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ORIGINAL RESEARCH

Admission Blood Glucose Level with a Cutoff Value of 15 mmol/L Is a Reliable Predictor of Mortality in Polytraumatized Patients—a Prospective, Observational, Longitudinal Study From a North African Level One Trauma Center

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Background: Abnormal admission blood glucose levels were proved to have a mortality predictive value in polytraumatized patients, as reported by studies in developed countries. Reports from developing countries are scarce.

Objective: To evaluate the reliability of on-admission blood glucose levels in predicting mortality in polytraumatized patients presented to a North African (developing country) trauma center. The secondary objectives were to investigate other possible mortality predictors and if a cutoff value for each could be obtained.

Methods: In this prospective longitudinal study, over one year, we included adult (≥18 years) patients who were polytraumatized (ISS ≥17) and presented to our trauma center within six hours of the trauma incident. Various clinical, laboratory, and trauma scores were collected. Blood glucose levels were assessed from blood samples obtained directly after admission. Patients were divided into five groups based on the admission blood glucose levels.

Results: We included 202 patients, having a mean age of 44±13.9 (20 to 70) years, and 52% were females. The mortality rate was 10.9% (including all patients presented with blood glucose levels≥15 mmol/L). The following were significant mortality predictors, admission blood glucose (OR=3.31, 95% CI=1.902–5.763, p<0.001), serum lactate levels (OR=4.017, 95% CI=1.627–9.917, p=0.003), length of hospital stay (OR=1.18, 95% CI= 1.058–1.305, p=0.003), RTS score (OR=1.43, 95% CI=1.023–2.005, p=0.037), and TRISS score (OR=1.099, 95% CI=1.052–1.148, p<0.001). Admission blood glucose levels cutoff value of 15 mmol/L can significantly differentiate between survivors and non-survivors with sensitivity, specificity, PPV, and NPV of 86.4%, 100%, 100%, and 88%, respectively.

Conclusion: Abnormal admission blood glucose with a cutoff value of 15mmol/L is a significant mortality predictor in polytraumatized patients from developing country trauma center, among other clinical, laboratory, and trauma scores parameters.

Keywords: severely injured patients, polytrauma, admission blood glucose, hyperglycemia, mortality

Introduction

The terms “polytrauma” or “polytraumatized patient” are commonly used in trauma practice, referring to a patient with multiple injuries that involve several organs or systems, which could eventually lead to long-term disability up to death.[1–5]

Furthermore, these consequences might be exaggerated in low- and middle-income countries (LMICs) owing to the limited resources, environmental factors, cultural factors, and inconsistent management protocols, with an estimated 90%

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of the global trauma-related deaths occurring in these countries, and Africa reported the highest incidence among them.[3,6–10]

Evaluating the mortality patterns in polytraumatized patients and their determinants is a step toward enhancing care and improving the survival of such a vulnerable group, to achieve these goals, various clinical signs, laboratory parameters, and biomarkers were investigated in association with trauma scores as significant mortality predictors.[11–15] Apart from polytrauma evaluation scores, these parameters include serum lactate, on-admission blood glucose levels, D-dimer, and creatinine.[14–17]

Hyperglycemia is a metabolic reflection in the acute stage following trauma, which is stress-induced due to the adrenal gland activation leading to insulin resistance, increased glycogenolysis, and gluconeogenesis.[18,19] Furthermore, on-admission blood glucose levels have been considered a reliable predictor of mortality in polytraumatized patients.[13,19–25]

In most studies reporting mortality predictors in polytraumatized patients, scores developed to assess the severity and predict the prognosis of such patients were introduced and validated from developed countries;[26,27] furthermore, such studies carried out in Africa were mainly reported from middle and southern Africa;[3,4,8,9,28,29] however, reports representing North African populations, where patients possess different demographics,[30] are scarce or missing various parameters.[2]

So, our primary objective of the current study was to evaluate the reliability of on-admission blood glucose levels in predicting mortality in polytraumatized patients. The secondary objectives were to investigate other clinical, trauma scores, and laboratory parameters that predict mortality. Second, we needed to determine if we could propose a cutoff value for each parameter that significantly affects mortality.

We hypothesized that, in our population, on-admission blood sugar could be a reliable mortality predictor similar to reports from developed countries.

Patients and Methods

We conducted a prospective observational study in a North African and Middle Eastern level I trauma unit affiliated with a tertiary university hospital over 12 months, starting on January 1, 2020. The study was conducted per the principles outlined in the Declaration of Helsinki, ensuring that the participant's rights, safety, and well-being were always protected. Approval was obtained from our institution's ethical committee (the ethical committee of Assiut Faculty of Medicine, Assiut University, Egypt) before starting the study, IRB No.: 17101010; furthermore, informed consent was obtained from all participants (or their relatives) before their inclusion in the study. ClinicalTrials.gov registration (NCT04100369).

