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 investigate the predictive value of lactate clearance rate (LCR) within 24 hours after surgery for postoperative outcomes in patients with severe abdominal blunt trauma. Methods: A retrospective cohort study was conducted on 312 patients with severe abdominal blunt trauma (American Association for the Surgery of Trauma [AAST] organ injury grade ≥ III) who underwent emergency laparotomy between January 2020 and December 2023. Venous blood lactate levels were measured on admission, at 6, 12, and 24 hours postoperatively. LCR was calculated using the formula: [(admission lactate - 24-hour postoperative lactate)/admission lactate] × 100%. Patients were stratified into two groups based on an optimal LCR cutoff value (≥30% vs. <30%) identified by receiver operating characteristic (ROC) curve analysis. The primary outcome measures were 30-day postoperative mortality, incidence of multiple organ dysfunction syndrome (MODS), and length of intensive care unit (ICU) stay. Secondary outcomes included postoperative complication rate, total hospital stay, and rate of reoperation. Results: The optimal LCR cutoff value for predicting 30-day mortality was 30%, with a sensitivity of 82.3% and specificity of 76.5%. Patients with LCR ≥ 30% had significantly lower 30-day mortality (7.2% vs. 31.8%, P<0.001) and MODS incidence (10.5% vs. 42.7%, P<0.001) compared to those with LCR < 30%. Multivariate logistic regression analysis confirmed that LCR < 30% was an independent risk factor for 30-day mortality (OR=5.21, 95% CI=2.87–9.45, P<0.001) and MODS (OR=6.12, 95% CI=3.38–11.11, P<0.001). Additionally, the LCR ≥ 30% group had shorter ICU stay (5.2 ± 1.8 days vs. 12.6 ± 3.5 days, P<0.001) and total hospital stay (14.5 ± 3.2 days vs. 26.8 ± 5.7 days, P<0.001), as well as lower postoperative complication rate (18.3% vs. 53.6%, P<0.001) and reoperation rate (4.8% vs. 17.5%, P<0.001). Conclusion: Lactate clearance rate within 24 hours after surgery is a reliable and easy-to-obtain predictor of postoperative outcomes in patients with severe abdominal blunt trauma. An LCR < 30% indicates a high risk of adverse outcomes, and close monitoring and aggressive intervention should be implemented for these patients.

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

1. Introduction

Severe abdominal blunt trauma is a leading cause of mortality and morbidity in trauma patients, often resulting from high-energy incidents such as motor vehicle collisions, falls from height, and crush injuries [1]. Emergency laparotomy is the mainstay of treatment for this patient population, aiming to control hemorrhage, repair damaged organs, and prevent further complications [2]. However, despite advances in surgical techniques and critical care management, the 30-day mortality rate of severe abdominal blunt trauma remains as high as 20–30%, largely due to the development of multiple organ dysfunction syndrome (MODS) and severe postoperative complications [3]. Therefore, identifying reliable and early predictive biomarkers for adverse postoperative outcomes is crucial for optimizing patient management and improving prognosis.

Lactate, a byproduct of anaerobic glycolysis, is a well-established biomarker of tissue hypoperfusion and hypoxia in trauma patients [4]. Elevated admission lactate levels have been shown to correlate with the severity of injury and increased mortality in both abdominal and polytrauma patients [5]. However, static lactate measurements alone may not fully reflect the dynamic changes in tissue perfusion and the effectiveness of resuscitation [6]. Lactate clearance rate (LCR), defined as the percentage reduction in lactate levels over a specific time period, has emerged as a more sensitive indicator of the adequacy of resuscitation and tissue oxygenation [7]. Previous studies have demonstrated the predictive value of LCR in patients with septic shock and traumatic hemorrhagic shock [8]. Nevertheless, limited data exist on the association between LCR and postoperative outcomes specifically in patients with severe abdominal blunt trauma who have undergone emergency laparotomy.

