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ORIGINAL RESEARCH

The role of test results in the emergency department in the evaluation of major torso injury patients

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Abstract

We studied the role of laboratory tests in the emergency department (ED) for the prediction of outcomes in major torso injury patients. We hypothesized that the laboratory test results in the ED could predict worse outcomes and be complement of the TRISS (trauma and injury severity score) which serves a popular prediction model for trauma patients. Patients with major torso trauma who were sent to a level-I trauma center between January 2016 and December 2020 were retrospectively studied. Demographic information, TRISS, and laboratory data (glucose, lactate, base deficit (BD)) were collected and analyzed. The early death (death within 24 hours from the ED arrival) and the long intensive care unit (ICU) length of stay (LOS) (over seven days) were defined as the primary and secondary outcomes. A prediction model that integrated TRISS and the laboratory test results was created and evaluated by using the receiver operating characteristic (ROC) curve with the area under the curve (AUC). In total, 827 patients were studied. The glucose (255.2 ± 109.9 *vs.* 192.1 ± 77.0, $p < 0.001$) and lactate (77.2 ± 43.4 *vs.* 39.2 ± 26.4, $p < 0.001$) levels were significantly higher in patients who died early. The performance of glucose, lactate and BD in identifying those major torso trauma patients who would die early demonstrated acceptable discrimination (glucose: AUC = 0.687; lactate: AUC = 0.778; BD: AUC = 0.734). Furthermore, a model that integrated the TRISS and laboratory tests showed calibration of AUC = 0.863. Moreover, the levels of BD and glucose were also independent factors of long ICU LOS. In conclusion, checking lactate, BD and blood glucose is recommended in the evaluation of major torso trauma patients. Biochemical markers are beneficial in predicting worse outcomes for patients with major torso trauma and can complement the TRISS for these patients.

Keywords

Major torso trauma; Laboratory test; Glucose; Lactate; Base deficit; TRISS

1. Introduction

Major torso trauma is estimated to account for 10% of global mortality [1, 2]. Among patients with major trauma, 30% of deaths occurred within 24 hours of arrival to a trauma center [3]. These patients with "early death" may be potentially treatable with prompt definite care at trauma centers. However, insufficient information, incomplete evaluation, limited diagnostic resources and a short study period lead to difficulties for physicians in guiding critical decision making during this period of triage and resuscitation. Therefore, a prediction model is needed to identify patients with the potential for early death, and it is crucial to devote immediate and appropriate medical resources to the emergency department (ED).

Current prediction models, such as the injury severity score (ISS), trauma and injury severity score (TRISS) and Revised Trauma Score (RTS), are based on the mechanism of injury, injury severity and condition upon ED arrival. Recently, laboratory tests have become easier and faster to obtain. The use of serum lactate, base deficit (BD) and serum glucose values to predict mortality and morbidity in critically injured or acute injury patients has been described [4–7]. Additionally, these laboratory data have been noted in the prediction of other clinical outcomes of trauma, such as intensive care unit (ICU) admission, hospital length of stay (LOS), blood product requirement, multiorgan failures and the need for emergency operation [4, 8–11].

In the current study, the role of laboratory tests that could be evaluated primarily in the ED was studied. We hypothesized that the laboratory test results in the ED could predict worse outcomes and be complement of the TRISS for trauma patients.

2. Material and methods

2.1 Study setting

Patients with major torso injuries who were primarily brought to our ED between January 2016 and December 2020 were studied retrospectively. Major torso injuries were defined as torso injury in patients with or in the context of (1) systolic blood pressure (SBP) <90 mmHg, (2) Glasgow Coma Scale (GCS) <14, (3) respiratory rate <10 or >29 per minute, (4) penetrating torso injuries, (5) trauma mechanisms such as falling from over 20 feet or (6) a high-risk auto crash (intrusion over 30 cm on occupant side, or over 45 cm on any side; ejection from vehicle; death in same passenger compartment; vehicle telemetry data consistent with high risk injury; auto *vs.* pedestrian/bicyclist thrown, run over, or with significant (>20 mph) impact; motorcycle crash >20 miles per hour) [12]. Patients with isolated head injuries or incomplete records or who died in the ED without responses to resuscitation or were treated in the local hospital primarily and then transferred to our ED were excluded.

