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Need for intensive care admission based on point-of-care measurement of serum lactate levels in early trauma care

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ABSTRACT

Trauma is the leading cause of preventable death in the world. The time delay in presentation and the lack of knowledge about the availability of early markers of severity assessment decrease the success of survivability. The serum lactate analyses help the intensivist in effective triaging and thereby sorting out the indeed need of trauma victims for early intensive care management. Moreover, it guides orthopaedic surgeons, on when they should impart definitive surgery on polytrauma patients. Serum lactate analysis is an excellent 'resuscitation predictor' and its value have well utilized for framing a resuscitation protocol in advanced trauma care. The objective of this review is to enlighten the usage of serum lactate analysis at the point of early trauma care. Nevertheless, it describes the application of a continuous lactate monitoring system using sensor-based technologies in sports as well as trauma medicine.
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1. Introduction

Trauma is the leading cause of morbidity and mortality among young individuals in developing countries. Triaging the trauma patients reduces the economic burden and further improves the care of the injured. An adequate clinical survey and the assessment of blood parameters including serum lactate analysis are critical in framing the treatment options including the need for intensive care management. Serum lactate level is usually increased in trauma patients with hypotensive shock. Though some of the polytrauma victims with multiple injuries are normotensive, their lactate levels are still higher due to peripheral vasoconstriction-mediated local tissue hypoxia.[1] Various scoring systems have been used to assess the severity of the physiological insults in trauma victims, but they are seldom helpful in categorizing the need for intensive management.

2. Mechanism of elevated lactic acidosis in trauma

Following the trauma-induced hypovolemic shock, there will be tachycardia, impaired cardiac output, and hypotension. The persistent hypotension leads to inadequate tissue perfusion, thus impaired oxygenation causes increased anaerobic metabolism as shown in Fig. 1. This anaerobic metabolism drives the glycolysis pathway towards the production of lactic acid (type A lactic acidosis) which in turn produces high anion gap metabolic acidosis and decreased base excess.

Type B lactic acidosis is due to an inherent problem associated with pyruvate processing in the mitochondria. Other conditions which cause type B lactic acidosis such as diabetic ketoacidosis, thiamine deficiency, total parenteral nutrition, and excessive exercise.[2]

3. Measurement and interpretation

The serum lactate levels can be measured and interpreted in clinical settings. A systematic recent review by Kruse et al. based on 33 articles on the serial measurement of serum lactate in the patients admitted at the casualty concluded that the levels of lactate in venous sampling are highly correlated with arterial blood

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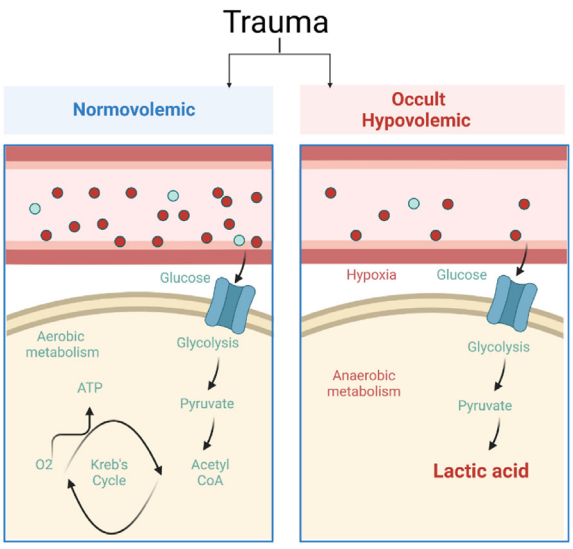

Fig. 1. The pathophysiology of lactic acidosis in occult hypovolemic trauma victims.

analyses, thus establishing that venous blood measurement is equally efficacious and minimal inconvenience to the patient.[3] The application of a rubber tourniquet to facilitate easy blood withdrawal does not affect the blood lactate levels provided that samples are measured at the handheld point of care testing (HPOC), preferably within 15 min.