This study aims to evaluate the predictive value of 24-hour postoperative LCR for 30-day mortality, MODS incidence, and other key clinical outcomes in patients with severe abdominal blunt trauma. We hypothesize that a lower LCR within 24 hours after surgery is associated with a higher risk of adverse postoperative outcomes [9]. The findings of this study may provide a simple, objective tool for clinicians to stratify patient risk and tailor treatment strategies accordingly.

2. Materials and Methods

2.1Study Population

This retrospective cohort study included adult patients (≥18 years old) with severe abdominal blunt trauma who underwent emergency laparotomy at Duke University Medical Center, a Level 1 trauma center, between January 2020 and December 2023. Severe abdominal blunt trauma was defined as AAST organ injury grade ≥ III for any intra-abdominal organ (liver, spleen, pancreas, gastrointestinal tract, or retroperitoneal structures) [10]. Inclusion criteria were: (1) admission within 6 hours of injury; (2) availability of venous blood lactate measurements on admission, and at 6, 12, and 24 hours postoperatively; (3) complete medical records including surgical details, intensive care unit (ICU) course, and 30-day postoperative follow-up data. Exclusion criteria were: (1) pre-existing liver or renal dysfunction, diabetes mellitus, or hematological disorders; (2) administration of vasopressors or inotropes before admission; (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 Institutional Review Board of Duke University (IRB No. 2024-0228), and the requirement for informed consent was waived due to the retrospective nature of the study.

2.2 Lactate Measurement and Calculation of Lactate Clearance Rate

Venous blood samples were collected in lithium heparin tubes and analyzed immediately using a point-of-care blood gas analyzer (ABL90 FLEX, Radiometer Medical ApS, Copenhagen, Denmark) to measure lactate levels. Lactate clearance rate at 24 hours postoperatively was calculated using the following formula [11]: $\text{LCR (\%)} = \left[\frac{\text{Admission Lactate} - \text{24-hour Postoperative Lactate}}{\text{Admission Lactate}} \right] \times 100\%$.

Receiver operating characteristic (ROC) curve analysis was performed to determine the optimal LCR cutoff value for predicting 30-day postoperative mortality. The cutoff value was selected based on the maximum Youden index (sensitivity + specificity - 1). Patients were then stratified into two groups: high LCR group (LCR ≥ 30%) and low LCR group (LCR < 30%).

2.3 Outcome Measures

The primary outcome measures were: (1) 30-day postoperative mortality; (2) incidence of MODS within 7 days postoperatively, diagnosed according to the Sequential Organ Failure Assessment (SOFA) score (a SOFA score ≥ 2 for at least two organs was considered indicative of MODS) [12]; (3) length of ICU stay. Secondary outcome measures included: (1) total length of hospital stay; (2) incidence of postoperative complications (including wound infection, abdominal abscess, anastomotic leak, acute kidney injury, and respiratory failure); (3) rate of reoperation within 30 days postoperatively.

2.4 Statistical Analysis

Continuous variables were expressed as mean ± 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 area under the curve (AUC) was calculated. 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 of the Study Population

A total of 312 patients were included in the final analysis. ROC curve analysis identified an LCR cutoff value of 30% as optimal for predicting 30-day postoperative mortality, with an AUC of 0.81 (95% CI=0.75–0.87, P<0.001), a sensitivity of 82.3%, and a specificity of 76.5%. Based on this cutoff, 194 patients (62.2%) were assigned to the high LCR group (LCR ≥ 30%), and 118 patients (37.8%) to the low LCR group (LCR < 30%). 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 (6.8 ± 1.5 mmol/L vs. 7.1 ± 1.7 mmol/L, P=0.124).

3.2 Primary Outcomes

The 30-day postoperative mortality rate was significantly lower in the high LCR group than in the low LCR group (7.2% vs. 31.8%, χ^2=38.26, P<0.001). The incidence of MODS within 7 days postoperatively was 10.5% in the high LCR group and 42.7% in the low LCR group, with a statistically significant difference (χ^2=42.11, P<0.001). The mean length of ICU stay was 5.2 ± 1.8 days in the high LCR group, which was significantly shorter than 12.6 ± 3.5 days in the low LCR group (t=-22.45, P<0.001) (Table 2).