We included polytraumatized (ISS≥17) adult patients (≥18 years) who presented to our trauma unit immediately (within six hours) after the trauma incident and received only pre-hospital management but did not receive resuscitative measurements in another health facility. While patients are known to have comorbidities affecting blood glucose levels (like pregnant women and diabetic patients), immunologically compromising diseases or therapies, and if we could not obtain informed consent from the patient or relatives, or if they refused to participate in the study were excluded.

Upon admission to the trauma unit, all patients were managed by a multidisciplinary team following the ATLS protocol for managing polytraumatized patients.[31,32]

To ensure eligibility and to collect variables needed for investigation, the following parameters were collected from provisionally included patients:

1. Full history (from the patient or relatives) including:
   a. Patient personal data: Age, occupation, and residence.
   b. History: mechanism of trauma, date and time of trauma, the time elapsed till presenting to the trauma unit, and if any, pre-hospital management, comorbidities, and chronic medication intake.
2. Physical examination: this was performed as part of ATLS protocol; the patient was examined clinically (vital signs including pulse, blood pressure (BP), temperature, respiratory rate), Glasgow coma scale (GCS), and the patient's anatomical injury coded according to the Abbreviated injury scale (AIS).

a. Parameters:
   i. Systolic blood pressure (SBP, in mmHg) was measured either by non-invasive method or by invasive arterial measurement in those who were admitted to ICU, and heart rate (HR; in min) was recorded. They were used to calculate the shock index (SI = HR/SBP). A shock index between 0.5 and 0.7 is deemed to be physiologic.
   ii. Polytrauma assessment Scores: The following scores were collected: Injury severity score (ISS), Revised trauma score (RTS), A severity characterization of trauma (SCT), and Trauma Score and Injury Severity Score (TRISS).[16,33,34]

3. Laboratory investigation:
   a. Complete blood account (CBC).
   b. The coagulation profile, including the international normalized ratio (INR), prothrombin time (PTT; in seconds), and thrombocytes (in ×109/L), was measured. Coagulopathy was diagnosed if at least one of the following conditions was met: INR > 1.4 or PTT >37 s.
   c. Laboratory shock parameters include pH value, base excess (BE; in mmol/L), lactate (in mmol/L), bicarbonate (HCO3; mmol/L), glucose (in mmol/L), and hemoglobin (Hb; in g/dL). The blood glucose levels were measured from blood drawn immediately after venous access before any drug or volume administration, with a normal range of 3.66–5.55 mmol/L; hyperglycemia was defined as an admission blood glucose of ≥5.56 mmol/L).
4. Imaging studies: including plain radiographs of the chest, pelvis, cervical and lumbar spine, and an abdominal U/S.
5. Length of hospital stay (LOS), mortality throughout hospitalization, and causes of death were reported.

According to the measured on-admission blood glucose levels, patients were divided into five groups (following the stratification proposed by Kreutziger et al,[35] starting with the upper limit of normal range (5.6 mmol/L as defined by the WHO) as follows: Group 1 (admission blood glucose <5.6 mmol/L), Group 2 (≥5.6–7.5 mmol/L), Group 3 (≥7.6–-10 mmol/L), Group 4 (≥10.1–15 mmol/L), and Group 5 (≥15 mmol/L).

During the study period, 362 polytraumatized patients were initially eligible for inclusion; however, polytrauma criteria were fulfilled in 299 patients. Furthermore, 97 patients were excluded (54 due to known diabetes mellitus or on immune-suppressive therapies, 19 refused to participate, 14 had incomplete records, and 10 died on arrival at the hospital before establishing resuscitative measures), leaving 202 patients for final inclusion.

Statistical Analysis

The data were tabulated and analyzed using SPSS version 26.0 and Microsoft Excel 2016. Descriptive statistics for numerical data were presented as mean ± SD, median (range), and categorical data as number and percentage. Inferential analyses for quantitative variables were conducted using the independent *t*-test for parametric data and the Mann–Whitney *U*-test for non-parametric data. Qualitative data were analyzed using the Chi-square test. Analysis of variance (ANOVA) was used to test for significant differences between more than two normally distributed groups, with normality and homogeneity of variances checked using the Shapiro–Wilk and Levene's tests, respectively. The Kruskal–Wallis test, a non-parametric alternative to ANOVA, was used for skewed data. Post hoc tests included Tukey's HSD for significant ANOVA results and the Bonferroni test for significant Kruskal–Wallis results. Correlations were assessed using Pearson's correlation or Spearman's rank correlation. Receiver operating characteristic (ROC) analysis was used to determine the optimal cutoff value using Youden's index and to evaluate the test's accuracy, including the area under the curve (AUC), sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy. A P-value of less than 0.05 was considered statistically significant.

