A Clinical Study on the Initial Assessment of Arterial Lactate and Base Deficit as Predictors of Outcome in Trauma Patients

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Abstract

Background: Trauma is a leading cause of mortality in India. Outcomes can be improved by early recognition of hemorrhagic shock and expedited management. At present, we rely on traditional vital signs, which are not sensitive measures. Point of care biochemical markers have been emerging as prognostic markers in trauma, but have not been studied in Indian setting. **Aims:** This study aims to study the association between arterial lactate and base deficit (BD) at emergency department (ED) admission and 24 h outcome in trauma patients at risk of hemodynamic compromise. **Materials and Methods:** This was a prospective observational study on 100 trauma patients at risk of hemodynamic compromise in tertiary care center ED. Arterial blood gas analysis at admission and 24 h outcomes were noted and statistically analyzed. **Results:** Arterial lactate ≥ 4 mmol/L (sensitivity 100% and specificity 85.9%), BD ≥ 12 mEq/L (sensitivity 87.5% and specificity 82.6%) had more sensitivity than vital signs for predicting 24 h mortality. Higher lactate and BD were associated with increased blood transfusion requirement. Best cutoff values for predicting transfusion were lactate ≥ 2.9 mmol/L (sensitivity 65.2% and specificity 90.7%), BD ≥ 8 mEq/L (sensitivity 78.3% and specificity 75.9%). BD-based classification was comparable to ATLS classification in predicting mortality and determining transfusion requirements. Patients with higher arterial lactate and BD were found to have higher 24 h Intensive Care Unit (ICU) admission. **Conclusion:** Emergency admission arterial lactate and Base Deficit are useful predictors of mortality, need for blood transfusion and ICU admission at 24 h. It can be used to triage, identify shock early, assess transfusion requirement, and prognosticate trauma patients.

Keywords: Base deficit, blood transfusion, lactate, mortality, trauma

INTRODUCTION

Worldwide, trauma is a leading cause of mortality and morbidity.^[1] India features amongst the countries with highest age-standardized mortality rates due to injuries (116 per 100,000 population).^[2] The golden hour of care after injury is characterized by rapid assessment and resuscitation. It is aimed at the early recognition of hemorrhagic shock and early intervention, which forms the centerpiece of ATLS.^[3]

At present, we rely on traditional vital signs such as blood pressure (BP) and heart rate (HR) to guide the initial workup of injured patients.^[4] BP is usually well maintained and may only fall after 30%–40% of the circulating volume has been lost.^[3] Tachycardia is not a reliable sign to recognize shock. Therefore, vital signs should only be surrogate markers and not direct measures of oxygen delivery. Better marker for

the presence and extent of ongoing hemorrhage may be the actual metabolic products of tissue hypoperfusion such as base deficit (BD) and lactate.

Emergency care system is in its infancy in India.^[5] There is a lacuna of studies regarding trauma care and predictors of outcome in trauma. Our study aims to help bridge this gap in knowledge and assess whether a point of care arterial blood gas (ABG) analysis in the emergency department (ED) can help us detect shock early and manage trauma optimally.

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How to cite this article: Javali RH, Ravindra P, Patil A, Srinivasarangan M, Mundada H, Adarsh SB, *et al.* A clinical study on the initial assessment of arterial lactate and base deficit as predictors of outcome in trauma patients. *Indian J Crit Care Med* 2017;21:719-25.

Access this article online

Quick Response Code:

Website:
www.ijccm.org

DOI:
10.4103/ijccm.IJCCM_218_17

Objectives

The objective of this study is to study the association between ED admission arterial lactate, BD and the 24 h mortality, blood transfusion requirement and Intensive Care Unit (ICU) admission in trauma patients at risk of hemodynamic compromise.

MATERIALS AND METHODS

Study design

Prospective observational study carried out over a period of 18 months on trauma patients presenting to the ED of a tertiary care center. After applying the inclusion and exclusion criteria, a total of 100 patients were eligible to participate in our study.

Inclusion criteria

Poly/isolated trauma patients at risk of hemodynamic compromise such as:

- Penetrating trauma to chest, abdomen, or pelvis
- Pelvis fracture
- Shaft of femur fracture
- Blunt injury to abdomen or chest.