In our institution, all major torso trauma patients were managed according to a protocol based on the Advanced Trauma Life Support (ATLS) guidelines [12]. Our institution serves a level-I trauma center with 24/7 in-house trauma surgeons who can perform primary evaluation and trauma surgeries for patients with major torso trauma. The angiographic suite and operation room can be available within one hour for patients who needed emergency hemostatic procedures. Furthermore, an intensive care unit (ICU) specific to trauma patients is also facilitated. The patient distribution and study protocol are shown in Fig. 1.

2.2 Study design

The laboratory test was the focus of the current study. Therefore, blood glucose, BD and lactate values in the ED were routinely recorded and collected. Other evaluated covariables included the general demographics (age and sex), the TRISS score, which was used as a standard scoring system for survival probability prediction, and the need for hemostasis procedures (surgery or angioembolization).

Major torso trauma patients classified as with and without early death (death within 24 hours from ED arrival) were compared. Furthermore, a subsequent multivariate logistic regression (MLR) analysis was performed to evaluate independent factors of early death. The same methodology was also applied for a comparison between major torso trauma patients with and without a long ICU LOS (>seven days).

Performance details related to blood glucose, BD and lactate testing in the evaluation of early death were assessed by determining discrimination and calibration. Discrimination was measured by calculating the area under the curve (AUC) of the receiver operating characteristic (ROC) curve. Calibration was assessed using the Hosmer-Lemeshow Ĉ-test (with $p >$ 0.05 indicating no significant difference between the predicted and observed outcomes) [13]. In addition, the performance outcomes of the conventional TRISS score and the TRISS score with additional laboratory tests were also evaluated using the AUC of the ROC curve.

2.3 Outcome measurement

In the current study, we assessed the impact of laboratory test results on outcomes of major torso trauma patients. The primary outcome is the early death (death within 24 hours after ED arrival) and the secondary outcome is the long ICU LOS (ICU LOS over seven days).

2.4 Statistical analysis

In the current study, nominal data are presented as numbers with percentages and were compared using Chi-square tests. Numerical data are presented as the means (standard deviations) and were compared using Student's *t* test. The significant factors in the univariate analysis were put into the MLR model.

3. Results

During this 60-month study period, a total of 827 major torso trauma patients with a mean ISS of 28.7 ± 11.7 were enrolled in the current study. The mortality rate, ICU LOS and overall hospital LOS were 10.6%, 9.0 ± 10.6 days and 21.1 ± 19.9 days, respectively. Of all patients, there were 88 patients (10.6%) classified as "early death" (death within 24 hours of ED arrival), and had a significantly higher glucose (255.2 ± 109.9 *vs.* 192.1 ± 77.0, $p < 0.001$), higher lactate (77.2 ± 43.4 *vs.* 39.2 ± 26.4, $p < 0.001$) and greater BD (12.6 ± 9.3 *vs.* 6.7 ± 5.5, $p < 0.001$). The proportion of patients with glucose over 200 mg/dL in the early death group was also significantly higher than that in the late death group (69.3% *vs.* 34.9%, $p < 0.001$) (Table 1). Furthermore, a subsequent MLR analysis showed that lactate (odds = 1.026, $p < 0.001$) and glucose over 200 mg/dL (odds = 2.215, $p = 0.004$) served as independent factors associated with early death in major torso trauma patients (Table 2). Blood glucose was not included due to high multicollinearity between the blood glucose level and the proportion of patients with blood glucose over 200 mg/dL (variance inflation factor >10). Moreover, the performance of glucose, lactate and BD in the prediction of major torso trauma patients classified as "early death" showed acceptable discrimination (glucose: AUC = 0.687, 95% confidence interval (CI): 0.620–0.755; lactate: AUC = 0.778, 95% CI.: 0.722–0.833; BD: AUC = 0.734, 95% CI.: 0.670–0.798) and calibration (lactate: Hosmer-Lemeshow Ĉ-test p = 0.769; BD: Hosmer-Lemeshow Ĉ-test p = 0.051) (Fig. 2). The performance of TRISS in the prediction of major torso trauma patients classified as "early death" is shown in Fig. 3. It was characterized by discrimination and calibration of AUC = 0.806, 95% CI.: 0.762–0.850; Hosmer-Lemeshow Ĉ-test p = 0.057. However, after integrating the TRISS and laboratory tests (glucose >200 mg/dL and lactate), the performance in predicting early death in major torso trauma patients improved (AUC = 0.863, 95% CI.: 0.828–0.899; Hosmer-Lemeshow Ĉ-test p = 0.233) (Fig. 4).