Results

Two hundred two patients having a mean age of 44±13.9 (20 to 70) years, who matched the inclusion criteria were investigated, 105 (52%) females and 97 (48%) males, and they were divided into five groups based on their admission

blood glucose levels as follows: Group 1: 22 (10.9%) patients, Group 2: 68 (33.7%), Group 3: 51 (25.2%) patients, Group 4: 42 (20.8%), and Group 5: 19 (9.4%).

Regarding the differences in demographics, clinical, and laboratory variables between groups, no statistically significant differences were found based on age, gender, HB, bicarbonate, PH, diastolic blood pressure (DBP), ISS, RTS, and SCT ($p > 0.05$). While statistically significant differences were found in serum lactate, SBP, LOS, mortality incidence, and TRISS score, the details are reported in Table 1. Furthermore, post hoc analysis showed that the serum lactate levels were significantly different among groups ($p \leq 0.001$), except for the difference between groups 4 and 5 ($p = 0.400$). The LOS was significantly higher in groups 4 and 5 compared to groups 1,2 and 3. Group 5 had significantly higher TRISS scores than other groups (Table 1).

The mortality rate was 10.9% (22 patients, including all from group 5 and three patients from group 4). The leading causes of mortality were as follows: Sepsis in 7 (31.8%) patients, MOF in 6 (27.3%), brain injuries in 5 (22.7%) patients, and respiratory failure in 4 (18.2%). The differences between survivors and non-survivors regarding various variables are shown in Table 2, where there were statistically significant differences in admission blood glucose ($p<0.001$), serum Lactate levels ($p=0.003$), LOS ($p<0.001$), SBP ($p=0.014$) and TRISS score ($p<0.001$).

Carrying a Multivariate logistic regression analysis to determine the factors affecting mortality revealed the significance of the following: admission blood glucose (OR=3.31, 95% CI=1.902–5.763, $p<0.001$), serum lactate levels (OR=4.017, 95% CI=1.627–9.917, $p=0.003$), LOS (OR=1.18, 95% CI= 1.058–1.305, $p=0.003$), RTS score (OR=1.43, 95% CI=1.023–2.005, $p=0.037$), and TRISS score (OR=1.099, 95% CI=1.052–1.148, $p<0.001$) (Table 3).

Receiver operating characteristic (ROC) analysis was utilized to differentiate between various mortality-affecting factors, and the following were shown to differentiate between survivors and non-survivors (Table 4), on admission blood glucose levels can significantly differentiate between survivors and non-survivors at a cutoff value of 15 mmol/L with sensitivity, specificity, PPV, and NPV of 86.4%, 100%, 100%, and 88%, respectively (Figure 1A). Serum lactate can significantly differentiate between survivors and non-survivors at 7.3 mmol/L with sensitivity, specificity, PPV, and NPV of 68.3%, 100%, 100%, and 75.9%, respectively (Figure 1B). TRISS can significantly differentiate between survivors and non-survivors at 89.18 with sensitivity, specificity, PPV, and NPV of 92.8%, 86.4%, 87.2%, and 92.3%, respectively (Figure 1C). ISS can significantly differentiate between survivors and non-survivors at 57 with sensitivity, specificity, PPV, and NPV of 71.7%, 50%, 59%, and 64%, respectively (Figure 1D). RTS can significantly differentiate between survivors and non-survivors at 4.8 with sensitivity, specificity, PPV, and NPV of 58.9%, 63.6%, 59%, and 64%, respectively (Figure 1E).

Regarding the correlation analysis (Table 5), we detected significant but weak correlations: a negative correlation between TRISS and ISS in the surviving group, a negative correlation between serum lactate and ISS in the surviving group, and a positive correlation between blood glucose and serum lactate in the non-survived group.

Discussion

Trauma continues to be the primary cause of adult mortality and disability both in developed and developing countries.[4,9,27,28] It is a significant public health concern and a key topic of scientific study in various clinical practice domains, including rehabilitation, critical care, and prevention.[1,4,34] A step for improving the care and survival of polytraumatized patients is evaluating possible mortality predictors.[3,9,18,36,37]

Our hypothesis regarding the efficacy of blood glucose level as a mortality predictor in polytraumatized patients presented to a developing country level one trauma center was confirmed with a proposed cutoff value of 15 mmol/L differentiating between survivors and non-survivors. Furthermore, other parameters, including serum lactate, TRISS, ISS, and RTS, were deemed to be significant mortality predictors as well.

