Original Article

Utility of blood lactate level in triage

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Aim: Simple Triage and Rapid Treatment (START) is commonly used at disaster scenes. The Canadian Emergency Department Triage and Acuity Scale (CTAS) is used in urban and rural emergency departments (ED). However, triage is not always accurate or appropriate. The blood lactate level (BLL) is a major biomarker of physical status. We measured BLL using the Lactate Pro-1710 Test Meter in all patients transported to our ED and assessed their correlation with the triage level determined using START and the CTAS.

Methods: This retrospective study included 510 patients admitted to our ED between January 2011 and July 2012 whose BLL was measured. The patients were classified into triage divisions (green, yellow, red, and black) according to vital signs and chief complaints, and correlations among BLL, triage level, and prognosis were assessed in all groups.

Results: Of the total, 62 patients had cardiopulmonary arrest (CPA), 262 had internal pathologies, and 186 had external pathologies. Significant correlations were observed between BLL and both START and CTAS triage. Also BLL was significantly higher in severe patients categorized with START and CTAS ($P < 0.0001$), especially in the death group when the patients were divided into two groups according to prognosis ($P < 0.0001$). Two patients categorized yellow with START died during the hospitalization, however BLL of these two patients were high on admission at the ED.

Conclusion: BLL could be used to correct the triage level, and decide the priority of treatment and transportation even within the same triage level, thereby avoiding under-triage.

Key words: Blood lactate level, Lactate Pro-1710, Simple Triage and Rapid Treatment (START), The Canadian Emergency Department Triage and Acuity Scale (CTAS), Triage

INTRODUCTION

SIMPLE TRIAGE AND Rapid Treatment (START) is commonly used at disaster scenes.¹ It is a simple triage system that can be used by lightly trained laypeople and emergency department (ED) personnel.² It was developed in 1983 by staff members of the Hoag Hospital³ and Newport Beach Fire Department in California, USA. The most important task of START is the rapid selection of severely injured patients from a large number of patients. In many situations, START is used in chaotic pre-hospital settings. Under these conditions, even trained medical staff may have difficulty in executing triage accurately and rapidly.^{4,5}

The Canadian Emergency Department Triage and Acuity Scale (CTAS) has been recognized as a significant improvement for standardizing triage in urban and rural EDs in Canada.⁶ In 1999, the Society of Rural Physicians of Canada's Emergency Committee began discussions on issues raised by the implementation of the CTAS in rural communities.⁷ By 2000, the CTAS had become a major system, which is now being used worldwide to classify and evaluate a large number of patients in EDs or mass casualties at disaster sites. On the basis of the CTAS, the original triage system used in Japan has developed into the Japanese Triage and Acuity System. In most EDs, specially trained nurses use the CTAS to evaluate physical status and decide treatment priority.

These representative major triage systems are slightly different according to their location. However, they are similar in regard to the evaluation of injury severity and treatment priority in chaotic and emergency situations. The first responder at the disaster scene or trained medical staff at the

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ED evaluates injury severity and decides treatment priority. Each triage system has objectivity to classify triage status to some extent, but the final decision regarding treatment priority depends on the subjective opinion of the responder. Therefore, the triage level is not always accurate or appropriate.

The blood lactate level (BLL) is a major biomarker of physical status^{8–12} and is reportedly a prognostic factor for survival in patients with critical external and internal injuries. We have been focusing on the applicability of BLL measurement during triage in EDs. In addition, portable instruments (Lactate Pro-1710; Arklay, Kyoto, Japan) that can measure BLL rapidly have recently been developed.

We investigated whether BLL could be used to classify and correct the triage level for critical patients at EDs or disaster scenes by measuring BLL in all patients transported to our ED and assessing the correlation of BLL with the triage level determined as per START and CTAS.

PATIENTS AND METHODS

THE STUDY PROTOCOL was approved by the Institutional Review Board of Juntendo University (Chiba, Japan). Written informed consent was obtained via the Internet website of our hospital or after providing a verbal explanation of the study to each patient or a close relative.

The ED of Urayasu Hospital (Urayasu, Japan) covers approximately 1.6 million individuals residing in southeast Chiba and along the eastern border of Tokyo. Annually, approximately 17,000–22,000 patients walk in, and 5,000 critically ill patients are transported by ambulance to our ED. Therefore, we treat all conditions ranging from common ailments to severe and critical conditions such as trauma, burn, toxicity, shock, sepsis, and cardiopulmonary arrest (CPA).