Another concern was the long ICU LOS of patients with major torso trauma, in addition to early death. Table 3 shows comparisons between major torso trauma patients with and without ICU LOS over 7 days. Compared with patients without ICU LOS over 7 days, patients with ICU LOS over 7 days had

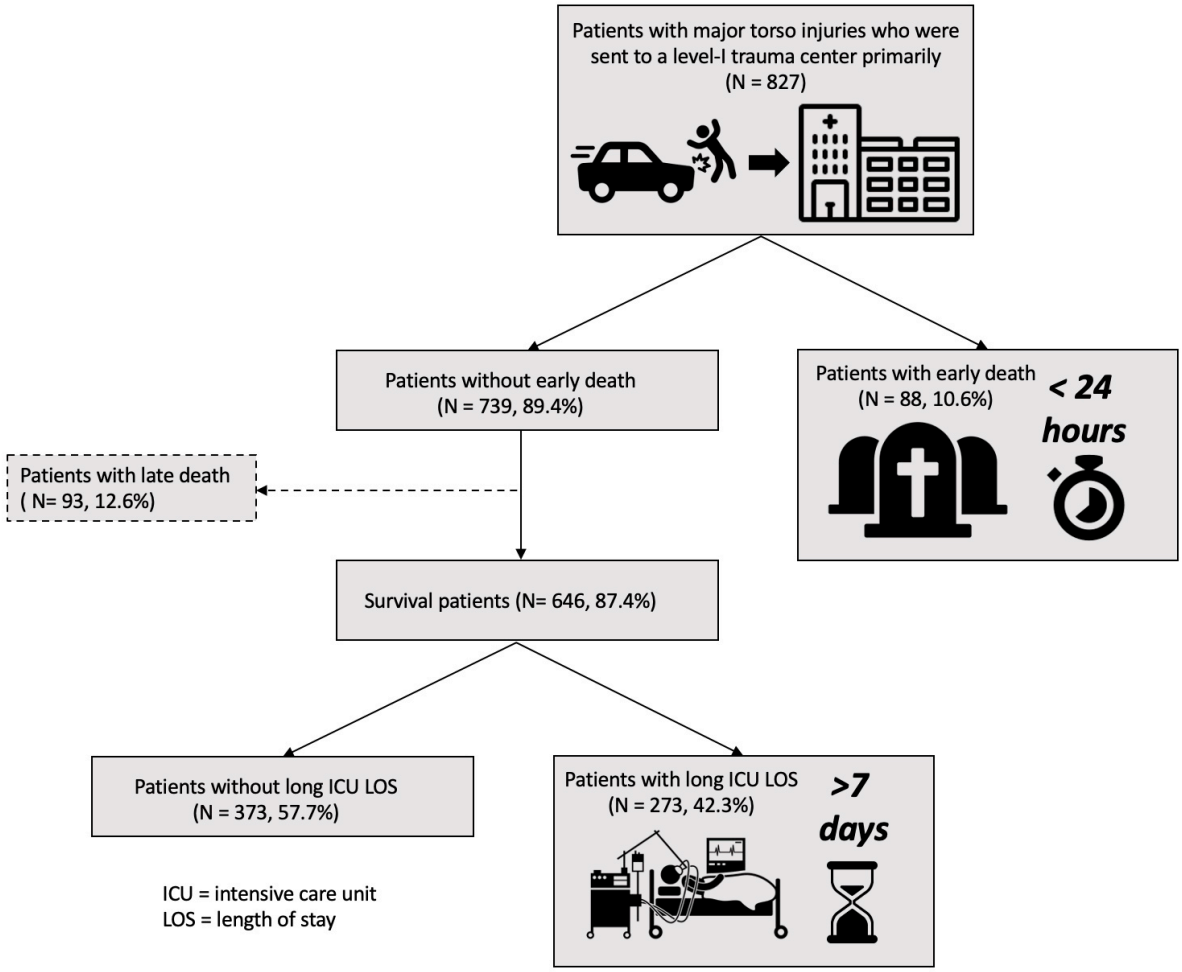

FIGURE 1. Study population, protocol and key numbers in the current study.

TABLE 1. Comparisons between major torso trauma patients with and without early death (death within 24 hours after ED arrival) (N = 827).

	Early death (+) (N = 88)	Early death (−) (N = 739)	*p* value
Age (yr)	49.4 ± 19.9	41.8 ± 20.1	<0.001*
Age >65 (N, %)	19 (21.6%)	112 (15.2%)	0.118†
Age >80 (N, %)	5 (5.7%)	28 (3.8%)	0.391†
Male (%)	68 (77.3%)	557 (75.4%)	0.793†
Laboratory tests at ED arrival			
Lactate (mg/dL)	77.2 ± 43.4	39.2 ± 26.4	<0.001*
Base deficit (mmol/L)	12.6 ± 9.3	6.7 ± 5.5	<0.001*
Blood glucose (mg/dL)	255.2 ± 109.9	192.1 ± 77.0	<0.001*
Glucose >200 mg/dL (N, %)	61 (69.3%)	258 (34.9%)	<0.001†
Need for surgery or angioembolization (N, %)	39 (44.3%)	405 (54.8%)	0.070†

Numerical data: mean ± SD.
Nominal data: N (percentage).
**Student's t test, †Chi-square test.*
ED: emergency department; SD: standard deviation.

TABLE 2. Multivariate logistic regression analysis of the independent risk factors for early death (death within 24 hours after ED arrival) in major torso trauma patients (N = 827).

Variables	*p* value*	Odds of mortality	95% CI.	
			Lower	Upper
Age	0.004	1.018	1.006	1.030
Lactate (mg/dL)	<0.001	1.026	1.016	1.036
Base deficit (mmol/L)	0.817	-	-	-
Blood glucose >200 mg/dL	0.004	2.215	1.299	3.779

