ORIGINAL ARTICLE

Identifying traumatic brain injury in patients with isolated head trauma: are arterial lactate and base deficit as helpful as in polytrauma?

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Background: Increase in lactate (LAC) within the central nervous system after head trauma is an established marker of traumatic brain injury (TBI).

Objective: To investigate the utility of arterial base deficit (BD) and LAC in identifying TBI in patients with isolated head injury (IHI).

Materials and methods: TBI was defined as Glasgow Coma Scale ≤ 8 , head Abbreviated Injury Severity Score >2 or brain haematoma on CT scan. Patients were divided into two groups: IHI with and without TBI. Data were reported as means (SDs). 131 patients with IHI were studied (mean (SD) age 39 (19) years, 78% male).

Results: 17% of the patients sustained TBI. The mean differences for arterial BD (0.65 mmol/l, 95% CI -0.8 to 2.1) and LAC (0.34 mmol/l, 95% CI -0.7 to 1.4) in patients with and without TBI were not significant. Analysis of receiver operating characteristic curves confirmed that arterial BD and LAC were unable to detect TBI in patients with IHI.

Conclusion: Arterial BD and LAC are poor predictors of TBI in isolated head trauma.

Increased brain tissue or cerebrospinal fluid (CSF) lactate (LAC) has been correlated with severity of injury in the setting of head trauma.^{1–6} Damage to the brain tissue leads to central nervous system (CNS) mitochondrial dysfunction and deformation of membrane. This process impedes pyruvate from entering the Krebs cycle and results in intracellular and extracellular accumulation of LAC.^{7–10} Early reduction in cerebral blood flow and a transient “sub-threshold” brain ischaemia may account for increased brain tissue LAC;¹¹ persistent increase in cerebral and CSF LAC suggests poor prognosis.^{12, 13}

In patients with multiple trauma, arterial LAC is a widely recognised indicator of severity of injury, adequacy of resuscitation and prediction of outcomes.^{14–17} Although most patients suspected of major injury undergo extensive laboratory and radiological testing, both base deficit (BD) and LAC have been used to triage patients with higher potential of sustaining fatal injuries. The value of these screening markers derives from their feasibility and immediate availability. In crowded trauma centres, BD and LAC are commonly used to assign priority for resource allocation in the management of patients with trauma. However, a few studies have examined their diagnostic performance in detecting TBI in patients with isolated head trauma. The widespread use of these markers in emergency settings justifies examination of their applicability in this subgroup of patients with trauma.

We designed this prospective cohort study of patients with isolated head trauma to investigate the utility of arterial LAC in differentiating a minor head injury from a major head injury. We concurrently evaluated arterial BD, a more readily available surrogate for arterial LAC.

METHODS

From January 2004 to January 2005, we conducted a prospective, observational study at the Kings County Hospital Center (KCHC), Brooklyn, New York, USA. KCHC is a level I trauma centre in Brooklyn that receives approximately 150 000

emergency department (ED) visits and 1600 trauma admissions annually. The joint institutional review boards of KCHC and the State University of New York, Downstate Medical Center, Brooklyn, New York, USA, approved the study and waived the requirement of informed consent.

With the assistance of trained data abstractors (academic associates), we prospectively enrolled a convenience sample of patients with trauma who sustained head injury that require imaging studies and arterial blood gas analysis as part of their investigation. The emergency medicine attending physician determined the need for imaging to rule out traumatic brain injury (TBI) following significant head trauma. Patients with extracranial injuries on clinical examination or on completion of the trauma investigation (CT scans, serial haematocrit measurements, diagnostic peritoneal lavage, laparotomy and so on, as indicated) were excluded. Patients transferred from other institutions were also excluded. Data analysis was performed only on patients with isolated head injury (IHI).

We obtained arterial LAC and BD values (Radiometer ABL 725, Copenhagen, Denmark) from patients with IHI upon arrival at ED. Other recorded information included demographic data, vital signs and mechanism of injury.

