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Base deficit is superior to lactate in trauma

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ABSTRACT

Background: Base Deficit (BD) and lactate have been used as indicators of shock and resuscitation. This study was done to determine the association of BD and lactate and to determine if one is superior.
Methods: A retrospective review from 3/2014–12/2016 was performed. Data included demographics, systolic BP, ISS, BD, lactate, blood transfusion, and outcomes. BD and lactate were modeled continuously and categorically and compared.
Results: 1191 patients were included. BD and lactate correlated strongly ($r = -0.76$ $p < 0.001$). Higher lactate and more negative BD were associated with transfusion and mortality. On multivariate regression, only BD was associated with transfusion ($OR = 0.8$, $p < 0.001$). As a categorical variable, worsening BD was associated with decreased BP, higher ISS, increased transfusions and worse outcomes.
Conclusions: BD and lactate are strongly related. BD was superior to lactate in assessing the need for transfusion. The BD categories discriminate high risk trauma patients better than lactate.

1. Introduction

Base deficit (BD) and lactate have been used as biochemical markers of shock, injury severity and mortality since the 1960s.[1–3] Studies have demonstrated that clearance of both lactate and base deficit are associated with volume of resuscitation required, the need for transfusion of blood products and mortality.[4–7] Although BD and lactate are widely used, relatively few studies have evaluated the relationship between them.

An animal study demonstrated strong correlation between lactate and base deficit[8] but human data has been limited. A recent study in trauma patients concluded that lactate was superior to base deficit in determining the risk of mortality.[9] However, there were some methodologic concerns with the study. The purpose of this study was to determine the association of base deficit and lactate and determine if one is superior in the assessment of the acute trauma patient. Our hypothesis was that there is a strong association between lactate and base deficit, and that base deficit is more useful to the clinician in the evaluation of the injured patient.

2. Methods

A retrospective review of all trauma patients admitted to Community Regional Medical Center (CRMC), an ACS verified level I trauma center, from March 2014 through December 2016 was performed. CRMC is a 650 bed hospital in Fresno, California serving a population of greater than 2 million people in central California. The trauma admission lab panel included both an arterial blood gas and serum lactate for the patients with the highest level of trauma team activation, or at physician discretion for lower activation levels. Patients were excluded for missing base deficit or lactate data, or if the samples were drawn more than 10 min apart.

Data collected included demographics, systolic blood pressure on arrival, injury severity score (ISS), base deficit and lactate levels on arrival, administration of blood components (packed red blood cells and fresh frozen plasma) in the first 24 h and outcomes. Base deficit was modeled both as a continuous variable and as a categorical variable: normal (2 to −2), mild (−3 to −5), moderate (−6 to −9), and severe (≤-10).[6,7] Lactate was also modeled both as a continuous variable and as a categorical variable with different cut points (≥2, ≥2.5 and ≥ 4 mmol/L) as described in the literature.[10–12]

Continuous data are expressed as mean ± standard deviation and categorical data as percentages. Lactate and base deficit were correlated using Pearson's correlation coefficient. Groups were compared using Mann Whitney U tests, Chi square, and regression analyses with significance attributed to a p value < 0.05. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS 23.0, IBM).

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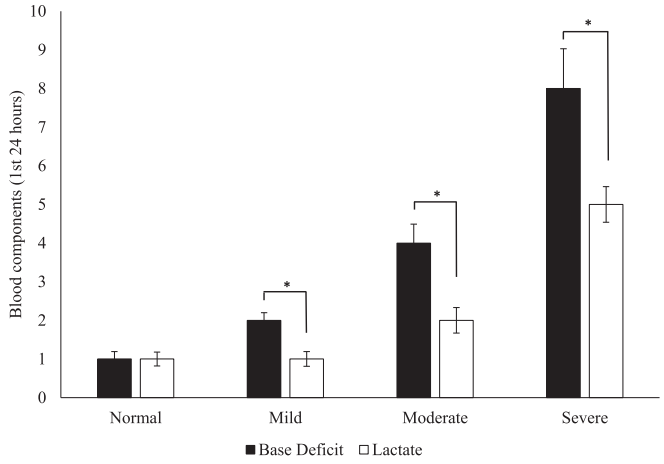

Fig. 1. Blood Component use in the first 24 h by base deficit and lactate categories. *p ≤ 0.001. Error bars represent standard error of the mean.

