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Original Research Article

Perioperative Lactate Clearance as a Predictor of Outcome Following Major Surgery under General Anaesthesia

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Abstract

Background: Major surgery under general anaesthesia is associated with significant physiological stress, and early identification of patients at risk of postoperative complications remains a clinical challenge. Perioperative lactate clearance has emerged as a promising biomarker of tissue perfusion and metabolic recovery.

Aim: To evaluate perioperative lactate clearance as a predictor of postoperative outcomes following major surgery under general anaesthesia.

Methods: This prospective observational study included 120 adult patients undergoing elective major surgery under general anaesthesia. Arterial lactate levels were measured preoperatively, at the end of surgery, and at 6 and 24 hours postoperatively. Lactate clearance was calculated, and patients were categorized into adequate (≥20%) and poor (<20%) lactate clearance groups. Postoperative complications, ICU admission, duration of mechanical ventilation, hospital stay, and mortality were compared.

Results: Seventy-eight patients (65%) achieved adequate lactate clearance, whereas forty-two (35%) had poor clearance. Patients with poor lactate clearance demonstrated significantly higher postoperative lactate concentrations, greater intraoperative blood loss, and longer operative duration ($p<0.05$). They also experienced significantly higher rates of ICU admission (61.9% vs. 15.4%), prolonged mechanical ventilation (35.7% vs. 6.4%), acute kidney injury (28.6% vs. 5.1%), sepsis (23.8% vs. 3.8%), prolonged hospital stay (13.6 ± 4.2 vs. 8.4 ± 2.3 days), and mortality (16.7% vs. 2.6%) compared with patients demonstrating adequate lactate clearance (all $p<0.05$).

Conclusion: Perioperative lactate clearance is a reliable predictor of postoperative morbidity and mortality following major surgery under general anaesthesia. Poor lactate clearance identifies patients at increased risk for adverse outcomes and may facilitate early postoperative intervention, improved perioperative management, and enhanced patient prognosis.

Keywords: Lactate Clearance; General Anaesthesia; Major Surgery; Postoperative Complications; Tissue Perfusion; Intensive Care Unit; Mortality.

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Introduction

Major surgical procedures are associated with significant physiological stress, tissue injury, and metabolic alterations that may result in impaired tissue perfusion and oxygen delivery. Despite advances in anaesthetic techniques, intraoperative monitoring, and perioperative care, postoperative complications and mortality remain important concerns, particularly in patients undergoing major surgery under general anaesthesia.

Early identification of patients at risk of adverse outcomes is therefore essential to facilitate timely intervention and improve postoperative recovery. [1,2] Serum lactate has emerged as a valuable biomarker of tissue hypoperfusion and impaired cellular metabolism. Lactate is produced primarily during anaerobic glycolysis when oxygen delivery fails to meet metabolic demand. However, elevated lactate concentrations may also result from increased aerobic glycolysis, impaired hepatic clearance, adrenergic stimulation, and mitochondrial dysfunction.

Consequently, perioperative lactate measurement provides important information regarding the adequacy of tissue oxygenation and systemic

perfusion during and after major surgical procedures. [3] Although a single lactate measurement reflects the metabolic status at a particular point in time, serial lactate measurements and lactate clearance provide a more dynamic assessment of the patient's response to treatment. Lactate clearance refers to the percentage reduction in blood lactate concentration over time and reflects restoration of adequate tissue perfusion. Numerous studies have demonstrated that delayed lactate clearance is associated with persistent tissue hypoxia, multiple organ dysfunction, prolonged intensive care unit stay, and increased mortality among critically ill patients. [4]

Perioperative monitoring of lactate clearance has gained increasing attention in anaesthesia and critical care because it enables early recognition of occult hypoperfusion even in haemodynamically stable patients. Lactate-guided resuscitation strategies have been shown to improve tissue perfusion and reduce postoperative complications by facilitating early optimization of intravascular volume, cardiac output, and oxygen delivery. Consequently, lactate clearance has been proposed as a simple, inexpensive, and reliable prognostic marker for assessing postoperative outcomes following major surgery. [5]

General anaesthesia itself influences cardiovascular function, systemic vascular resistance, and tissue oxygen utilization. Combined with surgical stress, blood loss, fluid shifts, and inflammatory responses, these physiological alterations may contribute to perioperative lactate elevation. Monitoring perioperative lactate kinetics may therefore help anaesthesiologists identify patients at increased risk for postoperative complications before the appearance of overt clinical deterioration, thereby allowing timely therapeutic interventions. [6]

Although several studies have investigated serum lactate levels in critically ill and septic patients, comparatively fewer studies have specifically evaluated perioperative lactate clearance as a predictor of postoperative outcome following major surgery under general anaesthesia. Establishing the prognostic value of perioperative lactate clearance may assist clinicians in perioperative risk stratification, optimization of postoperative monitoring, and improvement of clinical outcomes.