**Multivariate logistic regression.*
ED: emergency department; CI: confidence interval.

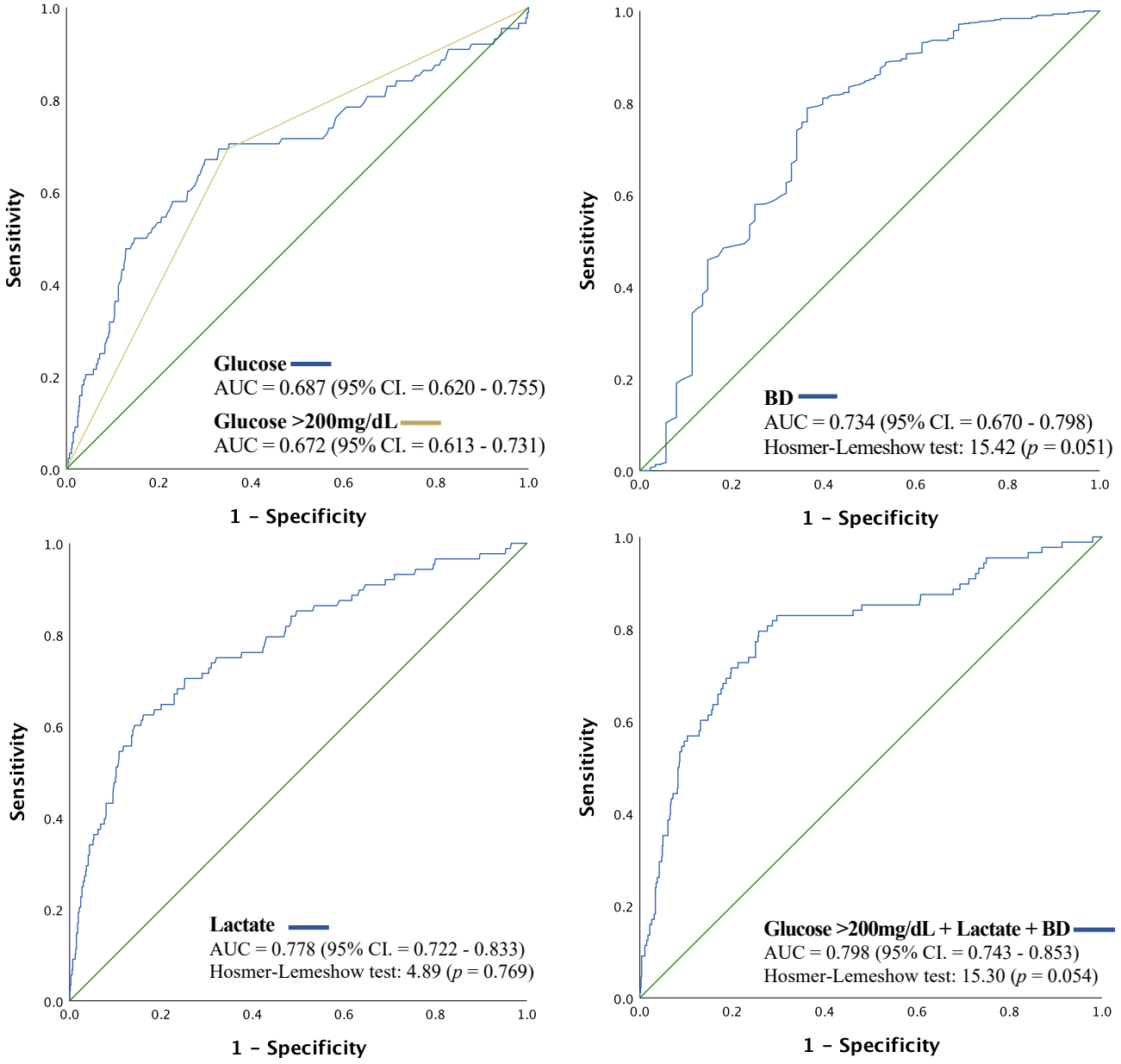

FIGURE 2. The performance of glucose, lactate, BD and combined laboratory tests in the prediction of major torso trauma patients classified as "early death". AUC: area under the curve; CI: confidence interval; BD: base deficit.