3. Results

During the study, period there were 8733 trauma admissions with 1964 patients having the highest level of trauma activation. Of these, 977 were excluded for missing lactate or base deficit values or lactate and base deficit samples drawn more than 10 min apart. An additional 204 patients with lower level activation had lactate and base deficit drawn on arrival, resulting in a study cohort of 1191.

The majority of patients were male (78%), with blunt trauma as the mechanism of injury in 71%. The average injury severity score was 18 ± 12. As a categorical variable, worsening base deficit was associated with decreased blood pressure, higher injury severity score, increased transfusion requirements (Fig. 1) and mortality (Table 1) (Fig. 2). As a categorical variable and using the previously established lactate values, differences in blood pressure, ISS, LOS, blood component use and mortality were not significant until the severe category was reached (Table 2) (Figs. 1 and 2). As a dichotomous variable, the cut point for lactate of ≥4 mmol/L had better association with mortality.

Base deficit and lactate had a strong correlation ($r = -0.76$, $p < 0.001$) (Fig. 3). The mean BD in survivors was −4, and −6 in the non-survivors ($p < 0.001$). The difference in mean lactate between survivors and non-survivors was 3.6 and 5.4, respectively ($p < 0.001$). As continuous variables, higher lactate and more negative base deficit were associated with administration of blood components in the first 24 h (OR = 0.8, $p < 0.001$; OR = 1.2, $p < 0.001$, respectively) and mortality (OR = 0.9, $p < 0.001$; OR = 1.1, $p < 0.001$, respectively). On multivariate regression using lactate and base deficit as continuous variables, only base deficit was associated with administration of blood components (OR = 1.2, $p < 0.001$).

On univariate regression analysis a BD ≤ −6 had an Odds Ratio of 2.3 for mortality ($p < 0.001$). Univariate regression analysis of previously reported cut points for lactate were examined. With a lactate level greater than normal (≥2 mmol/L), the Odds ratio for mortality was 1.5 ($p < 0.05$). A lactate ≥2.5 mmol/L had an Odds Ratio of 1.7 for mortality ($p = 0.004$). When the lactate cut point was increased to ≥4 mmol/L, the Odds Ratio increased to 2.4 ($p < 0.001$). On multivariate regression analysis, BD ≤ −6 (OR 1.6, $p = 0.018$) and lactate ≥ 4 mmol/L (OR 2.0, $p = 0.005$) remained significant for mortality whereas lactate below this threshold did not.

4. Discussion

This study demonstrated a strong correlation between base deficit and lactate. On univariate analysis, both BD and lactate were significantly associated with administration of blood products (packed red blood cells and fresh frozen plasma) and mortality. On multivariate regression analysis, only base deficit was associated with administration of blood products. When modeled as categorical variables, both markers were associated with increased ISS, increased transfusion requirement and mortality.

The association of lactate to increased mortality in shock was initially described by Broder and Weil[1] and Vitek and Cowley.[3] Subsequent studies demonstrated that longer time to normalization of lactate was associated with increased mortality.[5,13,14] However, one study found that admission lactate levels did not predict mortality in trauma patients.[15] There are a number of studies that attempted to categorize lactate levels or describe a 'cut point' for lactate, but there has been a lack of consensus to date. Lavery et al. found that a higher than normal lactate level (≥2 mmol/L) in trauma patients predicted an ISS ≥ 13, the need for ICU resources and prolonged hospital stays.[10] Neville et al. noted that elderly trauma patients with a lactate ≥2.5 mmol/L were 3.7 times more likely to die than those with a lactate level <2.5 mmol/L.[11] Mikulaschek et al. found that the serum lactate was significantly higher in non-survivors versus survivors at 16 h after admission to the ICU (4.0 versus 2.8).[12] Gale et al. used a lactate level ≥4 mmol/L to define a 'shock' subgroup to predict early and late deaths.[9]

Base deficit was described in assessing response to resuscitation, at the Da Nang Medical Research group, noting a greater improvement in base deficit than pH with resuscitation.[2] In a civilian setting, Davis et al. noted that with worsening BD, patients had lower initial systolic blood pressure, increased resuscitation requirements, ISS and mortality.[4] Subsequent studies also demonstrated an association between worsening BD and admission blood

Table 1
Base Deficit by category.