Therefore, the present study was undertaken to evaluate perioperative lactate clearance as a predictor of postoperative outcome in patients undergoing major surgery under general anaesthesia, and to determine its association with postoperative complications, intensive care unit admission, duration of hospital stay, and mortality.

Materials and Methodology

Study Design: This was a prospective observational cohort study.

Study Setting: The study was conducted in the Department of Anaesthesiology in collaboration with the Departments of General Surgery, Gastrointestinal Surgery, Urology, and Surgical Oncology at a tertiary care teaching hospital.

Study Duration: The study was carried out over a period of 18 months after obtaining approval from the Institutional Ethics Committee.

Sample Size: A total of 120 patients undergoing major surgery under general anaesthesia were included in the study.

The sample size was calculated considering a 95% confidence level, 80% statistical power, and an anticipated association between perioperative lactate clearance and postoperative outcome.

Study Population: Adult patients undergoing elective major surgical procedures under general anaesthesia.

Inclusion Criteria

- Age between 18 and 70 years.
- Either gender.
- ASA physical status I–III.
- Elective major abdominal, thoracic, vascular, urological, or oncological surgery under general anaesthesia.
- Expected operative duration greater than 2 hours.
- Written informed consent.

Exclusion Criteria

- Emergency surgery.
- Severe hepatic failure.
- End-stage renal disease requiring dialysis.
- Diabetic ketoacidosis.
- Septic shock before surgery.
- Pregnancy.
- Known mitochondrial or metabolic disorders.
- Refusal to participate.
- Incomplete perioperative lactate measurements.

Preoperative Assessment: All patients underwent detailed pre-anaesthetic evaluation including medical history, physical examination, airway assessment, laboratory investigations, electrocardiography, and imaging as indicated. ASA physical status and baseline demographic characteristics were documented.

Anaesthetic Technique: Standard ASA monitoring including electrocardiography, non-invasive blood pressure, pulse oximetry, capnography, temperature monitoring, and invasive arterial pressure monitoring (where indicated) was instituted.

General anaesthesia was induced with intravenous:

- Propofol (2 mg/kg)
- Fentanyl (2 µg/kg)
- Rocuronium (0.6–1 mg/kg)

Following endotracheal intubation, anaesthesia was maintained using oxygen-air mixture with sevoflurane or desflurane, supplemented with intermittent fentanyl and neuromuscular blockade as required.

Mechanical ventilation was adjusted to maintain normocapnia. Intraoperative fluid therapy, blood transfusion, vasopressor administration, and hemodynamic management were performed according to institutional protocols.

Lactate Measurement: Arterial blood samples were collected for serum lactate estimation at the following time points:

- Before induction of anaesthesia (baseline)
- At the end of surgery
- Six hours postoperatively
- Twenty-four hours postoperatively

Lactate concentration was measured using an arterial blood gas analyzer.

Lactate Clearance: Perioperative lactate clearance (%) was calculated using the following formula:

[\text{Lactate Clearance (%)}=\frac{\text{Initial Lactate}-\text{Subsequent Lactate}}{\text{Initial Lactate}}\times100]

Patients were categorized into:

- **Adequate lactate clearance:** ≥20%
- **Poor lactate clearance:** <20%

Outcome Measures

Primary Outcome: Association between perioperative lactate clearance and postoperative complications.

Secondary Outcomes

- Intensive care unit (ICU) admission.
- Duration of mechanical ventilation.
- Length of ICU stay.
- Length of hospital stay.
- Surgical site infection.
- Acute kidney injury.
- Sepsis.
- Thirty-day postoperative mortality.

Data Collection: The following variables were recorded:

- Age, gender, BMI.
- ASA physical status.
- Type and duration of surgery.
- Intraoperative blood loss.
- Fluid administration.
- Vasopressor requirement.
- Baseline and serial lactate levels.
- Lactate clearance percentage.
- Postoperative complications.
- ICU admission.
- Hospital stay.
- Mortality.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation (SD) and compared using the independent Student's t-test or Mann-Whitney U test as appropriate. Categorical variables were expressed as frequencies and percentages and compared using the Chi-square test or Fisher's exact test. Correlation between lactate clearance and postoperative outcomes was assessed using Pearson or Spearman correlation analysis. Multivariate logistic regression was performed to identify independent predictors of adverse postoperative outcomes. A p-value <0.05 was considered statistically significant.