The continuous lactate monitoring system (CLMS) uses a microneedle array, Lactate oxidase (LOX) biosensors, and ceria-copper oxide biosensors to provide a non-invasive, bloodless measurement of one's lactate level with minimal pain and costs.[4]

The medications such as acetaminophen, β adrenergic agonists, alcohol, metformin, salicylates, sulfasalazine, isoniazid, and valproic acid can cause lactic acidosis. The point of care lactate level ≥2 mmol/L is significant independent mortality and the need for ICU admission predictor in trauma patients evaluated in causality. This increased serum lactate level of ≥2 mmol/L increases the mortality rate from 1.94 to 10.89 times that of the patients with admission lactate of <2 mmol/L.[5]

4. Clinical significance

Increased serum lactate levels have been associated with various clinical conditions and it has been extensively evaluated for its utility in the early predictability of hypovolemic shock.

In the late 1990s, Blow et al. conducted a pilot to assess the significance of occult tissue hypoxia using serum lactate levels at arrival time and due intervals. They found that the patients with LA levels greater than 2.5 mmol/L needed intensive care management irrespective of the severity of the injury. Further, they showed that increased LA levels had been associated with poor cardio-respiratory drive, prolonged ICU stay, and increased morbidity and mortality.[6] They concluded that persistent occult hypoperfusion (framed the resuscitation protocol based on serum LA levels) has been associated with increased infection rate and multiorgan dysfunction.

The ideal injury-surgery time interval is often unclear in orthopaedic polytrauma. Vallier et al. advocated early appropriate care (EAC) for patients with major trauma (mean Injury Severity Score − 26.9). The EAC recommends fracture fixation within 36 h, only when the LA level is < 4 mmol/L. They found EAC guidelines based on serum LA levels are safe, effective, and plausible for managing polytrauma patients. The prolonged resuscitation of metabolic acidosis for more than 36 h can cause infection, poor cardiac performance, sepsis, pulmonary embolism, deep vein thrombosis, and multiorgan dysfunction. Further, they have predicted the success of resuscitation (Full protocol resuscitation, FPR) using the markers of acidosis (lactate <4.0 mmol/L; pH ≥ 7.25; or base excess (BE) ≥ −5.5 mmol/L).[7]

Crowl et al. in their study evaluated the association between occult hypoperfusion and the postoperative complications who had intramedullary nailing for femur fracture. The patients with incompletely resuscitated patients (lactic acid levels > or = 2.5 mmol/L) had a double-fold rise in postoperative complications.[8] Alternatively, Pal et al. proved the data against the conventional dictum for predictability of mortality using arterial LA level. However, they stated that lactate analysis is mandatory for patients who will need ICU admission and/or require immediate surgery.[9] Baxter et al. conducted a large systemic study using 28 studies across eight countries and showed a significant association between admission lactate level and the need for ICU admission, duration of hospital stay, emergency procedures, and the mortality rate.[10]

Tailoring the fracture management protocol based on serum lactate levels has revolutionized the early recovery of severely injured trauma victims. The concept of early total care will be inappropriate in patients with persisting lactic acidosis following major trauma. Early surgical trauma fuelling the inflammatory response, constitutes a second hit phenomenon that may aggravate respiratory distress, and sepsis. Nevertheless, the point of care equipped with early diagnosis and management of hypovolemic acidosis yields dramatic improvement in the parameters of damage control resuscitation (DCR). The effective DCR (lactate level <2.0 mmol/L) will pave the way for "safe definitive fracture surgery" or early appropriate care within 24–36 h of admission. In unstable patients (lactate level >2.5 mmol/L), damage control orthopaedic surgery (DCO) should be implicated wherever possible. In special situations, the decision should be reached after consulting with the trauma team comprising orthopaedic surgeons, intensivists, and operating room anaesthetists. The surgical plan should be framed based on the 'sit reps' (situation reports) based on the dynamic varying clinical condition and lab parameters of the patient. Even in resuscitated patients, the intraoperative monitoring of serum lactate will guide us in real-time to make a proper decision on fracture management (whether ETC or DCO).

5. Conclusion

Identifying the pathophysiology of shock, the early response, regulation, and management of lactic acidosis in those trauma victims is highly crucial for improving survivability. With the extensive clinical utility of lactate levels in the point of care changes the philosophy of golden hour to diamond minutes in acute trauma care. It serves as a prognostic and therapeutic marker, in addition to the other tools of severity assessment. The potential role of minimally invasive, bloodless continuous lactate monitoring based on percutaneous microneedle array and cyclic voltammetry analysis is of intense research in emergency and sports medicine.