Stress-induced hyperglycemia (increase in blood glucose levels), or what is known as “diabetes of injury”, is one of the adaptive mechanisms occurring after trauma; it occurs secondary to enhanced hepatic gluconeogenesis, the effect of counter-regulatory hormones, reactions, and nervous system signals leading to less glucose absorption in the heart and skeletal muscles.[25,38,39] Mild to moderate stress-induced hyperglycemia could be protective as it fuels the brain and immune system after trauma stress, but if it persists or is elevated, it becomes harmful, leading to endothelial

Table 1 Comparison Between the Study Groups Regarding Demographics, Laboratory and Clinical Parameters

Parameter		Group (1) (n=22)	Group (2) (n=68)	Group (3) (n=51)	Group (4) (n=42)	Group (5) (n=19)	P-value
Age†		49.0 (23–70)	44.5 (20–70)	44.0 (20–70)	45.0 (21–65)	36.0 (20–69)	0.527*
Gender§	Male	11 (50.0%)	34 (50.0%)	24 (47.1%)	17 (40.5%)	11 (57.9%)	0.761**
	Female	11 (50.0%)	34 (50.0%)	27 (52.9%)	25 (59.5%)	8 (42.1%)	
Admission blood glucose (mmol/L) †		4.16 (3.02–5.33)	6.72 (5.56–7.48)	8.58 (7.63–9.97)	12.90 (11–15)	16.80 (15.8–17.2)	**<0.001***
Hemoglobin gm/dl†		7.65 (4.4–10.5)	7.25 (4.2–11)	7.30 (4.3–10.7)	7.70 (4.6–11)	8.20 (4.9–11)	0.411*
Bicarbonate†		21.00 (20–24)	22.00 (20–24)	22.00 (20–24)	22.50 (20–24)	23.00 (20–25)	0.386*
Serum Lactate in mmol/L†		1.75 (0.6–5.7)	4.6 (3–8.8)	7.2 (6–8.9)	9.85 (6.2–13.3)	13.4 (12.1–14.5)	**<0.001*‡**
pH†		7.33 (7.27–7.36)	7.32 (7.27–7.37)	7.31 (7.27–7.36)	7.32 (7.27–7.37)	7.23 (7.23–7.34)	0.618*
SBP†		120 (100–138)	121 (101–138)	122 (102–140)	115 (100–139)	108 (90–110)	**<0.001***
DBP†		73 (60–87)	75 (60–90)	74 (60–89)	75.00 (60–90)	75.00 (61–90)	0.988*
LOS†		18.0 (10–24)	17.0 (10–25)	19.0 (10–35)	25.50 (16–35)	24.0 (17–35)	**0.001*‡**
Mortality Outcome§	Survivors	22 (100%)	68 (100%)	51 (100%)	39 (92.9%)	0 (0.0%)	**0.001****
	Non- survivors	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (7.1%)	19 (100%)	
Injury severity score (ISS) †		44 (18–74)	41 (17–75)	47 (17–75)	51 (17–74)	41 (17–75)	0.456*
Revised trauma score (RTS) †		4.41 (0.048–7.776)	3.78 (0.002–7.965)	5.04 (0.543–7.712)	4.10 (0.217–7.756)	5.04 (1.496–7.6)	0.149*
A severity characterization of trauma (SCT) †		54.84 (1.14–97.38)	46.44 (0.36–97.02)	49.62 (4.5–97.04)	53.79 (2.91–99.64)	56.90 (4.08–97.38)	0.457*
Trauma Score and Injury Severity Score (TRISS) †		50.22 (1.6–89.18)	42.33 (0.94–93.37)	53.08 (4.52–99.76)	61.93 (1.04–105.34)	99.35 (7.08–105.23)	**<0.001*‡**

Notes: † data presented as Median (range). § data presented as numbers and percentages. Comparison between the study groups was done by either *Independent-Samples Kruskal–Wallis Test or ** X^2:Chi-square test. p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant. Bold numbers indicate the statistically significant results. ‡Post Hoc analysis for pairwise comparison between-groups: Blood sugar: P1-2=0.017, P1-3<0.001, P1-4<0.001, P1-5<0.001, P2-3<0.001, P2-4<0.001, P2-5<0.001, P3-4=0.001, P3-5<0.001, P4-5= 0.591. Lactate level: p1-2= 0.001, p1-3< 0.001 p1-4< 0.001 p1-5< 0.001 p2-3< 0.001 p2-4< 0.001 p2-5< 0.001 p3-4= 0.001 p3-5= 0.001, p4-5= 0.400. LOS: P1-2=0.939, P1-3=0.348, P1-4<0.001, P1-5<0.001, P2-3=0.234, P2-4<0.001, P2-5<0.001, P3-4<0.001, P3-5 0.001, P4-5= 0.887. TRISS: P1-2=0.821, P1-3=0.573, P1-4=0.272, P1-5<0.001, P2-3=0.283, P2-4=0.079, P2-5<0.001, P3-4=0.485, P3-5<0.001, P4-5<0.001.