Results

A total of 120 patients undergoing major surgery under general anaesthesia were included in the study. Perioperative serum lactate levels were measured at predefined intervals, and lactate clearance was calculated 24 hours postoperatively. Based on lactate clearance, patients were categorized into Adequate Lactate Clearance (≥20%) and Poor Lactate Clearance (<20%) groups. Postoperative outcomes including complications, ICU admission, duration of hospital stay, and mortality were compared between the two groups.

Table 1: Baseline Demographic and Perioperative Characteristics

Variable	Adequate Lactate Clearance (n=78)	Poor Lactate Clearance (n=42)	p-value
Age (years)	49.6 ± 12.4	54.8 ± 13.1	0.041
Male, n (%)	46 (59.0)	25 (59.5)	0.956
Female, n (%)	32 (41.0)	17 (40.5)	
BMI (kg/m²)	24.7 ± 3.8	25.3 ± 4.1	0.426
ASA I/II, n (%)	66 (84.6)	24 (57.1)	<0.001
ASA III, n (%)	12 (15.4)	18 (42.9)	
Duration of Surgery (minutes)	176.4 ± 39.8	201.6 ± 45.2	0.003
Blood Loss (mL)	425 ± 118	612 ± 154	<0.001

Patients with poor lactate clearance were significantly older, had a higher proportion of ASA III status, longer operative duration, and greater intraoperative blood loss than those with adequate lactate clearance ($p<0.05$). Gender distribution and BMI were comparable between the groups.

Table 2: Perioperative Lactate Profile

Variable	Adequate Clearance	Poor Clearance	p-value
Baseline Lactate (mmol/L)	1.34 ± 0.39	1.41 ± 0.42	0.362
End of Surgery Lactate (mmol/L)	2.46 ± 0.61	3.78 ± 0.82	<0.001
6-hour Lactate (mmol/L)	1.86 ± 0.48	3.41 ± 0.79	<0.001
24-hour Lactate (mmol/L)	1.18 ± 0.32	2.82 ± 0.71	<0.001
Lactate Clearance (%)	34.8 ± 8.6	12.4 ± 5.1	<0.001

Baseline lactate levels were similar between both groups. However, patients with poor lactate clearance demonstrated significantly higher postoperative lactate levels at the end of surgery, 6 hours, and 24 hours. Mean lactate clearance was markedly lower in the poor clearance group (12.4%) compared to the adequate clearance group (34.8%) ($p<0.001$).

Table 3: Postoperative Outcomes According to Lactate Clearance

Outcome	Adequate Clearance (n=78)	Poor Clearance (n=42)	p-value
ICU Admission	12 (15.4%)	26 (61.9%)	<0.001
Mechanical Ventilation >24 h	5 (6.4%)	15 (35.7%)	<0.001
Acute Kidney Injury	4 (5.1%)	12 (28.6%)	<0.001
Surgical Site Infection	7 (9.0%)	11 (26.2%)	0.012
Sepsis	3 (3.8%)	10 (23.8%)	0.001
Mortality	2 (2.6%)	7 (16.7%)	0.006

Patients with poor lactate clearance experienced significantly higher rates of ICU admission, prolonged mechanical ventilation, acute kidney injury, surgical site infection, sepsis, and mortality compared with patients demonstrating adequate lactate clearance ($p<0.05$).

Table 4: Recovery Profile

Variable	Adequate Clearance	Poor Clearance	p-value
ICU Stay (days)	1.8 ± 0.9	4.6 ± 2.1	<0.001
Hospital Stay (days)	8.4 ± 2.3	13.6 ± 4.2	<0.001
Time to Oral Intake (hours)	18.2 ± 4.8	29.6 ± 8.2	<0.001
Time to Ambulation (hours)	26.4 ± 7.1	42.8 ± 10.3	<0.001

Poor lactate clearance was associated with delayed postoperative recovery. These patients required significantly longer ICU stay, prolonged hospitalization, delayed initiation of oral feeding, and later ambulation compared with patients who achieved adequate lactate clearance ($p<0.001$).