As an initial study, we measured BLL using a conventional method and the Lactate Pro-1710 in patients transported by ambulance from January 2011 to March 2011. Blood lactate levels in venous or arterial blood samples were measured using the RapidLab 1265 Test Meter (Siemens, Munich, Germany). The Lactate Pro-1710 can be used to measure BLL within 60 s in only 5 μ L blood. In addition to ease of use, this instrument is superior in terms of portability (about the size of a credit card) and weight (50 g). The correlation between BLL measured using the conventional method and that measured using this new instrument was evaluated in a preliminary study.

As a secondary study, BLL was measured using the Lactate Pro-1710 in all patients transported to our ED between January 2011 and July 2012. All patients were retrospectively classified into groups that received triage using START or CTAS. On the basis of clinical records and labo-

ratory findings, we retrospectively checked physical status, including vital signs, chief complaints, and final diagnosis, and classified the patients into four groups: green, including subjects with minor injuries requiring less urgent assistance; yellow, including injured patients whose transport can be delayed; red, including injured patients who can be helped by immediate transportation; black, including expectant patients who are beyond help using START. We also classified patients into five groups (levels 1–5) with CTAS. Finally, we evaluated BLL and triage status in all groups.

Blood lactate levels measured using the conventional method and Lactate Pro-1710 were compared using Pearson's correlation with GraphPad Prism version 5.02 (GraphPad, San Diego, CA, USA). Each BLL measurement for each triage type was evaluated by one-way ANOVA. If ANOVA suggested differences between triage groups, pairwise comparisons were made by calculating Dunnett's *q* statistic. A *P*-value of <0.05 was considered statistically significant.

RESULTS

A TOTAL OF 166 patients were transported to our ED during the first research period from January 2011 to March 2011. Eighty patients were enrolled in this preliminary study after providing informed consent. A strong correlation was observed between BLL measured using the conventional method and that measured using the Lactate Pro-1710 ($R^2 = 0.94941$; Fig. 1). Therefore, we concluded that BLL measurement was easier and quicker when the Lactate Pro-1710 was used compared to the conventional

Fig. 1. Correlation of blood lactate levels measured by the Lactate Pro-1710 Test Meter and a conventional blood gas analysis apparatus (BGAA). Blood lactate levels measured by these two methods showed a strong correlation ($R^2 = 0.94941$).

Fig. 2. Blood lactate levels (BLL) in each triage level in simple triage and rapid treatment scores. Patients in our emergency department (ED) were retrospectively subjected to triage with the Simple Triage and Rapid Treatment (START) method ($n = 514$). The y-axis shows the BLL measured using the Lactate Pro-1710, a blood lactate test meter. The x-axis shows the triage level according to the START method. The BLL of each triage group was: black, 106 ± 44 mg/dL; red, 47 ± 39 mg/dL; yellow, 20 ± 13 mg/dL; green, 16 ± 11 mg/dL (mean $\pm$ SD). This graph shows that the triage level increases with an increase in BLL. Significant correlations were seen between the black group and the red, yellow, and green groups, also between the red group and yellow and green groups ($P < 0.0001$). Closed diamonds, survivors; cross marks, non-survivors.

method. On the basis of this preliminary study, we decided to use this device for the evaluation of BLL.

A total of 523 patients were transported to our ED during the second research period from January 2011 to July 2012; of these, 510 were enrolled. A total of 262 patients (51%) were admitted to our ED for acute internal pathologies, 186 (37%) for external pathologies such as trauma, burn, and toxicity, and 62 for CPA. Traumatic CPA was included as an external pathology.

We checked vital signs and their symptoms from medical records. Triage was retrospectively carried out for all 510 patients: 89 were classified in the black category, 77 in the red category, 303 in the yellow category, and 41 in the green category (Fig. 2).