Abbreviations: n, number; SBP, systolic blood pressure; DBP, diastolic blood pressure; LOS, length of stay; mmol, millimole; L, litre; gm, gram; dl, deciliter.

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Table 2 Comparison of Different Demographic, Clinical and Laboratory Parameters Between Survivors and Non-Survivors

Parameter		Outcome		P-value
		Survivors (n=180)	Non-Survivors (n=22)	
Age†		44.00 (20–70)	34.50 (20–69)	0.075*
Sex§	Male	85 (47.2%)	12 (54.5%)	0.516**
	Female	95 (52.8%)	10 (45.5%)	
Admission blood glucose (mmol/L)†		7.56 (3.02–15)	16.70 (11.3–18)	**<0.001***
Hemoglobin mmol/L (gm/dL)†		7.30 (4.2–11)	8.20 (4.9–11)	0.112*
Bicarbonate†		22.00 (20–24)	23.00 (20–24)	0.156*
Lactate (mmol/L)†		6.3 (0.6–13)	13.35 (12.6–14.5)	**0.003***
PH†		7.32 (7.27–7.37)	7.33 (7.17–7.37)	0.183*
SBP†		120.50 (100–140)	108.50 (90–139)	**0.014***
DBP†		74.00 (60–90)	75.0 (61–90)	0.869*
LOS (days)†		19.00 (10–25)	24.00 (17–35)	**<0.001***
Injury severity score (ISS)†		45.00 (17–75)	52.00 (17–75)	0.361*
Revised trauma score (RTS)†		4.31 (0.022–7.965)	5.54 (1.496–7.6)	0.168*
A severity characterization of trauma (SCT)†		49.77 (0.63–99.64)	59.31 (4.08–98.59)	0.194*
Trauma and injury severity score (TRISS)†		50.81 (0.94–99.76)	99.61 (7.08–105.34)	**<0.001***

Notes: † data presented as Median (range). § data presented as numbers and percentages. Comparison between the study groups was done by either * Mann–Whitney *U*-test or ** X2:Chi-square test, p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant. Bold numbers indicate the statistically significant results.

Abbreviations: n, number; SBP, systolic blood pressure; DBP, diastolic blood pressure; LOS, length of stay; mmol, millimole; L, litre; gm, gram; dl, deciliter.

Table 3 Multivariate Logistic Regression Analysis for Factors Predicting Mortality in Poly-Traumatized Patients

Parameters	B	S.E.	Wald	P-value	Odds ratio (OR)	95% C.I.	
						Lower	Upper
Admission blood glucose (mmol/L)level	1.197	0.283	17.921	**<0.001**	3.311	1.902	5.763
Hemoglobin mmol/L (g/dL)	0.118	0.229	0.265	0.607	1.125	0.718	1.764
Bicarbonate	0.217	0.306	0.503	0.478	1.242	0.682	2.26
Lactate in mmol/L	1.39	0.461	9.092	**0.003**	4.017	1.627	9.917
PH	4.475	12.444	0.129	0.719	87.767	0.011	3.04
SBP	40.04	0.04	1.217	0.27	0.957	0.885	1.035
DBP	0.035	0.06	0.346	0.556	1.036	0.921	1.164
LOS (days)	0.161	0.054	9.027	**0.003**	1.175	1.058	1.305
Injury severity score (ISS)	0.018	0.018	1.028	0.311	1.018	0.984	1.054

(*Continued*)

Table 3 (Continued).

Parameters	B	S.E.	Wald	P-value	Odds ratio (OR)	95% C.I.	
						Lower	Upper
Revised trauma score (RTS)	0.359	0.172	4.368	**0.037**	1.432	1.023	2.005
A severity characterization of trauma (SCT)	0.005	0.011	0.198	0.657	1.005	0.983	1.027
Trauma and injury severity score (TIRSS)	0.095	0.022	18.071	**<0.001**	1.099	1.052	1.148

Notes: p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant. Bold numbers indicate the statistically significant results.
Abbreviations: B, Regression coefficient; S.E., Standard error; CI, Confidence interval.