Exclusion criteria

- Presenting after 12 h of injury
- Severe head injuries (arrival Glasgow coma scale ≤ 8) with intracranial bleed
- Blood transfusion before arrival
- Cardiac arrest before arrival
- Transferred after stabilization and resuscitation from a tertiary care center
- Discharged against medical advice within 24 h of admission
- Conditions predisposing to altered lactate levels: heart failure, respiratory failure, liver disease, severe dehydration, patients on metformin/antiretroviral therapy
- Not willing to participate.

Method of study

After taking informed consent, ED admission investigations including Hb, packed cell volume, and ABG were done. Demographic details, vital signs, type and nature of injury, ATLS Classification were noted.

Patients were followed up for a period of 24 h, and the following outcomes were noted:

- Mortality
- Blood transfusion received
- ICU admission.

The above details were statistically analyzed and results were calculated.

Summary statistics was done by measuring mean, median, standard deviation, and proportions. Inferential statistics was done using Chi-square test, independent t-test, receiver operating characteristic (ROC) curve, sensitivity, specificity, positive predictive value (PPV), negative predictive value

(NPV), ANOVA, and Mann–Whitney test. $P < 0.05$ was considered statistically significant.

RESULTS

Demographic analysis revealed 53% of the study population was in the age group of 21–40 years. At presentation, 9% had hypotension, 34% had tachycardia, 26% had shock index >1 , and 31% had Hb <11 g/dl. The overall 24 h mortality in our study population was 8%. Forty-six percent of the patients required blood transfusion and 48% required ICU admission in 24 h.

Outcome: 24 h mortality

ROC curve analysis showed that area under the curve (AUC) for arterial lactate was 0.955 (95% confidence interval [CI], 0.914–0.997) and BD was 0.898 (95% CI, 0.813–0.983) for 24 h mortality [Figure 1].

Difference between 24 h mortality for arterial lactate <4 mmol/L (0%) and ≥ 4 mmol/L (38.1%) was statistically significant ($P < 0.001$) [Figure 2].

ED admission arterial lactate ≥ 4 mmol/L had sensitivity of 100% (95% CI, 67.56%–100%) and specificity of 85.9% (95% CI, 77.31%–91.55%) for 24 h mortality. PPV was 38.1% (95% CI, 20.75%–59.12%) and NPV was 100% (95% CI, 95.36%–100%).

ROC curve analysis revealed a cut off of BD ≥ 12 mEq/L has a sensitivity of 87.5% (95% CI, 52.91–97.76) and specificity of 82.6% (95% CI, 73.6.89) for 24 h mortality. The PPV was 30.43% (95% CI, 15.6–50.87) and NPV was 98.7% (95% CI, 93%–99.77%).

Outcome: 24 h blood transfusion

ROC curve analysis showed AUC for lactate was 0.790 (95% CI, 0.697–0.884) and BD was 0.787 (95% CI, 0.694–0.879) for 24 h blood transfusion requirement [Figure 3].

Using the ROC curve, we arrived at the cutoff value of ≥ 2.9 mmol/L to be most appropriate for predicting transfusion.

Figure 1: Receiver operating characteristic curve analysis for 24 h mortality

ED admission arterial lactate ≥ 2.9 mmol/L had sensitivity 65.2% (95% CI, 50.77%–77.32%), specificity 90.7% (95% CI, 80.09%–95.98%), PPV 85.71% (95% CI, 70.62%–93.74%), NPV 75.38% (95% CI, 63.69%–84.24%), and diagnostic accuracy 79% (95% CI, 70.02%–85.83%).

Difference in blood requirement among the patients with lactate < 2.9 mmol/L (24.6%) and lactate ≥ 2.9 mmol/L (85.7%) was statistically significant ($P < 0.001$) [Figure 4].

Using the ROC curve, we arrived at the cut off of BD 8 mEq/L. BD ≥ 8 mEq/L had sensitivity of 78.3% (95% CI, 64.4%–87.7%) and specificity of 75.9% (95% CI, 63%–85.4%), PPV of 73.5% (95% CI, 59.8%–83.8%) and NPV of 80.4% (95% CI, 67.5%–89%) and Diagnostic accuracy of 77% (95% CI, 67.8%–84.1%).

