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CLINICAL RESEARCH

Predictors of mortality of trauma patients admitted to the ICU: a retrospective observational study☆

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Road traffic accident;
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Abstract
Background and objectives: Worldwide, trauma is one of the leading causes of morbidity and mortality. The aim of the present study is to identify the predictors of mortality of trauma patients requiring Intensive Care Unit (ICU) admission.
Methods: This retrospective study was conducted in the ICU of our institution in Greece during a six-year period (2010–215).
Results: Among 326 patients, trauma was caused by road traffic accidents in .5%, followed by falls (21.1%) and violence (7.4%). Thirty-day mortality was 27.3%. Multivariate analysis showed that higher New Injury Severity Score (NISS), severe head/neck injury, acute kidney injury, septic shock and hemorrhagic shock were significantly associated with mortality while higher Revised Injury Severity Classification, version II (RISC II) and the administration of enteral nutrition were associated with survival. NISS showed the higher accuracy in predicting 30-day mortality followed by RISC II, while scores based only in physiological variables had lower predictive ability.
Conclusions: Increased mortality was strongly associated with the severity of the injury upon admission. Traumatic brain injury, septic shock and acute kidney injury have also been found among the strongest predictors of mortality. NISS can be considered as a statistically superior score in predicting mortality of severely injured patients.
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Introduction

Trauma continues to present challenges to healthcare systems around the world and remains one of the leading causes of morbidity and mortality in Europe, with road traffic accidents accounting for the majority of fatal injuries.[1] More than 120,000 people die annually in Europe due to road traffic injuries. Greek mortality rate from road traffic injuries is 14.9 per 100,000 people, while European and the worldwide ones are 13.4 and 18.8, respectively.[2]

Mortality after trauma usually shows a trimodal pattern, consisting of immediate deaths (within the first hour), early deaths (during the first 24 hours) and late deaths (after the first day).[3] Severe traumatic injuries are life-threatening and require admission in the Intensive Care Unit (ICU).[2,4] In-hospital mortality of trauma patients admitted to the ICU is associated with severe brain injury and multi-organ failure.[1,3,5] Many severity scores have been proposed to predict mortality comprising of anatomical variables or physiological ones or combining both.[4,6–8]

The aims of this study are to identify the predictors of mortality of the trauma patients requiring ICU admission and assess the ability of different injury severity scores to predict the mortality of critically ill injured patients.

Methods

This single center retrospective study was conducted in the general ICU (capacity of 13 beds) of our institution, Greece, during a six-year period (2010–215). Our institution serves as the only teaching hospital in the south-west Greece, covering a total population of one-million people with a capacity of 700 beds. The study was approved by the Ethics Committee of our institution (nº 571).

All patients older than 18 years of age with traumatic injuries admitted at ICU were included in the study. Pre-hospital care was provided by crews consisted of paramedics with or without medical doctors. All study patients were treated according to ICU protocols. Epidemiologic data were collected from the ICU computerized database (Criticus™, University of Patras, Greece) and the patients' chart reviews. The parameters assessed included demographic characteristics (age, sex), severity scores of illness on admission [Injury Severity Score (ISS), New ISS (NISS), Trauma Score and Injury Severity Score (TRISS), Revised Trauma Score (RTS), Revised Injury Severity Classification, versão II (RISC II) (Table 1), Acute Physiology and Chronic Health Evaluation II (APACHE II) score, Simplified Acute Physiology Score II (SAPS II) and Sequential Organ Failure Assessment (SOFA) score],[8–13] mechanism of trauma, GCS (Glasgow Coma Scale), PaO_2/FiO_2, area of trauma, Length Of Stay (LOS) and complications (hemorrhagic shock, infection, acute kidney injury). Severe trauma injury for each area of trauma was considered as those with Abbreviated Injury Scale (AIS) ≥ 4 points. Infection was categorized as sepsis or septic shock according to new sepsis definition.[14] Acute kidney injury was defined according to Kidney Disease Improving Global Guidelines (KDIGO) recommendations.[15]

SPSS version 21.0 (SPSS, Chicago, IL) software was used for data analysis. Categorical variables were analyzed by using the Fisher exact test and continuous variables with Mann–Whitney *U* test. Multiple logistic regression analysis was used. Odds Ratios (ORs) and 95% Confidence Intervals (CIs) were calculated to evaluate the strength of any association. All statistic tests were 2-tailed and $p < 0.05$ was considered statistically significant. The ability of the scoring systems to predict ICU mortality of trauma patients was investigated using Receiver Ooperating Characteristic (ROC) analysis.