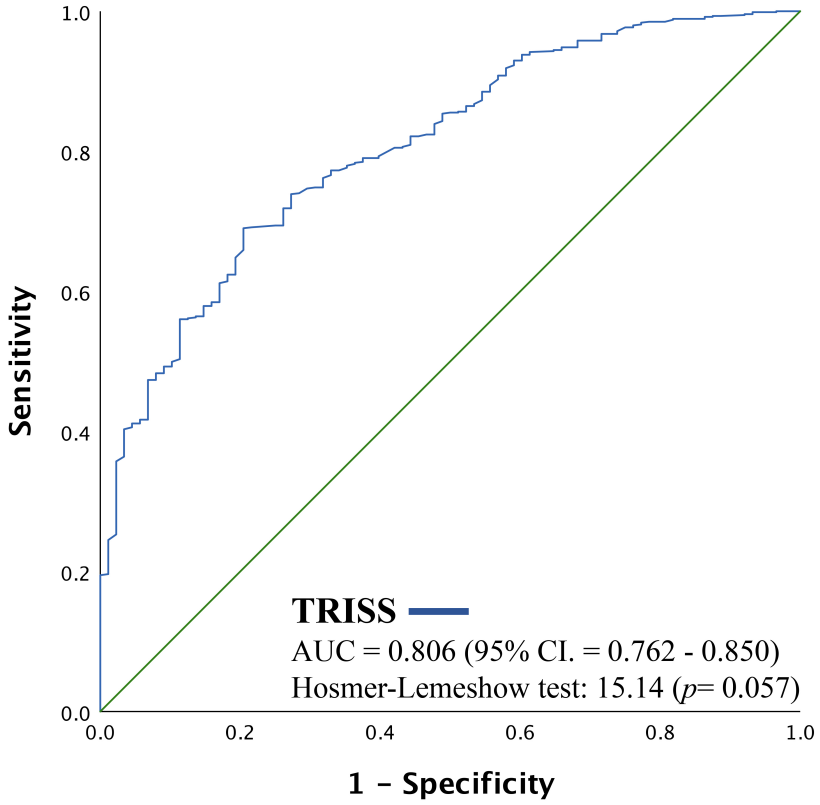

FIGURE 3. The performance of TRISS in the prediction of major torso trauma patients classified as "early death". TRISS: trauma and injury severity score; AUC: area under the curve; CI: confidence interval.

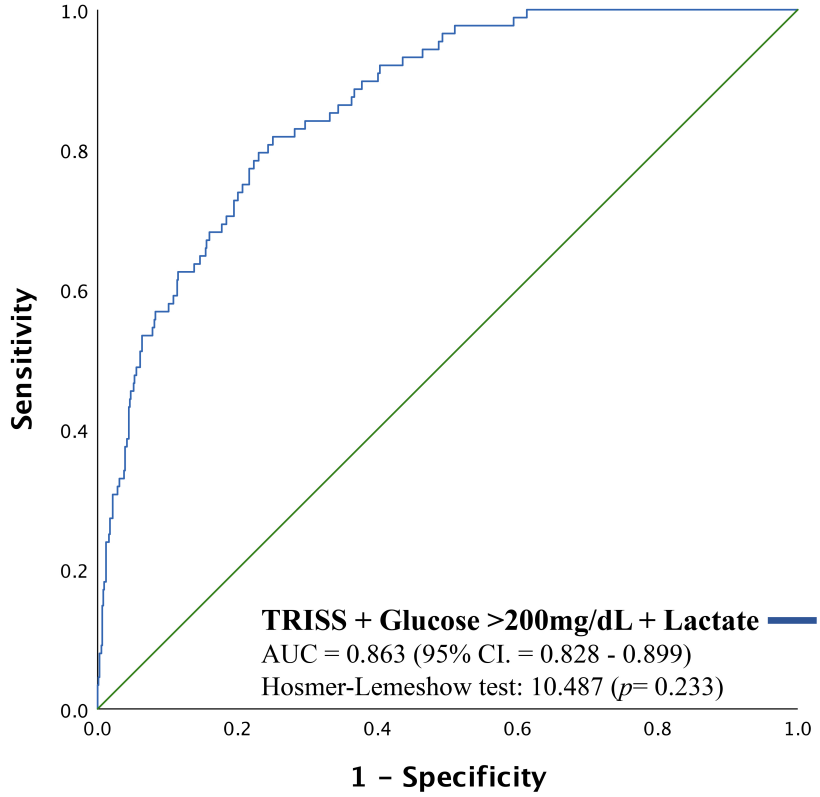

FIGURE 4. The performance of integrating the TRISS and laboratory tests (glucose >200 mg/dL and lactate) in the prediction of major torso trauma patients classified as "early death". TRISS: trauma and injury severity score; AUC: area under the curve; CI: confidence interval.