All patients were also assigned codes, namely blue ($n = 108$), red ($n = 93$), yellow ($n = 181$), and green ($n = 117$). Figure 3 shows the correlation between BLL and triage category classified using the CTAS. Patients with a higher BLL belonged to a more severe CTAS triage level. This result

Fig. 3. Blood lactate levels (BLL) in each triage level in the Canadian Emergency Department Triage and Acuity Scale (CTAS). Patients were retrospectively subjected to triage using the CTAS method. The y-axis shows the BLL measured using the Lactate Pro-1710 blood lactate test meter. The x-axis shows the triage grade according to the CTAS method. This graph shows that the triage level increases with an increase in BLL. The BLL of each triage group was: group 1, 96 ± 47 mg/dL; group 2, 37 ± 35 mg/dL; group 3, 20 ± 7 mg/dL; group 4, 18 ± 14 mg/dL; group 5, 15 ± 11 (mean $\pm$ SD). Significant correlations were seen between group 1 and groups 2, 3, 4, and 5, and group 2 and groups 3 and 4 ($P < 0.0001$).

suggests that BLL also reflected the severity of the condition as classified by the CTAS.

At a major disaster site, many casualties with various types of trauma are encountered. Therefore, as a subgroup analysis, we re-evaluated BLL to classify patients with external pathologies.

Figure 4 shows the data of patients with external pathologies including trauma, poisoning, and other invasive external forces classified according to START (Fig. 4A) and CTAS (Fig. 4B). In these patients, BLL correlated with each START and CTAS triage level. In addition to this subgroup analysis, we assessed triage quality for vital signs. In general, survivors were classified into severe triage levels such as black and red (Fig. 4). Almost all patients classified in the black group had a high BLL, and their prognosis after hospital admission was death. Conversely, almost all patients classified into the less severe triage levels of green or yellow had low BLL, and the prognosis after hospital admission was survival. However, two patients in the yellow classification had high BLL, and, unexpectedly, their prognosis was death. This result suggests that, even though the triage level of yellow or green is con-

Fig. 4. Blood lactate levels in patients with external pathologies in each triage level. The blood lactate levels of the patients with external pathologies including trauma, poisoning, and other invasive external forces in each triage level of the Simple Triage and Rapid Treatment (START) (A), and the Canadian Emergency Department Triage and Acuity Scale (CTAS) (B). Significant differences are shown in each figure (* $P < 0.0001$, ** $P < 0.01$).

Table 1. Chief complaints and final diagnoses of eight patients admitted to the emergency department with a higher blood lactate level than average (62 mg/dL), classified as non-severe

Lactate, mg/dL	Chief complaint	Diagnosis	Outcome
132	Right arm numbness	Lung cancer	Death
93	Left arm paralysis	Lacunar infarction	Survived
86	Post seizure	Epilepsy	Discharged home
74	Fever	Sepsis	Survived
69	Dyspnea	Myocardial infarction	Death
68	Dyspnea	Cardiac failure	Survived
86	Head injury (post intoxication)	Head bruise	Discharged home

sidered a safe level, the triage grade should be re-evaluated or upgraded for patients with a high BLL.

Table 1 summarizes eight patients with a higher BLL than average (62 mg/dL) who were classified into a non-severe group. Their chief complaints and final diagnoses are shown. Two patients were discharged, three were hospitalized and survived, and two died after hospital admission, one from myocardial infarction and the other from lung cancer. One patient who had epileptic stroke and another one who was intoxicated with alcohol had high BLLs but were allowed to go home. These findings indicate that some patients may present with a high BLL that is not related to disease severity, for example, after seizures or excessive alcohol consumption.

DISCUSSION

TRIAGE IS THE process used to decide treatment priority on the basis of the severity of the patient's condition.^{1–3} In particular, at the scene of major disasters,

medical personnel need to decide how to rescue as many casualties as possible with limited medical resources. Triage may result in determining the order and priority of emergency treatment, emergency transport, and the transport destination for the patient. Triage may be used not only at disaster scenes but also at EDs or through telephone-based medical advice systems.^{6,7} Both START^{4,5} and the CTAS^{6,7} are representative triage methods used at disaster scenes and EDs worldwide.

To conduct triage for many casualties or patients, medical personnel need to be trained appropriately. However, the use of these triage systems is not always easy for all staff. Although over-triage can be accepted, under-triage should be avoided.³ To improve precision, we repeatedly perform triage or re-evaluate it as primary triage and secondary triage. Inaccurate triage not only leads to a waste of inadequate medical resources but also delays the administration of appropriate medication to casualties. Therefore, we believe that a reliable biomarker that reflects the severity of the

illness or injury and can be readily measured at the scene is required.