Results

Among 2094 patients admitted to the ICU during the study period, 326 (15.6%) were admitted following severe trauma (Fig. 1). Most of the trauma cases were due to road traffic accidents (233 patients; 71.5%) followed by falls (69; 21.1%) and violence (24; 7.4%). Blunt trauma was the leading mechanism of traumatism (308 patients: 94.2%).

Table 1 Description of different trauma specific severity score.

Score	Type	Parameters assessed	Variables included
Injury Severity Score (ISS)	Anatomical	Three worst injured body regions according to AIS	3
New ISS (NISS)	Anatomical	Three worst injuries according to AIS (even from same body region)	3
Revised Trauma Score (RTS)	Physiological	GCS, systolic blood pressure, respiratory rate	3
Trauma Score and Injury Severity Score (TRISS)	Combined	Based in ISS and RTS	6
Revised Injury Severity Classification, version II (RISC II)	Combined	Mechanism, two worst AIS, TBI demographic, pupil reactivity/size, motor function, American Society of Anesthesiologists score, systolic blood pressure, laboratory values (INR, CRP, hemoglobin, base deficit)	15

AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale.

Table 2 Univariate analysis for predictors of 30-day mortality of all trauma patients admitted at Intensive Care Unit (ICU).

Characteristics	Survivors (237)	Non-survivors (89)	*p*
Demographics			
Age (years)	43.3 ± 20.2	48.3 ± 23.7	0.143
Age ≥ 65 years	46 (19.4%)	32 (36.0%)	0.003[a]
Male gender	196 (82.7%)	74 (83.1%)	1.000
Comorbidities			
Chronic obstructive pulmonary disease	1 (0.4%)	3 (3.4%)	0.064
Arterial hypertension	31 (13.1%)	23 (25.8%)	0.008
Coronary disease	13 (5.5%)	11 (12.4%)	0.054
Chronic heart failure	1 (0.4%)	3 (3.4%)	0.064
Obesity	28 (11.8%)	13 (14.6%)	0.574
Chronic renal insufficiency	4 (1.7%)	6 (6.7%)	0.028
Diabetes *mellitus*	11 (4.6%)	6 (6.7%)	0.417
Mechanism of trauma			
Road traffic accident	176 (74.3%)	57 (64.0%)	0.075
Fall	44 (18.6%)	25 (28.1%)	0.069
Violence	17 (7.2%)	7 (7.9%)	1.000
Penetrating trauma	12 (5.1%)	7 (7.9%)	0.425
Admission data			
First aid offered in hospital other than our institution	155 (65.4%)	56 (62.9%)	0.698
PaO_2/FiO_2 (mmHg)	278.8 ± 116.7	249.1 ± 127.5	0.032
$PaO_2/FiO_2 \leq 200$ mmHg	71 (30.0%)	39 (43.8%)	0.025[a]
Hemoglobin ($g.dL^{-1}$)	11.1 ± 2.2	10.3 ± 2.7	0.017
Hemoglobin ≤ 8 $g.dL^{-1}$	9 (3.8%)	19 (21.3%)	< 0.001
Alcohol consumption	28 (11.8%)	6 (6.7%)	0.225
Operation before admission	111 (46.8%)	42 (47.2%)	1.000
Injury severity scores (upon admission)			
GCS	9.7 ± 4.2	6.9 ± 4.0	< 0.001
GCS < 9	81 (34.2%)	60 (67.4%)	< 0.001
ISS	24.9 ± 8.8	39.9 ± 14.2	< 0.001
NISS	30.3 ± 10.1	50.9 ± 12.2	< 0.001[a]
RTS	6.3 ± 1.2	5.0 ± 1.4	< 0.001
TRISS	82.4 ± 18.7	44.8 ± 30.1	< 0.001
RISC II	−1.3 ± 1.6	−4.1 ± 2.0	< 0.001[a]
APACHE II	13.8 ± 6.3	18.2 ± 5.9	< 0.001
SAPS II	31.8 ± 11.5	44.3 ± 47.8	< 0.001
SOFA	6.9 ± 3.0	8.9 ± 2.8	< 0.001
Area of trauma			
Head/Neck	165 (69.6%)	75 (84.3%)	0.007
Severe (AIS ≥ 4)	40 (28.4%)	37 (60.7%)	< 0.001[a]
Midline shift	29 (12.2%)	33 (37.1%)	< 0.001
Face	70 (29.5%)	27 (30.3%)	0.893
Severe (AIS ≥ 4)	12 (5.1%)	6 (6.7%)	0.589
Chest	127 (53.6%)	41 (46.1%)	0.263
Severe (AIS ≥ 4)	43 (18.1%)	17 (19.1%)	0.873
Abdominal	71 (30.0%)	25 (28.1%)	0.786
Severe (AIS ≥ 4)	26 (11.0%)	13 (14.6%)	0.443
Extremity	46 (19.4%)	15 (16.9%)	0.637
Severe (AIS ≥ 4)	3 (1.3%)	4 (4.5%)	0.091
External	18 (7.6%)	10 (11.2%)	0.374
Hospitalization data			
ICU length of stay (days)	13.8 ± 13.1	7.5 ± 10.0	< 0.001
Hemorrhagic shock	29 (12.2%)	34 (38.2%)	< 0.001[a]
Number of transfusions	2.1 ± 3.3	3.6 ± 5.8	0.187
Acute kidney injury	27 (11.4%)	49 (55.1%)	< 0.001[a]
Hemodialysis	6 (2.5%)	3 (3.4%)	0.709
Infection	98 (41.4%)	52 (58.4%)	0.006
Sepsis (excluding septic shock)	80 (33.8%)	22 (24.7%)	0.140
Septic shock	42 (17.7%)	47 (52.8%)	< 0.001[a]