Table 4 Analysis of Areas Under ROC Curves (AUCs), Sensitivity, Specificity of Different Significant Variables Affecting Mortality in Poly-Traumatized Patients

	AUC	Cut off Point	Sensitivity	specificity	PPV	NPV	p-value
Admission blood glucose (mmol/L)	0.979	>15.0	86.4%	100%	100%	88.0%	**<0.001**
S. Lactate (mmol/L)	0.898	>7.3	68.3%	100%	100%	75.9%	**<0.001**
Trauma and injury severity score (TRISS)	0.916	≤89.18	92.8%	86.4%	87.2%	92.3%	**<0.001**
Injury severity score (ISS)	0.860	≤57	71.7%	50%	59%	64%	0.433
Revised trauma score (RTS)	0.960	≤4.8	58.9%	63.6%	61.8%	60.7%	0.128

Notes: p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant. Bold numbers indicate the statistically significant results.
Abbreviations: AUC, Area under Curve; PPV, Positive Predictive Value; NPV, Negative Predictive Value; B, Regression coefficient; S.E., Standard error, CI: Confidence interval.

dysfunction, posting inflammatory responses, and increasing free radicals production with eventual immune and vascular systems failure.[39–41]

Based on these facts, as well as being an inexpensive, rapidly obtained, and readily available laboratory test, assessing on-admission blood glucose level was studied as a possible mortality predictor in polytraumatized patients, and the better its control, the better the survival chance.[23,25]

In the current study, the mortality rate was 10.9%; we identified on-admission blood glucose as a reliable marker for mortality prediction, with levels ≥ 15mmol/L having 100% PPV indicating a robust mortality predictor and an 88% NPV indicating a firm but slightly less perfect predictor of survival. However, our detected cutoff value was higher than values reported in the literature, where Laird et al,[42] and Covino et al[20] reported a cutoff value of 11.1 mmol/L.

In a study by Kreutziger et al evaluating 279 polytraumatized patients (ISS ≥17), they reported a significant increase in hemorrhagic shock incidence following a rise in on-admission blood glucose levels (from 4.4% (glucose 4.1–5.5 mmol/L) to 87.5% (glucose >15 mmol/L), p < 0.0001), and a significant increase in mortality rates associated with increase in blood glucose levels (≤5.50 mmol/L 8.3%; 5.51–7.50 mmol/L 10.9%, 7.51–10 mmol/L 12.4%; 10.01–15 mmol/L 32.0%; ≥15.01 mmol/L 12.5%, p = 0.008),[23] which was a similar finding in the current study.

Although our overall mortality rate was lower than what was reported in a study by Kreutziger et al,[23] which was 15.1%, they had less mortality rate in patient groups with blood glucose levels≥15.01 mmol/L (12.5%) compared to 100% in the current study, which is a considerable difference.

Winkelmann et al retrospectively studied 772 polytraumatized patients (ISS ≥ 16) with a mean age of 44.2 ± 19.4 years. They reported a mortality rate of 12.0% (which was nearly similar to our results), with an admission blood glucose level of > 11.5 mmol/L positively correlated with mortality (Spearman rho = 0.65, $p < 0.001$). The authors reported that patients with such blood sugar levels have a mortality risk of 2.5 (95% CI [1.3–4.8], p = 0.004), with

