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Risk factors for the mortality of trauma victims in the intensive care unit

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Summary
Objective: To identify the risk factors associated with mortality of trauma victims during hospitalisation in the intensive care unit (ICU).
Design: Prospective cohort.
Setting: Brazilian ICU specialising in the care of trauma victims.
Methods: The subjects were divided into two groups: survivors and non-survivors. The variables used to compare the groups included demographic and clinical characteristics and illness/injury severity (Acute Physiology and Chronic Health Evaluation [APACHE II], Simplified Acute Physiology Score [SAPS II], Logistic Organ Dysfunction System [LODS], Injury Severity Score [ISS] and New Injury Severity Score [NISS]). The data were analysed using descriptive and inferential statistics and multiple logistic regression analysis.
Results: The sample consisted of 200 patients (164 males) with a mean age of 40.7 years. The predominant causes of injury were traffic accidents (57.5%) followed by falls (31.0%). The ICU mortality was 19.0%. Logistic regression analysis revealed that one point on the NISS and SAPS II scores increased the risk of death by 6% and 7%, respectively. In contrast, the risk of dying decreased 4% for each day of ICU hospitalisation.
Conclusion: Professionals must use the SAPS II and NISS for the early identification of trauma victims at high risk for death especially during the first days of ICU hospitalisation.

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Implications for Clinical Practice

- The identification of risk factors for ICU mortality of trauma victims offers subsidies to improve the quality of care, reducing the risks of morbidity and mortality in this group of patients.
- The early identification of trauma patients at risk of death in the ICU is relevant to developing treatment strategies to improve the outcome.
- The findings may contribute to risk adjustment of this subset of trauma patients when treatment results from different centres are compared.
- Moreover, these findings may contribute to the choice of illness and trauma severity score used to estimate the risk of death of trauma patients admitted in ICU.

Introduction

Currently traumatic injuries are the primary cause of death and permanent disabilities among youth and are a consistent worldwide public health problem. Improvements in pre-hospital care and the efficacy of hospital treatment have contributed to the reduction of these mortalities and morbidities over the last decades (Probst et al., 2009).

Severe trauma is characterised as an emergency, and victims frequently require surgical intervention, intensive care unit (ICU) admission or both (Duane et al., 2008). The ICU is a complex unit in which advanced technology and the continuous assistance of qualified professionals are essential for optimising and improving the outcome of critically unstable trauma victims. Thus, this setting is necessary in the treatment of trauma victims who are critically unstable.

Results from an American study revealed that treating trauma victims in a specialised ICU reduces mortality (Nathens et al., 2006); however, despite continuous advances in ICU technology and interventions, major trauma patients continue to die in the ICU. The identification of factors responsible for this mortality is of paramount importance for improving the quality of care that is offered to these patients (Chalya et al., 2011). Moreover, the early identification of trauma victims who have higher risk of death is fundamental to ICU clinical practice as such identification allows for the adoption of therapeutic and preventive interventions that can reduce undesirable outcomes.

The Acute Physiology and Chronic Health Evaluation II (APACHE II) (Knaus et al., 1985), the Simplified Acute Physiology Score II (SAPS II) (Le Gall et al., 1993) and the Logistic Organ Dysfunction System (LODS) (Le Gall et al., 1996) are indicators that are used with patients hospitalised in the ICU to identify the severity of their situation. These indicators use logistic regression equations to calculate the risks of death of patients in the critical unit. Physiological and laboratory variables are utilised for these calculations and are scored according to the level of deviation from normality (higher alteration values indicate higher final scores). In addition to these variables, the APACHE II and SAPS II use information about chronic diseases and age. The LODS also allow for the identification of failures in six organ systems: neurologic, cardiac, pulmonary, renal, haematologic and hepatic.

In the estimation of trauma severity, the literature highlights the Injury Severity Score (ISS) (Baker et al., 1974) and the New Injury Severity Score (NISS) (Osler et al., 1997); these indicators are calculated based on the Abbreviated Injury Scale (AIS) (AAAM, 2008). To identify AIS values, a manual of anatomical injury descriptors is used to determine a score from one (minor injury) to six (major injury, normally fatal) for the severity of each traumatic injury according to body regions. In mortality studies of trauma victims, injuries with AIS scores $\geq$3 represent a potential threat to life (AAAM, 2008).

The ISS is defined as the sum of the squares of the single highest AIS score for each of the three most severely injured body regions (Baker et al., 1974). In 1997, the authors of the ISS changed this indicator due to an identified failure in the calculation that resulted in the consideration of only single injuries to each body region and thus underestimated the severity of the injuries to the patient. To correct this limitation, the NISS was created and includes the three most serious injuries according to the AIS in the calculation regardless of body region (Osler et al., 1997).