Using BD-based classification, there was higher mortality and blood transfusion requirement in class 3 and Class 4. These data were statistically significant [Table 1 and Figures 5, 6].

The mortality and transfusion rates linearly increased through class 1 to class 4 of ATLS classification and the relationship was statistically significant.

Outcome: Intensive Care Unit admission

There was a statistically significant difference in 24 h ICU admission in patients with lactate < 4 mmol/L (25.9%) and ≥ 4 mmol/L (86.9%). ($P < 0.001$) [Figure 7].

Figure 2: Twenty-four hours mortality rate for different values of arterial lactate

Figure 4: Blood transfusion requirement in 24 h at different values of arterial lactate

In patients with BD < 12 mEq/L, 35.1% patients required ICU admission. In patients with arterial lactate ≥ 12 mmol/L, 91.3% required ICU admission. This difference was statistically significant ($P < 0.001$) [Figure 8].

Predictors of 24 h mortality

Although hypotension is 95.6% specific for 24 h mortality, its sensitivity is only 62.5%. Tachycardia and shock index have a sensitivity of 87.5%, which is similar to the BD of cutoff value > 12 mEq/L (chosen according to the ROC curve). Arterial lactate > 4 mmol/L has the highest sensitivity among the parameters, with specificity of 85.9% [Table 2 and Figure 9].

Predictors of 24 h blood transfusion requirement

Hypotension has sensitivity of 17.39% for 24 h blood transfusion. Tachycardia and Hb at admission < 11 g/dl has sensitivity of 50%.

Arterial lactate > 2.9 mmol/L (65.22%) and BD ≥ 8 mEq/L (78.26%) has greater sensitivity in predicting requirement of 24 h blood transfusion [Table 3 and Figure 10].

Outcomes arterial lactate ≥ 4 mmol/L and BD ≥ 12 mEq/L are summarized in Table 4.

Figure 3: Receiver operating characteristic curve analysis for requirement of blood transfusion in 24 h

Figure 5: Twenty-four-hour mortality rates in the various classes of the base deficit-based classification

Table 1: Mortality blood transfusion requirement rates in different classes of base-deficit-based classification

BD value (mEq/L)	BD-based classification class	Number of patients	Number of deaths in 24 h	Percentage of 24 h mortality	Number requiring blood in first 24 h	Percentage of patients requiring blood transfusion
<2	1 (no shock)	4	0	0	0	0
2-6	2 (mild shock)	30	0	0	8	26.7
6-10	3 (moderate shock)	33	1	2.9	13	38.2
>10	4 (severe shock)	25	7	21.9	25	78.1

BD: Base deficit

Table 2: Sensitivity and specificity of various clinical and laboratory parameters to predict 24 h mortality

Parameter	24 h mortality			
	Sensitivity		Specificity	
	Percentage	95% CI	Percentage	95% CI
Hypotension (SBP <90 mmHg)	62.5	30.57-86.32	95.6	89.35-98.3
Tachycardia (HR >100/min)	87.5	52.91-97.76	90.3	81.26-95.21
Hb at admission <11 g/dL	62.5	30.57-86.32	71.7	61.81-79.92
Shock index >1	87.5	52.91-97.76	79.4	69.98-86.36
Arterial lactate ≥ 4 mmol/L	100	67.56-100	85.9	77.31-91.55
BD ≥ 12 mEq/L	87.5	52.91-97.76	82.6	73.6-89
Anion gap ≥ 12 mEq/L	50	21.52-78.48	77.2	67.61-84.56

CI: Confidence interval; SBP: Systolic blood pressure; HR: Heart rate; BD: Base deficit; Hb: Haemoglobin

Figure 6: Comparison of 24 h blood transfusion requirement in various classes of base deficit-based classification of shock and ATLS classification

DISCUSSION

The measurement of ED admission arterial lactate and BD were found to be useful in predicting 24 h mortality in our study. This was depicted by ROC curve analysis.