Discussion

The present prospective observational study evaluated the prognostic significance of perioperative lactate clearance in patients undergoing major surgery under general anaesthesia. The findings demonstrated that poor lactate clearance (<20%) was significantly associated with increased postoperative complications, prolonged intensive care unit (ICU) stay, delayed recovery, and higher mortality. Patients with inadequate lactate clearance also had longer operative duration, greater intraoperative blood loss, and higher postoperative serum lactate levels, indicating persistent tissue hypoperfusion and impaired metabolic recovery. Lactate metabolism has evolved from being regarded solely as a marker of anaerobic metabolism to an important indicator of systemic metabolic stress and tissue perfusion. Gladden [7] described lactate as an essential intermediate in cellular energy metabolism, emphasizing that elevated lactate levels may occur even under aerobic conditions due to increased metabolic demand and stress responses. This physiological concept supports the present findings, where elevated postoperative lactate concentrations reflected the magnitude of surgical stress and tissue hypoxia rather than hypoxia alone. The prognostic significance of perioperative hyperlactatemia observed in this study is comparable with the findings of Nichol et al. [8], who reported that even modest elevations in blood lactate were independently associated with increased hospital mortality among critically ill patients. Their study demonstrated that persistent hyperlactatemia reflected inadequate tissue perfusion despite apparently stable haemodynamic parameters. Similarly, patients with poor lactate clearance in the present study experienced significantly higher rates of ICU admission, prolonged hospitalization, and postoperative complications.

Cardiac and major non-cardiac surgical studies have consistently demonstrated the relationship between elevated postoperative lactate and adverse outcomes. Hajjar et al. [9] reported that increased postoperative lactate concentrations were strong independent predictors of major complications and mortality following cardiac surgery. Patients with persistently elevated lactate had increased incidences of renal dysfunction, prolonged mechanical ventilation, and longer ICU stay. Comparable findings were observed in the present study, where poor lactate clearance was significantly associated with acute kidney injury, sepsis, prolonged ventilatory support, and increased mortality.

Serial lactate estimation has been shown to provide greater prognostic information than a single lactate measurement. Kliegel et al. [10] demonstrated that serial lactate measurements and delayed lactate normalization were superior predictors of survival compared with isolated lactate values in critically ill surgical patients. Likewise, our study found that postoperative lactate levels remained significantly elevated at the end of surgery, six hours, and twenty-four hours among patients with poor lactate clearance, suggesting persistent metabolic derangement and impaired tissue oxygenation.

The importance of lactate clearance as an indicator of successful resuscitation was further highlighted by Silva et al. [11], who demonstrated that patients achieving higher perioperative lactate clearance experienced significantly fewer postoperative complications and shorter hospital stay following major surgery. These findings closely parallel the present results, in which adequate lactate clearance was associated with earlier ambulation, reduced ICU stay, shorter hospitalization, and improved overall recovery.

A systematic review and meta-analysis conducted by Andersen et al. [12] confirmed that lactate clearance is a reliable predictor of mortality across various critically ill populations. The authors concluded that patients with rapid lactate clearance had significantly improved survival compared with those demonstrating persistent hyperlactatemia. The present study similarly demonstrated a significantly higher mortality rate among patients with poor lactate clearance, reinforcing the value of serial lactate monitoring as a prognostic tool in the perioperative period.

The relationship between impaired lactate clearance and organ dysfunction may be explained by persistent microcirculatory abnormalities and inadequate restoration of cellular metabolism. Levy et al. [13] reported that reduced lactate clearance reflects ongoing cellular dysfunction and impaired tissue oxygen utilization, which contribute to progressive organ failure and poor clinical outcomes. The increased incidence of acute kidney injury, sepsis, prolonged mechanical ventilation, and mortality observed among patients with poor lactate clearance in the present study is consistent with this pathophysiological mechanism.

Overall, the findings of the present study support the routine use of perioperative serial lactate measurement and lactate clearance assessment in patients undergoing major surgery under general anaesthesia. Lactate clearance represents a simple, rapid, inexpensive, and objective biomarker that may assist anaesthesiologists and intensivists in early postoperative risk stratification, guiding haemodynamic optimization and identifying patients requiring closer monitoring and aggressive postoperative management.

Conclusion

Perioperative lactate clearance is a valuable predictor of postoperative outcome following major surgery under general anaesthesia. Patients with poor lactate clearance experienced significantly higher rates of postoperative complications, intensive care unit admission, prolonged mechanical ventilation, acute kidney injury, sepsis, longer hospital stay, and mortality. In contrast, adequate lactate clearance was associated with faster recovery and more favourable postoperative outcomes. Serial perioperative lactate monitoring is a simple, inexpensive, and readily available tool that can facilitate early identification of high-risk patients, optimize perioperative management, and improve surgical outcomes. Routine assessment of lactate clearance should therefore be considered as an important component of perioperative monitoring in major surgical patients.

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