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Declaration of competing interest

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Erratum regarding missing peer review statement in previously published articles

Owing to a Publisher error, peer review statement was not included in the published versions of the following articles, that appeared in previous issues of Journal of Clinical Orthopaedics and Trauma.

The appropriate peer review statements, for each article are provided below.

1. "Correlation between height and semitendinosus tendon length, prediction of minimum semitendinosus tendon length based on height-an easy and accurate method" (Journal of Clinical Orthopaedics and Trauma., 31 (2022) 101918) https://doi.org/10.1016/j.jcot.2022.101918

Peer review statement: The author list of this article includes an editorial board members, namely Ankit Goyal and Hitesh Lal. We would like to note that they were not involved in the peer review process or any of the decision-making steps of the manuscript.

2. "Cystic bone Lesions: Diagnostic pitfalls and therapeutic considerations" (Journal of Clinical Orthopaedics and Trauma., 67 (2025) 103046) https://doi.org/10.1016/j.jcot.2025.103046

Peer review statement: The author list of this article includes an editorial board member, namely Ashish Gulia. We would like to note that they were not involved in the peer review process or any of the decision-making steps of the manuscript.

3. "Artificial intelligence-based orthopaedic perpetual design" (Journal of Clinical Orthopaedics and Trauma., 49 (2024) 102356) https://doi.org/10.1016/j.jcot.2024.102356

Peer review statement: The author list of this article includes an editorial board members, namely Abid Haleem, Abhishek Vaish and Raju Vaishya. We would like to note that they were not involved in the peer review process or any of the decision-making steps of the manuscript.

4. "Gut Microbiome - Should we treat the gut and not the bones?" (Journal of Clinical Orthopaedics and Trauma., 39 (2023) 102149) https://doi.org/10.1016/j.jcot.2023.102149

Peer review statement: The author list of this article includes an editorial board member, namely Vijay Kumar Jain. We would like to note that they were not involved in the peer review process or any of the decision-making steps of the manuscript.

5. "Decoding the hidden realm: Molecular pioneering unravelling osteoarticular tuberculosis diagnosis" (Journal of Clinical Orthopaedics and Trauma., 56 (2024) 102538) https://doi.org/10.1016/j.jcot.2024.102538

Peer review statement: The author list of this article includes an editorial board members, namely Vijay Kumar Jain and Kartikeyan Iyengar. We would like to note that they were not involved in the peer review process or any of the decision-making steps of the manuscript.

6. "Trends of publications on primary sarcomas of bone: A bibliometric analysis" (Journal of Clinical Orthopaedics and Trauma., 63 (2025) 102917) https://doi.org/10.1016/j.jcot.2025.102917

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7. "Bacteriophage therapy in infection after fracture fixation (IAFF) in orthopaedic surgery" (Journal of Clinical Orthopaedics and Trauma., 35 (2022) 102067) https://doi.org/10.1016/j.jcot.2022.102067

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8. "Combating antimicrobial resistance in osteoarticular infections: Current strategies and future directions" (Journal of Clinical Orthopaedics and Trauma., 58 (2024) 102791) https://doi.org/10.1016/j.jcot.2024.102791

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9. "*Mycobacterium Tuberculosis* infection of the wrist joint: A current concepts review" (Journal of Clinical Orthopaedics and Trauma., 44 (2023) 102257) https://doi.org/10.1016/j.jcot.2023.102257

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10. "Bone graft tuberculosis outbreak in USA: Is it a concern in India?" (Journal of Clinical Orthopaedics and Trauma., 39 (2023) 102145) https://doi.org/10.1016/j.jcot.2023.102145

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11. "Letter to editor: Sathyendra et al. Comparative study of local injections of autologous platelet rich plasma versus corticosteroid in management of chronic plantar fasciitis" (Journal of Clinical Orthopaedics and Trauma., 62 (2025) 102903) https://doi.org/10.1016/j.jcot.2024.102903

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