a significantly higher glucose (209.6 ± 80.5 *vs.* 174.8 ± 64.6, $p < 0.001$), higher lactate (44.6 ± 28.4 *vs.* 33.8 ± 23.1, $p < 0.001$) and greater BD (8.1 ± 5.9 *vs.* 5.4 ± 4.5, $p < 0.001$). The proportion of patients with glucose over 200 mg/dL in the "ICU LOS over 7 days" group was also significantly higher than that in the "without ICU LOS over 7 days" group (44.3% *vs.* 23.3%, $p < 0.001$) (Table 3). Furthermore, a subsequent MLR analysis showed that BD (odds = 1.078, $p = 0.003$) and glucose over 200 mg/dL (odds = 1.829, $p = 0.002$) served as independent factors of association in major torso trauma patients with ICU LOS over 7 days (Table 4). Per the results of current study, worse test results were observed in patients with long ICU LOS (over seven days).

4. Discussion

Current prediction models of trauma outcomes often rely on anatomical and physiological criteria, such as the known TRISS method, which integrates trauma mechanisms, ISS, RTS and age and is well accepted by others due to its accuracy [14]. However, this system does not include the evaluation of laboratory tests, which have been proven to assess current trauma outcomes effectively [4, 8–11]. Thus, we tried to evaluate the role of laboratory tests in the evaluation of major torso trauma patients classified as "early death" [3]. These initial laboratory tests that are easily accessed in the ED seemed able to complement the current prediction models.

Stress hyperglycemia has been described in acute injury or illness situations and may result in continuing hyperglycemia, insulin resistance and glucose intolerance [15]. These stress responses are mediated largely by the hypothalamic–pituitary–adrenal axis and the sympathoadrenal system. The production of cortisol and catecholamines by the hypothalamic–pituitary–adrenal axis and the sympathoadrenal system has a graded response to the degree of stress. Correlations have been observed in the type of surgery,

TABLE 3. Comparisons between survivors with and without ICU LOS over seven days (N = 646).

	ICU LOS >7 days (N = 273)	ICU LOS ≤7 days (N = 373)	*p* value
Age (yr)	45.9 ± 19.8	37.2 ± 18.4	<0.001*
Age >65 (N, %)	53 (19.4%)	32 (8.6%)	<0.001†
Age >80 (N, %)	14 (5.1%)	5 (1.3%)	0.005†
Male (%)	198 (72.5%)	293 (78.6%)	0.093†
Laboratory tests at the ED arrival			
Lactate (mg/dL)	43.3 ± 27.4	33.8 ± 23.1	<0.001*
Base deficit (mmol/L)	7.7 ± 6.0	5.4 ± 4.5	<0.001*
Blood glucose (mg/dL)	207.2 ± 81.1	174.3 ± 64.0	<0.001*
Glucose >200 mg/dL (N, %)	121 (44.3%)	87 (23.3%)	<0.001†
Need for surgery or angioembolization (N, %)	173 (63.4%)	181 (48.5%)	<0.001†

Numerical data: mean ± SD.
Nominal data: N (percentage).
**Student's t test, †Chi-square test.*
ED: emergency department; ICU: intensive care unit; LOS: length of stay; SD: standard deviation.

TABLE 4. Multivariate logistic regression analysis of the independent risk factors for a long ICU LOS (over seven days) in survivors (N = 646).

Variables	*p* value*	Odds of mortality	95% CI	
			Lower	Upper
Age	<0.001	1.025	1.016	1.034
Lactate (mg/dL)	0.942	-	-	-
Base deficit (mmol/L)	0.003	1.078	1.027	1.133
Blood glucose >200 mg/dL	0.002	1.829	1.249	2.678

**Multivariate logistic regression/n.*
ED: emergency department; CI: confidence interval; ICU: intensive care unit; LOS: length of stay.