An attending neuroradiologist confirmed all the official CT scan reports of the head. Upon completion of the trauma investigation, we calculated head Abbreviated Injury Severity Scores (AISSs). Head AISS was graded according to the 1990 revision of the Abbreviated Injury Scale.¹⁸ This scoring system is commonly used to estimate the Injury Severity Score. Only the highest AIS in each region (head in our study) was considered in the final scoring. We defined head injuries as TBI if they met

Abbreviations: AISS, Abbreviated Injury Severity Score; BD, base deficit; CNS, central nervous system; CSF, cerebrospinal fluid; ED, emergency department; GCS, Glasgow Coma Scale; IHI, isolated head injury; KCHC, Kings County Hospital Center; LAC, lactate; ROC, receiver operating characteristic; TBI, traumatic brain injury

any of the three criteria: (1) Glasgow Coma Scale (GCS) ≤ 8 ; (2) head AIS > 2 ; and (3) intracranial haematoma on CT scan of the head (cerebral contusion; subarachnoid, subdural or epidural haemorrhages). These criteria have been validated in identifying patients with TBI.¹⁹⁻²¹ We then divided study participants into patients with and without TBI.

We reported data as means (SDs). Mean differences and 95% CIs were used to compare the means. Student's *t* test and Fisher's exact test were used to compare continuous and categorical data, respectively. We used receiver operating characteristic (ROC) curves to compare the diagnostic performance of arterial BD and LAC in detecting TBI in patients with IHI. Wilcoxon's test permitted comparison of the areas under the curves. We defined significance as $p < 0.05$; all statistical tests were two tailed. Calculations were done using SPSS V.11.0.

A sample size analysis established that 37 patients in each group were needed to detect a significant difference of 1.5 mmol/l ($p < 0.05$) in LAC levels between the groups (SD 1.5; power 80%). We chose an effect size of 1.5 mmol/l as one SD above the normal range for arterial lactate in our institution (< 2.5 mmol/l).

RESULTS

We enrolled a convenience sample of 131 patients with isolated head injury: 102 men (78%) and 29 women (22%). The mean (SD) age was 39 (19) years (range 13–92 years). In all, 22 (17%) patients had TBI and the remaining 109 (83%) patients were categorised as no-TBI. Table 1 presents a comparison of baseline variables among the study groups.

A total of 22 patients (17%) sustained penetrating trauma and 109 (83%) sustained blunt trauma. Penetrating injuries included stab wounds (13, 59%) and gunshot wounds (9, 41%). Blunt trauma mechanisms were motor vehicle crashes (21, 19%), automobile vs pedestrian (13, 12%), assault (46, 42%), falls (19, 17%), motorcycle crashes (2, 2%), bicycle crashes (2, 2%), falling objects (1, 1%) and unknown (5, 5%).

We reviewed CT scan results of the head for all patients. Among patients with TBI, CT scan of the head revealed cerebral contusions ($n = 6$), subdural haemorrhages ($n = 6$), subarachnoid haemorrhages ($n = 7$), epidural haemorrhages ($n = 3$), skull fractures ($n = 4$), facial bone fractures ($n = 5$), intraparenchymal haemorrhages ($n = 3$), intraventricular haemorrhages ($n = 1$) and cervical spine fractures/dislocations ($n = 1$). Two patients with TBI had negative CT scan of the head for intracranial haemorrhage. Since extensive trauma investigation had ruled out the possibility of extracranial injuries and neither patient was intoxicated (ethanol or illicit drugs), a presumptive diagnosis of diffuse axonal injury was considered.

No significant difference was observed between the TBI and no-TBI groups on age ($p = 0.61$), gender ($p = 0.70$) and mechanism of injury ($p = 0.90$). We detected no significant difference between the means for BD (0.65 mmol/l, 95% CI -0.8 to 2.1 ; $p = 0.37$) and LAC (0.34 mmol/l, 95% CI -0.7 to 1.4 ; $p = 0.59$; table 1).

ROC curve analysis revealed no significant difference between the areas under the curves for BD (area: 0.56,

$p = 0.16$) and LAC (area: 0.53, $p = 0.34$) when compared with the unity line in TBI vs no-TBI groups (fig 1).

DISCUSSION

Early recognition of TBI significantly affects clinical outcome. Accurate assessment of the probability of TBI at triage permits more efficient resource utilisation for patients with head trauma. Traditionally, GCS has been used to rapidly identify patients with TBI at triage.²²⁻²³ However, sole reliance on GCS may result in excessive up-triage of patients with trauma; GCS could be affected by numerous factors unrelated to head trauma such as hypoxia, hypotension, medical sedation and ethanol or illicit drug intoxication.¹⁸ For this reason, investigators have been searching for other diagnostic modalities such as CNS-LAC to improve the performance of GCS. Unfortunately, brain tissue or CSF-LAC monitoring is impractical for routine use in the ED.