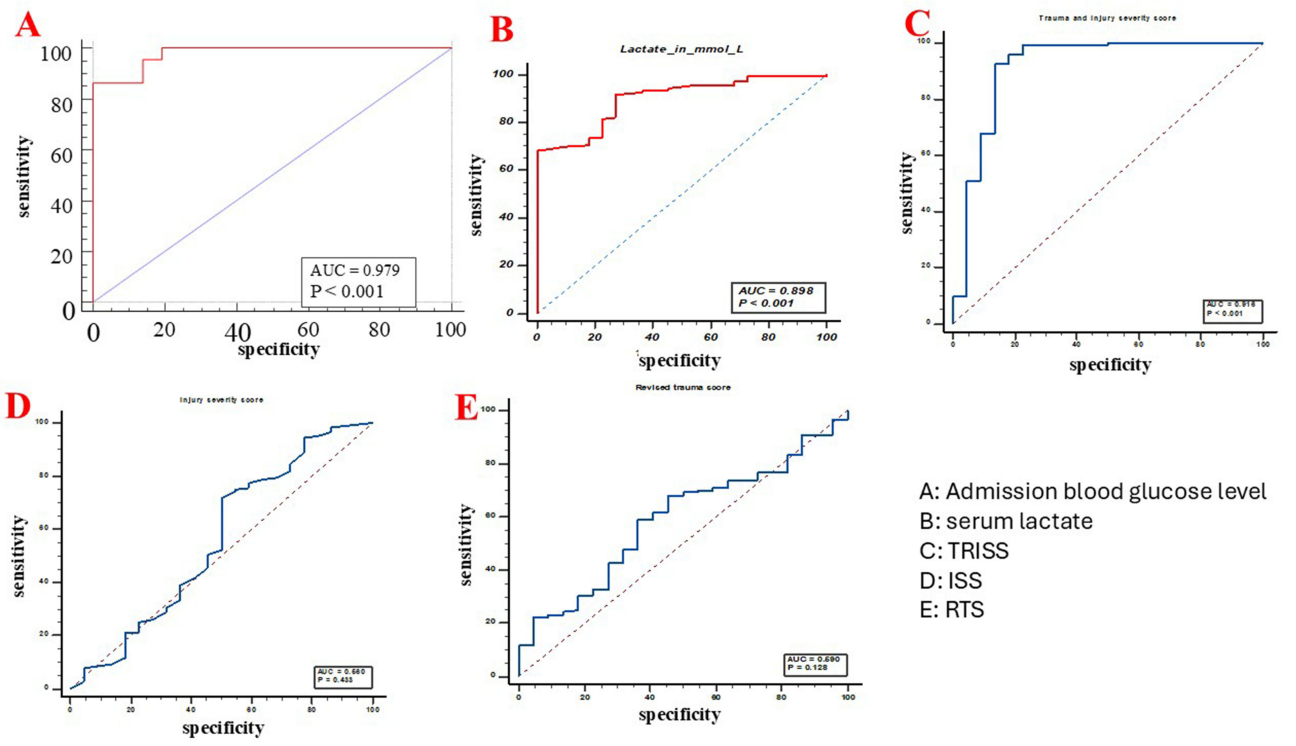

Figure 1 Analysis of areas under ROC curves (AUCs). (**A**), Admission blood glucose level. (**B**), Serum lactate. (**C**), Trauma and injury severity score. (**D**), injury severity score (ISS). (**E**), Revised trauma score (RTS).

a sensitivity and specificity of 45.2% and 87.2%, respectively.[13] In the current study, we reported a higher cutoff value of blood glucose level (>15 mmol/L); however, the mortality risk was 3.3 (95% CI [1.902–5.763], p <0.001), with higher sensitivity and specificity of %86.4 and 100% respectively.

Table 5 Correlation Between Different Predictors of Mortality Among Survived and Non-Survived Patients

		TRISS		**RTS**		**ISS**		**Admission blood glucose**		**Serum Lactate**	
		Survived	**Died**	**Survived**	**Died**	**Survived**	**Died**	**Survived**	**Died**	**Survived**	**Died**
TRISS	r										
	P-value										
RTS	r	−0.058	0.216								
	P-value	0.439	0.334								
ISS	r	−0.194	0.399	0.116	−0.145						
	P-value	**0.009**	0.066	0.121	0.520						
Admission blood glucose	r	0.122	0.053	0.034	−0.104	0.107	0.034				
	P-value	0.103	0.814	0.649	0.645	0.154	0.880				
Serum Lactate	r	−0.034	−0.310	−0.088	0.058	0.055	−0.492	−0.044	0.467		
	P-value	0.653	0.161	0.240	0.798	0.463	**0.020**	0.558	**0.029**		

Notes: p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant. Bold numbers indicate the statistically significant results.
Abbreviation: ISS, Injury severity score; TRISS, Trauma and injury severity score; RTS, Revised trauma score.

Serum lactate level was another significant predictor laboratory marker of mortality detected in the current study; its levels reflect the anaerobic metabolism associated with tissue hypoperfusion during shock, indicating microcirculatory perfusion status and the possibility of progression to a MOF.[43–45] We identified a cutoff value of 7.3 mmol/L to differentiate survivors from non-survivors, having a sensitivity, specificity, PPV, and NPV of 68.3%, 100%, 100%, and 75.9%, respectively. The same results were reported in the literature as well.[43,46] In a study by Sammour et al, the authors identified a much lower cutoff value (2 mmol/L); however, the reported sensitivity, specificity, PPV, and NPV of 81%, 56.8%, 13%, and 97.4%, respectively,[24] which are relatively lower than our results.