Table 2 (*Continued*)

Characteristics	Survivors (237)	Non-survivors (89)	*p*
Enteral nutrition	139 (58.6%)	28 (31.5%)	< 0.001[a]
Parenteral nutrition	80 (33.8%)	22 (24.7%)	0.140
Urgent operation during ICU stay	16 (6.8%)	19 (21.3%)	< 0.001

Data are number (%) of patients or Mean ± SD.
Our Institution: ISS, Injury Severity Score; NISS, New ISS; RTS, Revised Trauma Score; TRISS, Trauma Score and Injury Severity Score; RISC II, Revised Injury Severity Classification, version II; APACHE II, Acute Physiology and Chronic Health Evaluation II; SAPS II, Simplified Acute Physiology Score II; SOFA, Sequential Organ Failure Assessment; GCS, Glasgow Coma Scale; AIS, Abbreviated Injury Scale.
[a] Variables included in the multivariate analysis.

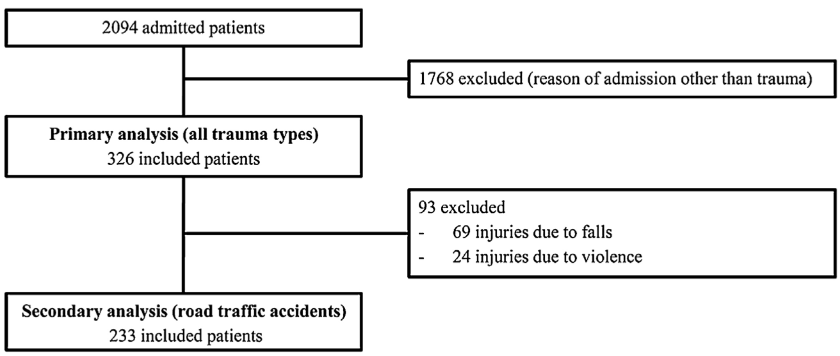

Figure 1 Flowchart of patients.

Thirty-day mortality was 27.3% (n = 89 patients). Univariate analysis for predictors of mortality is depicted in Table 2. Multivariate analysis found that higher NISS ($p <$ 0.001; OR = 1.1; 95% CI 1.1–1.2), severe head/neck injury (AIS ≥ 4) (p = 0.041; OR = 3.3; 95% CI 1.1–10.2), acute kidney injury (p < 0.001; OR = 7.7; 95% CI 2.6–22.6), septic shock (p = 0.001; OR = 6.2; 95% CI 2.1–18.1) and hemorrhagic shock (p = 0.018; OR = 3.7; 95% CI 1.4–10.8) were significantly associated with mortality while higher RISC II (p = 0.004; OR = 0.703; 95% CI 0.554–0.892) and administration of enteral nutrition were associated with survival (p < 0.001; OR = 0.121; 95% CI 0.040–0.365).