Some of these indicators of severity, together with other clinical and/or demographic variables, have been tested analyses of the mortality of trauma patients in the ICU (Brattström et al., 2010; Ulvik et al., 2007). However, some clinical characteristics of trauma patients have not yet been explored in the literature; these characteristics included body regions with significant injuries, the type of organic failure and the variables that are typically assessed in critical unit patients. Considering the importance of analysing these variables to clinical outcomes, the objective of this study was to identify the risk factors associated with mortality of trauma victims during ICU hospitalisation.

Methods

Setting

The study used a prospective cohort design and was conducted within an ICU of a trauma referral hospital in São Paulo, Brazil. The ICU specialises in the care of trauma victims and has 22 beds with an occupation rate of approximately 100%.

The ICU is located in a large teaching hospital that specialises in the care of a wide range of clinical conditions and is a referral hospital for the treatment of acute and emergency care patients in the metropolitan region of São Paulo, which is composed of 39 municipalities. This region has a population of 19,956,590 inhabitants, an area of approximately 7943 km^2 and an average of 2512.47 inhabitants/km^2 (IBGE, 2013).

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Ethical approval

The project received approval from the ethics committee of the institution (n° 24.491), and written consent for study participation was obtained from the patients or their relatives.

Participants

Victims of blunt and/or penetrating trauma aged 18 years and over who were admitted in the ICU for more than 24 h between May 2010 and January 2011 were included in the study. The victims of drowning and burns were excluded.

Data collection

A member of the research team visited the patients prior to each nursing shift (morning, afternoon and evening) to identify the patients who met the inclusion criteria.

Data were collected from medical records, laboratory investigations and patient observation records during the first 24 h of the patients' admission. All patients included in the study were monitored daily until ICU discharge at which point survival or non-survival was determined. The data were entered into the Microsoft Excel 2010 software and the Statistical Package for the Social Sciences (SPSS) version 3.0.1 software was used for statistical analyses.

The following nominal independent variables were analysed: gender, external cause of the trauma according to the International Classification of Diseases (WHO, 2010), admission origin, body regions with significant injuries based on AIS scores ≥3 and the type of organ failure as identified by the LODS.

The following numerical independent variables were analysed: age, interval between arrival to the emergency room and ICU admission, Charlson comorbidity modified score (Charlson et al., 1987), length of ICU stay, injury severity according to the risk of death as calculated with the SAPS II, APACHE II (Knaus et al., 1985) and LODS and trauma severity according to the ISS, NISS and number of injuries as determined by AIS scores ≥3.

Data analysis

The outcome considered in the analysis was ICU survivor or non-survivor status. Descriptive data were analysed using counts, percentages, averages and standard deviations.

Multiple logistic regression was used to determine the risk factors for the mortality of the trauma victims in the ICU. A first step comparison between the groups (survivor versus non-survivor) was performed. For the nominal variables, we used the Pearson's Chi-square and Fisher's exact tests. In the analyses of the discrete and continuous quantitative variables, we used the Mann—Whitney test because the hypotheses of normal distributions were not confirmed by the Kolmogorov—Smirnov test.

To construct the final regression model, all independent variables that produced *p* values <0.20 in the comparison analyses were selected and then tested with the backward stepwise method.

In all analyses, a significance level of 5% was considered significant.

Results

The sample consisted of 200 trauma patients. The majority were male (82.0%) and the mean age was 40.7 years (±18.6). The predominant causes of injury were traffic accidents (57.5%) and falls (31.0%). The ICU mortality rate of these victims was 19.0%.

Table 1 illustrates the significant associations between the groups (survivors and non-survivors) that were present in terms of the external cause and most of the organ failures as identified by the LODS (i.e., cardiac, hepatic, neurologic, renal and pulmonary). The incidence of organ failure was higher in the non-survivor group. However, pulmonary and neurologic failures affected the majority of victims in both groups, and nearly all of the patients who died (97.4%) exhibited pulmonary failure. The highest rate of death occurred among the fall victims (42.1%) followed by pedestrians or cyclists (31.6%).

Table 2 illustrates that the two groups differed in age, length of ICU stay, risk of death calculated by the APACHE II, SAPS II and LODS severity scores, trauma severity according to the NISS and number of significant injuries (AIS ≥ 3). The non-survivors were older on average (46.2 years) and stayed in the ICU for shorter periods of time (9.8 days) compared with the survivors (39.5 years and 14.5 days, respectively). Moreover, the average values indicated that the trauma severity was greater in the non-survivor group.

The following variables were tested in the logistic regression model: external cause, admission origin, age, length of ICU stay, risks of death according to the APACHE II, SAPS II and LODS, ISS, NISS, number of significant injuries (AIS ≥ 3) and presence of cardiac, hepatic, neurologic, renal and pulmonary failure.

Table 3 shows that the final logistic regression model identified the length of ICU stay, NISS and risk of death according to the SAPS II were associated with increased mortality. Death primarily occurred during the first days of ICU admission, and the risk of dying decreased by 4% for each day of hospitalisation. The analyses revealed that small increases of one point in the NISS or SAPS II scores increased the risk of death by 6% and 7%, respectively.