BD Category	Normal (2 to −2)	Mild (−3 to −5)	Moderate (−6 to −9)	Severe (<−10)
N	410	398	266	117
Systolic BP	129 ± 30	120 ± 28*	112 ± 33*	89 ± 49*
Lactate	2.1 ± 1.3	3.0 ± 1.4*	4.7 ± 2.5*	10.5 ± 4.9*
Blood (1st 24 h)	1 ± 4	2 ± 4*	4 ± 8*	8 ± 11*
ISS	15 ± 11	17 ± 11^	19 ± 13*	24 ± 16*
ICU LOS (survivors)	3 ± 6	5 ± 10^	7 ± 11*	9 ± 11*
Mortality %	45 (11%)	41 (10%)	35 (13%)	44 (38%)*

*p < 0.001 versus normal category, ^ p < 0.01 versus normal category.
BD = base deficit.
Systolic BP = systolic blood pressure.
Blood = packed red blood cells and fresh frozen plasma (units).
ISS = Injury Severity Score.
ICU LOS = intensive care unit length of stay.

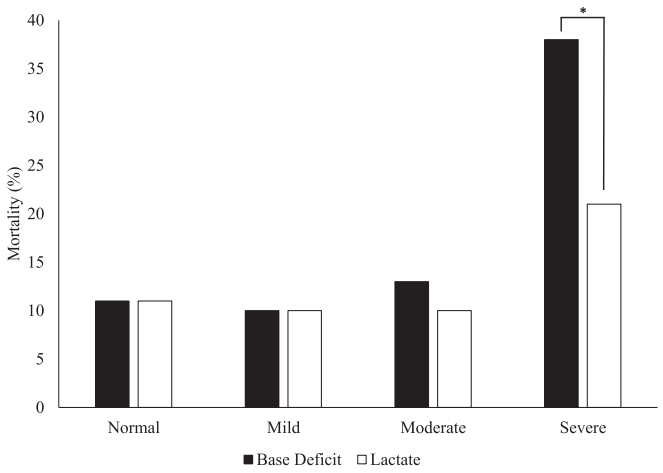

Fig. 2. Mortality percentage by base deficit and lactate categories. *p < 0.001.

pressure, injury severity score, volume of resuscitation, blood transfusion and mortality.[6,7,16] Base Deficit categories were initially defined as mild (2 to −5), moderate (−6 to −14) and severe (≤−15).[4] These categories were refined in 1996 and in other studies to include normal (2 to −2), mild (−3 to −5), moderate (−6 to −9) and severe (≤-10).[6,7,17]

There have been numerous studies evaluating and comparing biochemical markers of perfusion. Kaplan evaluated pH, BD, lactate anion gap and strong ion gap in patients with major vascular injury. All the indicators were strongly associated with outcome but the strong ion gap discriminated most effectively with the area under the receiver operator curve.[18] Mikulaschek et al. found that lactate was superior to both base deficit and anion gap 16 h after ICU admission.[12] Martin et al. noted similar performance of lactate and base deficit on admission to the intensive care unit, but only a modest correlation (r = –.52) between the markers. Additionally, they noted that increased lactate was more predictive of outcomes after ICU admission.[19] In an animal model of hemorrhagic shock and resuscitation, BD and lactate were shown to have strong correlation (r = –.79, p < 0.001).[8] The current study demonstrated a remarkably similar and strong correlation between base deficit and lactate (r = -.76, p < 0.001) on admission to the trauma center prior to resuscitation. Callaway et al. noted that both BD and lactate were significantly associated with mortality in normotensive blunt trauma patients. However, in that study, BD was more abnormal in the non-survivors compared to the survivors and that a 'normal

Table 2
Lactate by Category.

Category	Normal (<2)	Mild (2–2.4)	Moderate (2.5–3.9)	Severe (≥4)
N	361	133	315	382
Systolic BP	126 ± 29	127 ± 29	119 ± 29 ^	108 ± 41*
Base Deficit	−2 ± 2	−3 ± 2*	−4 ± 2*	−8 ± 5*
Blood (1st 24 h)	1 ± 3	1 ± 2	2 ± 6 ^	5 ± 9*
ISS	15 ± 10	16 ± 12	18 ± 12 ^	20 ± 14*
ICU LOS (survivors)	4 ± 8	4 ± 13	4 ± 8	6 ± 10*
Mortality	39 (11%)	13 (10%)	31 (10%)	82 (21%)*

*p < 0.001 versus normal category, ^ p < 0.01 versus normal category.
Systolic BP = systolic blood pressure.
Blood = packed red blood cells and fresh frozen plasma (units).
ISS= Injury Severity Score.
ICU LOS = intensive care unit length of stay.