Since the majority of patients included in the present study were injured during road traffic injuries, a second analysis comprised by such patients (n = 233) was conducted. Thirty-day mortality of such patients was 24.4% (n = 57). Univariate analysis of predictors of mortality is shown on Table 3. Mortality was independently associated with higher NISS (p < 0.001; OR = 1.2; 95% CI 1.1–1.3), acute kidney injury (p = 0.012; OR = 5.0; 95% CI 1.4–17.4) and septic shock (p = 0.008; OR = 5.5; 95% CI 1.6–19.1), while higher RISC II (p = 0.038; OR = 0.760; 95% CI 0.586–0.985) and administration of enteral nutrition (p = 0.001; OR = 0.124; 95% CI 0.036-0.426) were associated with survival.

The accuracy of different severity scores for 30-day mortality prediction is shown in Table 4. NISS showed the higher accuracy (0.901) followed by RISC II (0.883). Scores based only on physiological variables (RTS, GCS) and common scoring systems (APACHE II, SAPS II, SOFA) had low accuracy (< 0.750), while the rest (ISS, TRISS) had an intermediate one.

Discussion

Injury is one of the leading causes of death in both Greece and Europe comprising of 5% and 6%, respectively of all cases of deaths.[2] Thirty-day mortality was 27.3%, which is comparable to that reported from other studies (23.8–32.7%).[6,7,12] There are some studies that reported lower mortality rates (10.4–17.2%); this difference could be explained by the fact that patients in those studies had lower ISS (19.3–24.8).[1,4,11,16]

In Greece, more than half of fatal injuries are due to road traffic accidents, as was the case in the present study.[2,7,17] The predominance of vehicle accidents may be attributed to driving under the influence of alcohol or drugs, disregard for safety and traffic laws and poor condition of Greek roads.[18]

Early identification of patients at risk of mortality may improve the outcome of severely injured patients. Nine different prognostic scores were assessed for the prediction of 30-day ICU mortality. Other studies have compared these tests, with contradicting results.[12,19,20] Even though scores comprising only of physiological variables such as GCS and RTS are more easily calculated, their accuracy is low. In some studies, general severity scores such as APACHE II, SAPS II and SOFA showed high performance in predicting mortality as compared to anatomical ones, contradicting the results of our study.[4,20] Multivariate analysis independently associated mortality with higher NISS and lower RISC II. NISS showed the higher accuracy among tested scores and can be easily and readily applied in the Emergency Department, rendering it the best choice to rapidly guide physicians.[12,19] Our results contradict the study from Lefering et al.[11] which showed higher accuracy for RISC II (0.953) as compared to NISS (0.849). The main difference among aforementioned

Table 3 Univariate analysis for predictors of 30-day mortality of trauma patients after road traffic accidents admitted at Intensive Care Unit (ICU).