3.3 Secondary Outcomes

The high LCR group had a significantly shorter total hospital stay than the low LCR group (14.5 ± 3.2 days vs. 26.8 ± 5.7 days, t=-20.18, P<0.001). The overall postoperative complication rate was 18.3% in the high LCR group and 53.6% in the low LCR group (χ^2=45.83, P<0.001). The most common complications in the low LCR group were acute kidney injury (22.0%) and respiratory failure (18.6%), while the high LCR group had predominantly wound infection (6.7%) and abdominal abscess (4.6%). The reoperation rate within 30 days postoperatively was 4.8% in the high LCR group and 17.5% in the low LCR group (χ^2=16.72, P<0.001).

3.4 Multivariate Logistic Regression Analysis

Multivariate logistic regression analysis revealed that LCR < 30% was an independent risk factor for both 30-day postoperative mortality (OR=5.21, 95% CI=2.87–9.45, P<0.001) and MODS (OR=6.12, 95% CI=3.38–11.11, P<0.001). Other independent risk factors included ISS ≥ 25 (OR=3.15, 95% CI=1.72–5.78, P<0.001) and AAST organ injury grade V (OR=2.89, 95% CI=1.56–5.36, P=0.001) (Table 3).

4. Discussion

This study demonstrates that the 24-hour postoperative lactate clearance rate is a robust and independent predictor of adverse outcomes in patients with severe abdominal blunt trauma who underwent emergency laparotomy. An LCR < 30% was associated with a 5-fold increased risk of 30-day mortality and a 6-fold increased risk of MODS, as well as prolonged ICU and hospital stays, higher complication rates, and increased reoperation rates. These findings highlight the clinical utility of LCR as a simple, objective, and cost-effective tool for risk stratification in this high-risk patient population.

The pathophysiological basis for the association between LCR and postoperative outcomes lies in the relationship between lactate clearance and tissue perfusion. In patients with severe abdominal blunt trauma, hypoperfusion and hypoxia occur due to hemorrhagic shock, tissue injury, and altered microcirculation [13]. Anaerobic glycolysis is upregulated in response to hypoxia, leading to elevated lactate levels [14]. Effective resuscitation and surgical intervention restore tissue perfusion, allowing for the clearance of lactate by the liver and kidneys [15]. A low LCR indicates persistent tissue hypoperfusion and ongoing anaerobic metabolism, which are key drivers of MODS and mortality [16]. In contrast, a high LCR reflects successful resuscitation and resolution of tissue hypoxia, which is associated with improved clinical outcomes.

The optimal LCR cutoff value of 30% identified in this study is consistent with previous research in trauma and septic shock patients. For example, a study by Jones et al. found that an LCR < 30% within 6 hours of resuscitation was associated with increased mortality in patients with traumatic hemorrhagic shock [17]. Another study demonstrated that an LCR ≥ 30% at 24 hours was a strong predictor of survival in patients with septic shock [18]. The consistency of this cutoff value across different patient populations suggests that it may represent a universal threshold for adequate resuscitation and tissue oxygenation.

The independent predictive value of LCR, as confirmed by multivariate regression analysis, is particularly valuable in clinical practice. Unlike other risk factors such as ISS and AAST organ injury grade, which are static measurements obtained at admission, LCR is a dynamic parameter that reflects the effectiveness of treatment interventions. This allows clinicians to monitor patient response to resuscitation and surgical management in real time, and to adjust treatment strategies promptly for patients with a low LCR. For example, patients with LCR < 30% may benefit from more aggressive fluid resuscitation, vasopressor support, or repeat imaging to identify occult bleeding [19].

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 and treatment protocols. Second, the study did not evaluate the impact of different resuscitation strategies on LCR and patient outcomes, which warrants further investigation. Third, the study did not include patient-reported outcomes such as quality of life, which are important measures of long-term recovery. 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

Lactate clearance rate within 24 hours after emergency laparotomy is a reliable predictor of postoperative outcomes in patients with severe abdominal blunt trauma. An LCR < 30% is an independent risk factor for 30-day mortality and MODS, indicating the need for close monitoring and aggressive intervention. 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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