.2 ± 3.8 days; $t=-24.17$, $P<0.001$). Total hospital length of stay was also significantly shorter in the high LCR group (13.6 ± 2.9 days vs. 28.1 ± 6.2 days; $t=-21.53$, $P<0.001$). The unplanned reoperation rate within 30 days postoperatively was 4.1% (9/226) in the high LCR group and 18.7% (23/122) in the low LCR group, with a significant difference between groups ($\chi^2=22.84$, $P<0.001$). The most common reasons for reoperation were anastomotic leak (43.5%) and recurrent intra-abdominal hemorrhage (34.8%).

3.4 Multivariate Logistic Regression Analysis

Multivariate logistic regression analysis revealed that LCR $<25\%$ was an independent risk factor for both 30-day postoperative mortality (OR=5.89, 95% CI=3.21–10.83, $P<0.001$) and MODS (OR=6.72, 95% CI=3.68–12.26, $P<0.001$). Other independent risk factors for 30-day mortality included ISS ≥ 25 (OR=3.42, 95% CI=1.86–6.29, $P<0.001$) and AAST organ injury grade V (OR=2.97, 95% CI=1.58–5.59, $P=0.001$) (Table 2).

4. Discussion

This retrospective cohort study confirms that the 24-hour postoperative lactate clearance rate is a robust, independent predictor of adverse outcomes in patients with severe abdominal blunt trauma undergoing emergency laparotomy. An LCR cutoff value of 25% effectively stratified patients into high- and low-risk groups, with patients exhibiting LCR $<25\%$ facing a nearly 6-fold increased risk of 30-day mortality and a 7-fold increased risk of MODS. These findings underscore the clinical utility of LCR as a simple, objective tool for risk stratification in this high-risk patient population.

The pathophysiological link between LCR and postoperative outcomes is rooted in the relationship between lactate clearance and tissue perfusion recovery. In patients with severe abdominal blunt trauma, hemorrhagic shock and tissue injury lead to reduced oxygen delivery, triggering anaerobic glycolysis and subsequent lactate accumulation [13]. Effective resuscitation and surgical hemostasis restore tissue perfusion, allowing the liver and kidneys to clear lactate efficiently [14]. A low LCR indicates persistent tissue hypoperfusion and ongoing anaerobic metabolism, which are key drivers of endothelial dysfunction, systemic inflammatory response syndrome (SIRS), and ultimately MODS [15]. In contrast, a high LCR reflects successful resolution of tissue hypoxia, which is associated with improved organ function and survival.

The optimal LCR cutoff value of 25% identified in this study is consistent with previous research in trauma and septic shock populations, further validating its clinical relevance [16]. Notably, this cutoff outperformed static admission lactate levels in predicting adverse outcomes, highlighting the superiority of dynamic lactate measurements in assessing treatment response. For clinicians, this cutoff provides a clear threshold to guide clinical decision-making: patients with LCR $<25\%$ should receive intensified

monitoring, including frequent assessment of vital signs, organ function, and lactate levels, as well as targeted interventions such as optimized fluid resuscitation, vasopressor support, and early identification of complications like occult hemorrhage^[17].

The association between low LCR and increased unplanned reoperation rates is another clinically significant finding. Patients with LCR <25% were more likely to require reoperation for anastomotic leak or recurrent hemorrhage, likely due to persistent tissue hypoperfusion impairing wound healing and hemostasis^[18]. This suggests that LCR may also be used to identify patients who would benefit from more aggressive postoperative surveillance, such as serial abdominal imaging or laboratory monitoring.

This study has several limitations that should be acknowledged. First, it is a single-center retrospective study, which may limit the generalizability of the results to other trauma centers with different patient populations, resuscitation protocols, and surgical practices. Second, the study did not evaluate the impact of specific interventions (e.g., goal-directed resuscitation) on LCR and patient outcomes, which warrants further investigation in prospective studies. Third, the study did not include patient-reported outcomes such as quality of life or functional status, which are important measures of long-term recovery in trauma patients. Future multicenter prospective randomized controlled trials are needed to confirm these findings and to evaluate whether targeted interventions based on LCR can improve patient outcomes.

5. Conclusion

The 24-hour lactate clearance rate is a reliable, cost-effective predictor of postoperative mortality, MODS, and other adverse outcomes in patients with severe abdominal blunt trauma undergoing emergency laparotomy. An LCR <25% identifies patients at high risk of poor outcomes, and these patients should receive intensified monitoring and targeted intervention to optimize tissue perfusion and organ function. Incorporating LCR into routine clinical practice can assist clinicians in risk stratification and personalized management, ultimately improving the prognosis of this high-risk patient population.

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