Characteristics	Survivors (176)	Non-survivors (57)	*p*
Demographics			
Age (years)	39.7 ± 19.6	44.2 ± 22.8	0.332
Age ≥ 65 years	29 (16.5%)	16 (28.1%)	0.081
Male gender	150 (85.2%)	47 (82.5%)	0.674
Comorbidities			
Chronic obstructive pulmonary disease	1 (0.6%)	0 (0.0%)	1.000
Arterial hypertension	17 (9.7%)	11 (19.3%)	0.062
Coronary disease	8 (4.5%)	4 (7.0%)	0.494
Chronic heart failure	1 (0.6%)	2 (3.5%)	0.149
Obesity	20 (11.4%)	9 (15.8%)	0.365
Chronic renal insufficiency	3 (1.7%)	3 (5.3%)	0.158
Diabetes *mellitus*	5 (2.8%)	3 (5.3%)	0.417
Mechanism of trauma			
-Pedestrian	23 (13.1%)	12 (21.1%)	0.199
Two-wheel vehicle (driver or passenger)	101 (57.4%)	31 (54.4%)	0.759
Use of helmet	25 (24.8%)	6 (18.8%)	
Four-wheel vehicle (driver or passenger)	52 (29.5%)	14 (24.6%)	0.504
Use of seat-belt	24 (46.2%)	5 (35.7%)	
Admission data			
First aid offered in hospital other than our institution	115 (65.3%)	34 (59.6%)	0.433
PaO_2/FiO_2 (mmHg)	187.5 ± 120.5	255.1 ± 125.0	0.063
$PaO_2/FiO_2 \leq 200$ mmHg	51 (29.0%)	25 (43.9%)	0.050
Hemoglobin ($g.dL^{-1}$)	11.2 ± 2.1	10.4 ± 2.9	0.090
Hemoglobin ≤ 8 $g.dL^{-1}$	6 (3.4%)	13 (22.8%)	< 0.001
Alcohol consumption	23 (13.1%)	2 (3.5%)	0.048
Operation before admission	78 (44.3%)	27 (47.4%)	1.000
Injury severity scores (upon admission)			
GCS	9.5 ± 4.1	6.6 ± 3.7	< 0.001
GCS < 9	63 (35.8%)	41 (71.9%)	< 0.001[a]
ISS	25.5 ± 8.9	40.6 ± 12.9	< 0.001
NISS	30.3 ± 9.8	50.6 ± 11.0	< 0.001[a]
RTS	6.3 ± 1.2	5.0 ± 1.4	< 0.001
TRISS	83.4 ± 17.8	46.4 ± 29.8	< 0.001
RISC II	−1.2 ± 1.6	−3.7 ± 2.1	< 0.001[a]
APACHE II	13.4 ± 5.9	18.1 ± 5.9	< 0.001
SAPS II	31.1 ± 11.5	46.3 ± 58.3	< 0.001
SOFA	6.8 ± 3.0	8.7 ± 2.7	< 0.001
Area of trauma			
Head/Neck	129 (73.3%)	52 (91.2%)	0.005
Severe (AIS ≥ 4)	91 (51.7%)	48 (84.2%)	< 0.001
Midline shift	16 (9.1%)	19 (33.3%)	< 0.001
Face	57 (32.4%)	18 (31.6%)	1.000
Severe (AIS ≥ 4)	7 (4.0%)	3 (5.3%)	0.710
Chest	99 (56.3%)	31 (54.4%)	0.878
Severe (AIS ≥ 4)	30 (17.0%)	9 (15.8%)	1.000
Abdominal	53 (30.1%)	18 (31.6%)	0.869
Severe (AIS ≥ 4)	17 (9.7%)	9 (15.8%)	0.227
Extremity	42 (23.9%)	13 (22.8%)	1.000
Severe (AIS ≥ 4)	2 (1.1%)	3 (5.3%)	0.096
External	14 (8.0%)	8 (14.0%)	0.194
Hospitalization data			
ICU length of stay (days)	13.8 ± 13.1	7.5 ± 10.0	< 0.001
Hemorrhagic shock	18 (10.2%)	22 (38.6%)	< 0.001
Number of transfusions	2.1 ± 3.3	3.0 ± 4.3	0.289
Acute kidney injury	21 (11.9%)	29 (50.9%)	< 0.001[a]

Table 3 (*Continued*)

Characteristics	Survivors (176)	Non-survivors (57)	*p*
Hemodialysis	5 (2.8%)	1 (1.8%)	1.000
Infection	70 (39.8%)	33 (57.9%)	0.021
Sepsis (excluding septic shock)	54 (30.7%)	13 (22.8%)	0.313
Septic shock	30 (17.0%)	31 (54.4%)	< 0.001[a]
Enteral nutrition	107 (60.8%)	17 (29.8%)	< 0.001[a]
Parenteral nutrition	67 (38.1%)	14 (24.6%)	0.078
Urgent operation during ICU stay	13 (7.4%)	13 (22.8%)	0.003

Data are number (%) of patients or Mean ± SD.
Our Institution: ISS, Injury Severity Score; NISS, New ISS; RTS, Revised Trauma Score; TRISS, Trauma Score and Injury Severity Score; RISC II, Revised Injury Severity Classification, version II; APACHE II, Acute Physiology and Chronic Health Evaluation II; SAPS II, Simplified Acute Physiology Score II; SOFA, Sequential Organ Failure Assessment; GCS, Glasgow Coma Scale; AIS, Abbreviated Injury Scale.
[a] Variables included in the multivariate analysis.

Table 4 Accuracy of different scores in predicting 30-day mortality among critically ill trauma patients.