In our study, using the ROC curve, a cutoff value of ≥ 4 mmol/L for arterial lactate had sensitivity of 100% (95% CI, 67.56%–100%). There has been controversy over what cutoff value to use for arterial lactate. One study suggests that it should probably lie between 2 and 2.5 mmol/L.^[6] Okello *et al.* found that patients with lactate above 2.0 mmol/L had 1.19 times risk of death within 72 h per unit increase in lactate.^[7]

Although some studies use a lower cutoff, we found that using a cutoff of 2 mmol/L, our specificity for 24 h mortality decreased

Figure 7: Percentage of patients requiring Intensive Care Unit admission in 24 h at different levels of arterial lactate

to 40.2%. A slight elevation in lactate maybe due to the stress response to trauma and may not be indicative of increased risk of mortality. By using a higher cutoff of 4 mmol/L, we were able to get high sensitivity, and our specificity increased to 85.9%. This can be a more appropriate cutoff.

Odom *et al.* also found that lactate ≥ 4.0 mmol/L had mortality of 18.8% (95% CI, 15.7%–21.9%) and the initial lactate level strongly correlated with mortality.^[8]

In our study, lactate measurement had higher sensitivity than hypotension and tachycardia for predicting 24 h mortality. Therefore, lactate will aid us to detect patients with occult hypoperfusion.

Twenty-four-hour PRBC requirement is both a novel independent predictor of and has the greatest correlation

Table 3: Specificity and sensitivity for 24 h blood transfusion requirement for various clinical and laboratory parameters

Parameter	24 h blood transfusion requirement			
	Sensitivity		Specificity	
	Percentage	95% CI	Percentage	95% CI
Hypotension (SBP <90 mmHg)	17.39	9.1-30.7	98.2	90.2-99.7
Tachycardia (HR >100/min)	50	36.1-63.8	79.6	67.1-88.1
Hb at admission <11 g/dL	50	36.12-63.88	85.2	73.4-92.3
Shock index >1	43.5	30.21-57.75	85.2	77.81-94.81
Arterial lactate ≥ 2.9 mmol/L	65.22	50.77-77.32	90.74	80.09-95.98
BD ≥ 8 mmol/L	78.26	64.43-87.74	75.93	63.05-85.36
Anion gap >12 mEq/L	28.3	17.32-42.55	77.8	65.06-86.8

CI: Confidence interval; SBP: Systolic blood pressure; HR: Heart rate; BD: Base deficit; Hb: Haemoglobin

Figure 8: Percentage of patients requiring Intensive Care Unit admission in 24 h at different levels of base deficit

to mortality in adult trauma patients when compared to injury severity score and shock index.^[9] Our study showed that measurement of ED admission arterial lactate and BD is useful in predicting requirement of blood transfusion in 1st 24 h of admission. Arterial lactate ≥ 2.9 mmol/L (sensitivity 65.2% and specificity 90.6%) and BD ≥ 8 mmol/L (sensitivity 78.3% and specificity 75.9%) were found to be more sensitive measures than hypotension (sensitivity 17.39% and specificity 98.2%) and tachycardia (sensitivity 50% and specificity 79.6%) to predict blood transfusion requirement in 24 h.

Brooke *et al.* studied hemodynamically normal trauma patients and found that an admission lactate of >4 mmol/L had a greater need for massive transfusion (MT) and greater blood requirement.^[10]

BD was previously a widely used biomarker in critical patients. Not only has it been found to correlate with severity of injury and degree of hemorrhage,^[11] but also it has been advocated as a marker of resuscitation adequacy.^[12] This assessment of metabolic acidosis has been incorporated into the standard information that is reported on a routine blood gas analysis. However, due to various confounding factors, reliability of BD was questioned. Recently, there has been a renaissance in the use of BD for the initial assessment of trauma patients.^[13]

Figure 9: Sensitivity and specificity of various clinical and laboratory parameters to predict 24 h mortality

A BD-based classification for hypovolemic shock in trauma patients has also been designed and validated.^[13]

In our study, we found that BD ≥ 12 mEq/L has a sensitivity of 87.5% (95% CI, 52.91–97.76) and specificity of 82.6% (95% CI, 73.6–89) for 24 h mortality. Saad *et al.* found that in polytrauma patients, the cutoff for BD more than 5.6 mEq/L had 64% sensitivity, 93% specificity for predicting mortality. They recommended it to be used with other scoring systems for predicting mortality.^[14] Mofidi *et al.* studied BD in abdominal trauma patients and found a cutoff point of 6 mEq/L has 88.2% sensitivity and 95.2% specificity, with positive and NPVs of

79% and 97.5%, respectively.^[15] In our study, when we chose cutoff of 6 mEq/L, we had high sensitivity (100%), but low specificity (37%). Therefore, we derived the cutoff of 12 mEq/L to achieve better specificity [Table 5].