We focused on BLL measured using the Lactate Pro-1710 Test Meter, a small portable instrument. This instrument was as reliable and provided almost identical data as the conventional machine used by our research team (Fig. 1), but it was superior in regard to portability, weight, and rapidity of measurement. Using this instrument in the ED, we measured BLL and compared the triage level that was retrospectively determined as per START (Fig. 2) and the CTAS (Fig. 3). Blood lactate levels showed a significant correlation with the START and CTAS classifications for ED patients (Figs. 2, 3). For patients with external pathologies, who are generally present in large numbers at major disaster scenes, BLL correlated significantly with the triage methods (Fig. 4).

Previous reports have described the medical usefulness of lactate and base deficits in the prediction of mortality of trauma patients.^{8,9} These reports suggest that START and the CTAS, which are based on physiological parameters, are appropriate for classifying and deciding illness severity and treatment priority. In addition to the validity of these triage methods, BLL measurement in this convenient manner can enable its application as a triage at disaster scenes or EDs.

Even at major disaster scenes, there are individuals transported to the hospital with internal illness. To evaluate illness severity and determine the differential diagnoses, a triage system using BLL measurement would be useful. In support of this notion, BLL has been reported to be a predictor of the severity of sepsis,¹⁰ trauma,¹³ and infection¹¹ and the need for intensive care.^{1–5} The lactate level in venous blood is a sensitive and specific parameter to triage severely injured patients. An increased lactate level in venous blood can be used to predict moderate-to-severe injury. Also, a significant association between an increased lactate level and a maximum Abbreviated Injury Score of 4 and 5 was reported. A lactate level of ≥ 2 mmol/L in venous blood appears to predict an injury severity score of ≥ 13 , the need for intensive care unit resources, and prolonged hospitalization.^{14–15}

In an infection study, Shapiro *et al.* ascertained whether the serum lactate level was associated with an increased risk of death in patients with infection admitted to the ED.¹¹ In that study, 1,278 consecutive patients met the enrolment criteria. Mortality rates increased with an increase in BLL: 43 (4.9%) of 877 patients with a BLL of 0–2.5 mmol/L, 24 (9.0%) of 267 patients with a BLL of 2.5–4.0 mmol/L, and 38 (28.4%) of 134 patients with a BLL of ≥ 4.0 mmol/L died. A BLL of ≥ 4.0 mmol/L showed a sensitivity of 36% and a specificity of 92% for any death, whereas it showed a sensitivity of 55% and specificity of 91% for death within 3 days.

The results for this cohort of ED patients with signs and symptoms suggestive of infection support the notion that the lactate level in venous blood can be a promising risk stratification tool. Multicenter validation and comparison of BLL with clinical predictors are required before widespread implementation.

Both START and the CTAS are simple methods. However, they need to be repeated to enable proficiency without delay at disaster scenes and EDs. However, BLL can be measured without specialized training. Therefore, this study proposes a novel triage method using BLL for START or the CTAS.

In our study, two patients died during their hospital stay even though they were classified in a mild triage zone. Therefore, replacing the triage level with BLL measurement can prevent under-triage. Furthermore, BLL can help in determining treatment priority in the same triage group.

There may be limitations to the use of BLL measurement as a triage method at disaster scenes or EDs. First, triage must be completed within a few minutes; however, it takes longer to perform triage, obtain measurements, and compensate for the triage level. Second, measuring only BLL is not sufficient for triage. As shown in Table 1, some patients such as those who suffered seizures or were intoxicated with alcohol, showed a much higher BLL that was not consistent with their clinical condition. Third, the cost of a single measurement is approximately \$US2.20. Finally, before the application of BLL measurement at major disaster scenes, personnel need to gain experience in using this triage method and classifying a large number of patients together.

Further studies should focus on determining the category of patients that would benefit from BLL measurements as a triage method.

CONCLUSIONS

THE LACTATE PRO-1710 Test Meter can be used to measure BLL accurately using a simple and easy method of blood collection from the finger apex at EDs and disaster scenes. In this study, patients in the ED who were classified into severe triage levels as per START and CTAS showed significantly higher BLL. The findings of this study suggest that BLL can be used to correct the triage level and decide the priority of treatment and transportation even within the same triage level, thus preventing under-triage.

CONFLICT OF INTEREST

NONE.

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