Scores	Accuracy	95% CI
GCS	0.691	0.626–0.757
ISS	0.820	0.771–0.870
NISS	0.901	0.860–0.941
RTS	0.742	0.684–0.800
TRISS	0.859	0.816–0.903
RISC II	0.883	0.841–0.942
APACHE II	0.698	0.613–0.782
SAPS II	0.670	0.601–0.739
SOFA	0.690	0.626–0.755

GCS, Glasgow Coma Scale; ISS, Injury Severity Score; NISS, New ISS; RTS, Revised Trauma Score; TRISS, Trauma Score and Injury Severity Score; RISC II, Revised Injury Severity Classification, version II; APACHE II, Acute Physiology and Chronic Health Evaluation II; SAPS II, Simplified Acute Physiology Score II; SOFA, Sequential Organ Failure Assessment; GCS, Glasgow Coma Scale; AIS, Abbreviated Injury Scale.

study and the present one was that the former included all trauma patients, not only those requiring ICU admission. This difference was depicted in the higher values of severity scores (ISS, NISS, TRISS) and worst outcome reported in the present study. The advantage of NISS is its reliance solely on three anatomical variables (worst injuries) and not on any laboratory values, in contrast to RISC II which depends on 15 different variables (including anatomical, physiological and laboratory), leading to earlier recognition of severe trauma which is necessary to improve outcomes.

As previously shown, the most important cause of death among trauma patients was brain injury.[4,7] In our study, head and neck trauma was the most commonly injured area (73.6% of patients), while severe head injury (AIS $\geq$ 4) was independently associated with mortality among all trauma patients. The importance of head injury on mortality is depicted on the fact that head injury is incorporated into various trauma scoring systems either as an anatomical variable or as a physiological parameter (GCS).[10–12] The high rate of traumatic brain injury in the present study may be explained by the fact that more than half of those who drove a motorcycle (77.3%), or a four-wheel vehicle (56.1%) didn't wear helmet or seat-belt, respectively. The preventive effect of such safety measures is already well-established in the literature.[16,21]

In accordance to previous studies, common complications such as acute kidney injury and hemorrhagic shock were associated with mortality.[16,22,23] Sepsis and especially septic shock remain another important cause of morbidity and mortality among such patients. In the present study, 46.0% of patients developed at least one infection, as reported in previous studies (37–45%), resulting in higher mortality.[1,24,25] In 2013, a study of trauma ICU patients in the United States found an infection rate of 17.1%, significantly lower than that reported in our study.[26] The main explanation of such difference may be that only pneumonia and urinary tract infections were reported in that study,[26] while other types of infections, such as bloodstream infections, were not included; these type of infections are the main cause of infections of patients treated in the Greek ICUs.[27] The majority of infections in Greek ICUs, including ours, are caused by multidrug-resistant gram-negative bacteria, especially *Klebsiella pneumoniae*, that are associated with high mortality due to limited treatment options.[27]

Interestingly, enteral nutrition was associated with higher survival rates among our critically ill trauma patients. Even though enteral nutrition among critically ill patients in general is preferable to parenteral due to its effect in shortening ICU length of stay and reduction of infections, no effect on ICU or overall mortality is proven.[28] Among traumatic brain injury patients, guidelines propose the early initiation of nutritional support, although the method of feeding remains a debatable subject.[29] A study on patients with severe traumatic brain injury showed an important reduction in mortality and better GCS on the 7th day of ICU stay when enteral nutrition was used.[30] Early initiation of enteral nutrition maintains the intestinal tract's physical barrier and immune function, decreasing the risk for bacterial translocation.[31] As a result, a lower rate of complications (gastrointestinal hemorrhages, sepsis, pneumonia, renal failure) and better outcomes (lower mortality, shorter length of stay) were noted.

The study has several limitations. First, it was a retrospective study conducted in one ICU. Second, the number of patients included in our study was relatively small, even though, our hospital is the only university responsible for the one-million inhabitants of southwestern Greece. Third, the present study included only the most severely injured patients and might not represent patients hospitalized in other wards.

Conclusions

In conclusion, trauma admissions in the ICU were associated with increased mortality, which was attributed to an increase of injury severity upon admission. Since road traffic accidents represent the majority of admitted patients, prevention programs and strategies focusing on helmet and seatbelt wearing should be a priority of national and local authorities. Our results also indicated that NISS was a superior score in predicting short-term mortality of severely injured patients, followed by RISC II. Traumatic brain injury was an important predictor of mortality among such patients, followed by acute kidney injury, septic and hemorrhagic shock.

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Conflicts of interest

The authors declare no conflicts of interest.

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