The resurgence of interest in BD as an early marker in traumatic shock has led to a BD-based classification of hypovolemic shock in trauma. We found that BD-based classification could be used to predict mortality and 24 h blood transfusion.

Mutschler *et al.* studied patients identified from the Trauma registry to validate this BD classification. They found that BD distinguished more precisely between patients at risk of dying than the current ATLS classification of hypovolemic shock. They also found that when the two approaches to classify the extent of hypovolemic shock upon ED admission were compared (ATLS and BD based), the new BD-based classification displayed a higher accuracy for discriminating the need for early blood products than the current ATLS classification of hypovolemic shock. Through Groups II to IV, the percentage of patients who had received at least 1 blood unit during early ED resuscitation was significantly higher compared with patients classified according to ATLS. Regarding the need for blood products, they recommended to watch in class I, consider in class II, act in class III, and be prepared for MT in class IV of BD-based classification.^[13]

One of the important decisions in the ED is the disposition of the patient.

We found that patients' with higher admission arterial lactate and BD had increased ICU admission in 24 h.

Brooke *et al.* studied hemodynamically normal patients and found that admission lactate of >4 mmol/L along with having increased mortality, longer hospital length of stay, greater need for MT and greater blood requirement, had a longer ICU stay. They concluded that in hemodynamically normal trauma patients, the admission lactate of >4 mmol/L is a robust predictor of longer ICU stay and poor outcomes.^[10]

The standard triage criterion for trauma patients has been found to result in overtriage rates of 30%–50% to achieve undertriage rates of 10%. This large number of patients may stress trauma center resources. Lavery *et al.* found that patients with venous lactate ≥ 2 mmol/L had significantly increased relative risks of admission to the ICU, and length of stay >2 days. This study found no significant difference between arterial lactate and venous lactate measured; therefore both the samples could be

Figure 10: Specificity and sensitivity for 24 h blood transfusion requirement for various clinical and laboratory parameters

Table 4: Correlation of outcomes with biochemical markers

Parameter	Value	24 h mortality (%)	24 h blood transfusion (%)	ICU admission (%)
Arterial lactate	≥ 4 mmol/L	38.1	90.5	86.9
	< 4 mmol/L	0	34.2	25.9
BD	≥ 12 mEq/L	30.4	78.3	91.3
	< 12 mEq/L	1.3	36.4	35.1

BD: Base deficit; ICU: Intensive Care Unit

Table 5: Comparison of base deficit cutoff for mortality in different studies

	Cutoff: BD more than (mEq/L)	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Our study (24 h mortality)	12	87.5	82.6	30.43	98.7
Saad <i>et al.</i> ^[14] (mortality)	5.6	64	93	59.5	94.2
Mofidi <i>et al.</i> ^[15] (mortality)	6	88.2	95.2	79	97.5

BD: Base deficit

used. They found lactate is significantly better than Standard Triage Criteria in all patients and was most useful in victims of blunt trauma, especially motor vehicle collisions.^[16]

Davis *et al.* also found that both ICU and hospital length of stay increased with worsening BD ($P < 0.015$ and $P < 0.05$, respectively). The frequency of adult respiratory distress syndrome ($P < 0.01$), renal failure ($P = 0.015$), coagulopathy ($P < 0.001$), and multiorgan system failure (MOF) ($P = 0.002$) all increased with increasingly severe BD.

Dunne *et al.* did a study using multiple logistic and linear regression analyses and confirmed admission lactate and BD as significant independent predictors of mortality, ICU and hospital length of stay ($P < 0.01$).^[17]

Arterial lactate and BD measurement are readily available in most emergency departments, and their values at ED admission could help us in deciding their disposition.

CONCLUSION

Emergency admission arterial lactate and Base Deficit are useful in predicting 24 h mortality, blood transfusion requirement and ICU admission. These values can be used to triage, identify shock early, assess transfusion requirement, and prognosticate trauma patients.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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