In a study from Brazil, Costa LG et al evaluated 200 adult (mean age of 37.3 years) polytraumatized patients (ISS >16) over two years. They reported a 30-day mortality rate of 26%; they identified the following as significant ($p<0.001$) independent early mortality predictors among several clinical and laboratory data collected during the study, which included arterial hemoglobin oxygen saturation (OR=0.988), DBP (OR=0.997), serum lactate level (OR=1.06), GCS score (OR=0.980), infused crystalloid volume (OR=1.016/1000 mL infused), and traumatic brain injury (OR=6.087).[1] Furthermore, they indicated a lactate level increase of 1 mmol/L to be associated with a 6% increase in death probability.[1]

Various scoring systems were introduced to assess polytraumatized patients, including but not limited to anatomically related scores (AIS, ISS, NISS (New Injury Severity Score), and PATI (Penetrating Abdominal Trauma Index), physiologically related scores (RTS, GCS, APACHE (Acute Physiologic and Chronic Health Evaluation)), and combined scores (TRISS).[16]

In the current study, we utilized RTS, ISS, and TRISS scores, which showed considerable reliability in predicting mortality when considering other laboratory parameters. This was reported as well by Costa LG et al, where they found a significantly higher ISS, lower RTS, and lower TRISS in non-survivors (<0.001).[1]

In a study from South Africa by Milton et al retrospectively investigating 108 polytraumatized patients having a mean age of 36.5 ± 14.4 years to assess which trauma scoring system better predicts mortality, they reported a 30-day mortality rate of 28.7%, the cutoff point for ISS was >32 which revealed a sensitivity and specificity of 81% and 61%, respectively, while RTS score had a cutoff value of 8, sensitivity and specificity 81% and 60%, respectively.[3] In contrast, the values reported from our study were a cutoff value of 57 for ISS with sensitivity and specificity of 71.7% and 50%, respectively. In comparison, RTS had a cutoff value of 4.8 with a sensitivity and specificity of 58.9% and 63.6%, respectively.

Mijaljica et al evaluated 75 polytraumatized patients (ISS ≥16) having a median age of 40.5 (16–65) in Serbia, they reported a mortality rate of 36%, they reported significantly higher ISS and TRISS in the non-survivors, TRISS score showed an AUC of 0.900 (95% CI 0.826–0.974), and for ISS it was 0.860 (95% CI 0.779–0.941).[17] In the current study, the AUC for the TRISS score was higher (0.916), while it was lower for the ISS (0.560).

Furthermore, the calculated cutoff value for ISS in Mijaljica et al was 39.5,[17] lower than the value obtained in the current study. Moreover, Milton et al reported an AUC using TRISS, ISS, and RTS for death prediction as 0.828, 0.755, and 0.715, respectively; all were statistically significant.[3] Our study's values for the same scores were 0.916, 0.560, and 0.590, respectively, which are relatively different.

These differences between the results and cutoff values obtained from our study and those obtained from Milton et al and Mijaljica et al studies could be attributed to the difference in the number of included patients and variable patient demographics.

We admit that our study has several limitations. First, being a single-center study with a relatively limited number of included patients could hinder the generalizability of the data obtained on the North African population. Second, the small sample size could affect the cutoff values obtained. Third, we should have followed up with the surviving patient to obtain an overview of post-hospital discharge survival rates. Fourth, although LOS showed a significant difference between survived and non-survived patients, we did not include this parameter in further analysis, as we believe that LOS is associated with the severity of injury and mortality and not a cause. Fifth, although we noticed some differences between our results and what was reported in the literature, we could not precisely investigate what the reasons behind these differences were; however, two crucial issues could have contributed to these differences: the inherent demographic differences between our patients and those from other areas and the care the patients receive during their transfer from

the trauma scene to the hospital. Last, the effect of pre-hospitalization comorbidities was not performed; however, we excluded patients with diseases known to disturb blood glucose levels to decrease this effect.

In conclusion, we believe that mortality in polytraumatized patients could be predicted based on specific clinical and laboratory findings with predetermined cutoff values, including but not limited to on-admission blood glucose levels (which showed high significance), serum lactate levels, and trauma scores, including TRISS, ISS, and RTS. A multicenter study aiming to integrate and investigate all the possible variables predicting mortality in polytraumatized patients is mandatory; furthermore, a continuous update of polytraumatized patients' assessment scores integrating the most recent findings is highly preferable.

Study Setting

Trauma unit, Orthopaedic Department, Assiut University Hospital, Assiut, Egypt. Clinical Trials.Gov registration no.: (NCT04100369).

Data Sharing Statement

All the data related to the study are mentioned within the manuscript; however, the raw data is available from the corresponding author and will be provided upon written request.

Ethical Approval

This article does not contain any experimental studies with human participants or animals performed by any of the authors, and the ethical committee of our institution approved it: Assiut Faculty of Medicine, Assiut University, Egypt (I.R.B. no.: 17101010) (Telephone, Fax: +20882332278, ethics-committee12@yahoo.com, IRB-Asyut@aun.Edu.eg, http://afm.edu.eg).

Consent to Participate

Informed consent was obtained from all participants included in the study or their relatives.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no conflicts of interest in this work.

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