Measurement of arterial BD and LAC has proven an easy and fast method for predicting morbidity, mortality and resource consumption in patients with multiple trauma.¹⁴⁻¹⁷ Similarly, increased brain tissue or CSF-LAC correlates with the severity of injury in patients with head trauma.¹⁻⁶ Lannoo *et al*⁵ identified increased cerebral LAC as one of the predictors of mortality in patients with severe TBI. Goodman *et al*⁶ established an association between increased CSF-LAC levels (measured by microdialysis) and cerebral hypoxia and ischaemia. DeSalles *et al*⁴ found that patients with poor outcomes following head injury had significantly higher ventricular CSF-LAC levels than those with moderate disabilities or good outcomes. Wagner *et al*²⁴ showed a high increase in LAC concentration in the white matter within the territory of vasogenic oedema of contused area shortly after experimental head injury in an animal model.²⁴ Despite the availability of reasonable evidence on correlating cerebral LAC levels with severity of TBI, the diagnostic performance of arterial LAC and its ability to reflect CNS/CSF-LAC levels in patients with isolated head injury has been inadequately studied.

In pursuit of a convenient marker to predict TBI in emergency setting, our study attempted to determine the

Table 1 Comparison of baseline variables in two study groups (patients with TBI vs no-TBI)

	TBI (n = 22)	No-TBI (n = 109)	p Value
Mean (SD) age (years)	37 (19)	40 (19)	0.61
Gender (%)	79% Men	73% Men	0.70
Mechanism of injury	80% Blunt	82% Blunt	0.90
Mean (SD) BD (mmol/l)	-1.6 (2.9)	-0.99 (2.9)	0.37
Mean (SD) LAC (mmol/l)	2.3 (1.5)	2.6 (2.1)	0.59

BD, base deficit; LAC, lactate; TBI, traumatic brain injury.

Figure 1 Receiver operating characteristic curve for diagnostic performance of base deficit (BD) and lactate in identifying traumatic brain injury.

relationship between TBI and arterial BD and LAC. Our results demonstrated that neither BD nor LAC reliably predicts TBI. Analysis of the ROC curves for these two markers in isolated head trauma victims demonstrates that they perform poorly as diagnostic tests. Siegel²⁵ found that BD had a variable significance in the prediction of oxygen debt in patients with head trauma; arterial BD correlated to poor outcome only when head trauma was accompanied by extracranial injuries. This retrospective study was limited to patients with blunt TBI.

The complexity of LAC production and utilisation may provide an explanation for the findings of our study. Mechanical brain injury may induce mitochondrial metabolism dysfunction that results in the elevation of CSF-LAC.^{7,26} In addition, short-term hyperglycaemia after severe head injury, stress hyperglycaemia, impaired oxidative phosphorylation and decreased cerebral glucose uptake may exacerbate LAC production in cerebral tissue. Increased CNS-LAC persists even after normalisation of serum and CSF glucose.²⁶ However, isolated LAC production (from brain in this case) must exceed the rate of LAC utilisation by the liver, renal cortex, skeletal muscles and even brain itself before affecting systemic LAC. The heterogeneity and variability of brain injuries, as well as the physiological capability of each individual in utilising the excess LAC, may dampen the increase in systemic lactic acidosis.

In summary, increased arterial LAC or BD in patients with IHI should heighten clinical suspicion of extracranial injuries but should not be used as a surrogate marker for IHI alone. A complete investigation is warranted to rule out other significant injuries in these patients.

LIMITATIONS

The study analysed a convenience sample of trauma patients, which represents only a portion of our institution's trauma admissions. Therefore, our study may suffer from sampling bias. Additionally, our study is at risk for a type II error due to small sample size. Our definition of TBI may not encompass all patients at risk for long-term disability due to head trauma. Finally, the description of TBI selected in this study may not represent a wide spectrum of TBI and may rather characterise only moderate to severe injuries.

CONCLUSION

Arterial BD and LAC are not reliable early indicators of TBI in patients with IHI.

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