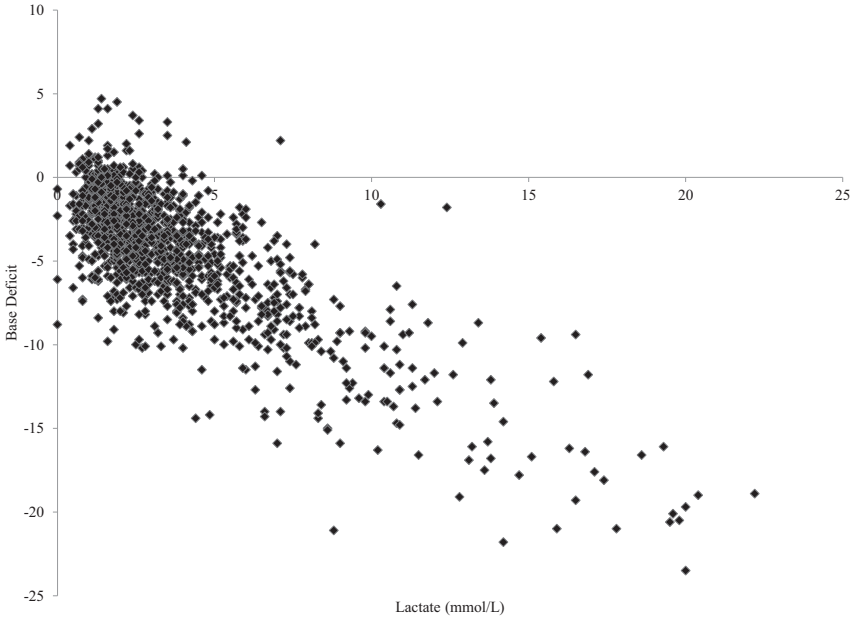

Fig. 3. Relationship of Lactate and Base Deficit. r = –.76, p < 0.001.

lactate does not offer complete reassurance to the clinician'.[17] Gale et al., noted that lactate and BD both correlated with mortality in their retrospective study of blunt trauma patients, presenting in shock.[9] When they excluded the early deaths, only lactate remained predictive. However, that study simply queried the data base for initial base deficit and lactate obtained in the Emergency Department and did not assure that both samples were drawn within minutes of each other. Because BD and lactate change rapidly with resuscitation,[4,5] values from specimens drawn at different time points may reflect the resuscitation rather than differences in the usefulness of the indicator. Other studies have identified and affirmed both BD and lactate as markers of hypoperfusion and predictors of mortality.[11,20]

The BD categories, as previously defined,[6] continued to show differences in blood pressure, ISS, blood component transfusion, ICU length of stay and mortality. Using the previously identified cut points for lactate categories did not discriminate between the groups significantly until the severe category was reached. Adjusting the cut points for lactate to correspond to the BD categories would increase the lactate values to 3 mmol/L for mild, 4.7 mmol/L for moderate and 10.5 mmol/L for severe.

The current study has the inherent limitations of all retrospective studies and is from a single institution. However, it is one of the few clinical studies comparing base deficit and lactate on admission in trauma. Unlike previous studies, the BD and lactate samples were drawn within 10 min to limit potential changes in values with resuscitation. Additionally, it includes both blunt and penetrating trauma patients. The findings and correlations are consistent with previous animal and clinical studies on BD and lactate during shock and resuscitation.

Base Deficit and lactate are useful biochemical markers of shock, resuscitation and the risk of mortality in trauma patients. BD and lactate are strongly correlated and both are associated with mortality and administration of blood, however, on multivariate regression, only BD was associated with administration of blood components. A BD ≤ -6 (or a lactate ≥ 4 mmol/L) should heighten the clinicians awareness that these are indeed high risk trauma patients. The previously defined BD categories (normal, mild, moderate and severe) discriminate high risk trauma patients better than lactate with its variously defined cut points.

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