severity of injury, GCS score, and the Acute Physiology and Chronic Health Evaluation score [16]. It has also been described that stress situations with hemorrhage, hypoxia and sepsis have the highest production levels of catecholamines [17]. Thus, stress may lead to reactive stress hyperglycemia. Blood sugar on admission is a simple and easily obtained biochemical marker in the ED. In a previous study, admission glucose could be seen as an independent predictive factor reflecting the physiological stress response to trauma, acute blood loss, or rapid volume shifts [5]. Similar results were also observed in the current study. A total of 69.3% of patients with blood glucose higher than 200 mg/dL died in the 24-hour group compared to 34.9% of patients in the survival group. The cutoff value was defined by stress hyperglycemia according to previous literature [18]. The MLR in this study proved that blood glucose higher than 200 mg/dL was an independent factor for early death and was associated with an increased risk of early death (odds ratio, 2.215) (Table 2). In conclusion, the additional indication provided by elevated glucose levels should be noted and utilized in planning the care of major trauma patients in the ED.

Serum lactate has been shown to be a sensitive marker of mortality and morbidity in critically injured patients [6]. Excess lactate production is believed to result from anaerobic metabolism and to be a marker of inadequate tissue oxygenation. However, elevated lactate may also result from increased aerobic glycolysis due to the body's stress response and/or from reduced metabolism [8]. Whatever the cause, elevated serum lactate is associated with increased morbidity and mortality in trauma patients and can serve as an effective triage and predictive tool according to previous studies [6, 7]. In our study, serum lactate also played a significant role in our prediction models as expected.

Base deficit was initially proposed as a measure of metabolic acidosis [19]. In trauma patients, it is used as a prognostic marker for outcomes, such as death, significant injuries, and major complications [4]. It has also been described that decreased BD was highly sensitive in detecting patients with significant internal bleeding and the need for blood transfusion [20, 21]. It has been stated in the literature that a threshold BD value of 6 mmol/L suggests the need for more aggressive resuscitation in trauma patients [4].

In the current study, early-death patients had significantly poorer laboratory test results than patients not classified as "early death" (higher glucose levels, greater BDs and higher lactate levels). Furthermore, the AUC of the ROC curves revealed acceptable performances of these laboratory tests in the evaluation of early death. An integration of the TRISS method, which has been applied popularly, and laboratory tests results led to a better performance in the evaluation of the early death of major trauma patients (AUC 0.863, compared to TRISS's AUC 0.806).

In addition to early death prediction, the test results also contributed to the prediction of long ICU admission (over seven days). Prolonged ICU stay may costly in terms of significant medical resource utilization and may be associated with heightened mortality [22–24]. Therefore, the results of the current study supported the usefulness of test results in the evaluation of major trauma patients. The application of laboratory tests to complement current trauma scoring systems could be considered. Results of these tests can be used to help guide further medical resource allocation, help with explaining patients' current conditions, and help with preparing for potential early death.

5. Limitations

There are several limitations in this study. This study is based on a single-center retrospective observation with potential selection bias. Furthermore, discrepancies in the definition of major torso trauma exist among institutions. A prospective study with a polycentric and larger patient sample size and clear definite inclusion criteria should be designed to determine appropriate ED evaluation for these patients.

6. Conclusions

Checking lactate, BD and blood glucose is recommended in the evaluation of major torso trauma patients. Biochemical markers are beneficial in predicting worse outcomes for patients with major torso trauma and can complement the TRISS for these patients.

AVAILABILITY OF DATA AND MATERIALS

Please contact the corresponding author.

AUTHOR CONTRIBUTIONS

CCC and CYF—study conception and design. CCC, PHL and CYF—acquisition of the data. CCC and TAH—analysis and interpretation of the data. CCC—drafting of the manuscript. SCK, YCK, CHH and CHL—critical revision.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the institutional research board of Chang Gung Memorial Hospital (202100283B0). The consent to participate was waived per the rule of the institutional research board of our institution. All authors agree with the publication of this article.

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CONFLICT OF INTEREST

The authors have no commercial associations or sources of support that might pose a conflict of interest.

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