Discussion

The severe injuries of ICU trauma patients increase the risk of death in the ICU. Our findings revealed a mortality rate of 19.0%; this value is intermediate compared with those reported in other studies, which typically vary between 10.4% and 32.7% (Brattström et al., 2010; Chalya et al., 2011; Ulvik et al., 2007). The risks of death as calculated by the LODS, SAPS II and APACHE II were compatible to the observed mortality and varied from 21.1% to 25.6%.

Similar to our findings, other studies (Brattström et al., 2010; Hefny et al., 2013; Ulvik et al., 2007) have also reported that the majority of patients were male (82.0%) and that gender did not influence mortality. Our findings demonstrated that the non-survivors were older than the survivors. Advanced age is considered a risk factor for

Table 1 Comparisons of the nominal variables between the groups (i.e., survivors and non-survivors) from São Paulo, Brazil between 2010 and 2011.

Variables	Survivors		Non-survivors		*P*-value
	N	%	*N*	%	
Gender					
Male	134	82.7	30	78.9	0.757[a]
Female	28	17.3	8	21.1	
External cause					
Transport accident — Pedestrian or cyclist	28	17.3	12	31.6	**0.006**[b]
Transport accident — Motorcyclist	49	30.3	6	15.8	
Transport accident — Occupant of an automobile, truck or heavy transport vehicle	20	12.3	—	—	
Falls	46	28.4	16	42.1	
Other blunt traumas	13	8.0	1	2.6	
Penetrating trauma in general	6	3.7	3	7.9	
Admission origin					
Emergency	44	27.2	10	26.3	0.144[a]
Surgical centre	115	71.0	25	65.8	
Other	3	1.8	3	7.9	
Body regions with significant injuries (AIS $\geq$ 3)					
Head or neck (yes)	103	63.6	28	73.7	0.322[a]
Face (yes)	11	6.8	—	—	0.209[b]
Chest (yes)	58	35.8	15	39.5	0.814[a]
Abdominal or pelvic contents (yes)	20	12.3	7	18.4	0.470[a]
Extremities or pelvic girdle (yes)	38	23.4	6	15.7	0.418[a]
External (yes)	—	—	—	—	—
Type of organic failure					
Cardiac (yes)	48	29.6	19	50.0	**0.028**[a]
Hematologic (yes)	8	4.9	—	—	0.357[b]
Hepatic (yes)	4	2.5	5	13.2	**0.013**[b]
Neurologic (yes)	105	64.8	33	86.8	**0.014**[a]
Renal (yes)	69	42.6	25	65.8	**0.016**[a]
Pulmonary (yes)	116	71.6	37	97.4	**0.002**[a]

Bold values highlight the variables that were different between the groups, considering the significance level equals or less than 5%.
[a] Pearson's Chi-square test.
[b] Fisher's exact test.

mortality in this group of ICU trauma patients (Brattström et al., 2010; Hefny et al., 2013; Taylor et al., 2002) due to the reduction in physiological reserves that is inherent to the ageing process (Hefny et al., 2013; Taylor et al., 2002).

Transportation accidents, followed by falls, were the main cause of trauma that led to ICU admission; these findings are similar to those of other studies (Brattström et al., 2010; Hefny et al., 2013; Ulvik et al., 2007). There was an association between mortality and the cause of trauma. When the pedestrians, cyclists and motorcyclists in the non-survivor group were considered as a single group, the mortality of this group was higher (47.4%). This finding is related to the lack of adequate protection from trauma among this group, which makes them more exposed to multiple traumas and severe injuries (Chandran et al., 2012; Oliveira and Sousa, 2012).

Our findings revealed a high mortality rate among the victims of penetrating trauma; one-third of the nine of these victims examined here did not survive their ICU admission. This finding supports the results of previous studies. Millham and LaMorte (2004) analysed 72.570 patients from the National Trauma Database (NTB) and showed that penetrating trauma was associated with a higher mortality rate than that of blunt injuries.

Previous research has focused on scoring systems that estimate the physiologic changes and trauma severity to predict the mortality of trauma victims who are admitted to the ICU and have shown that these systems are excellent

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Table 2 Comparison of the numerical variables between the groups (i.e., survivors and non-survivors) from São Paulo, Brazil between 2010 and 2011.

Variables	Survivors (Mean ± SD)	Non-survivors (Mean ± SD)	*P*-value[a]
Age	39.5 ± 18.4	46.2 ± 18.9	**0.027**
Interval between arrival to the emergency room and ICU admission	30.5 ± 61.7	24.7 ± 39.5	0.649
Charlson comorbidity score	0.5 ± 1.2	1.0 ± 2.0	0.486
Length of ICU stay	14.5 ± 14.1	9.8 ± 16.3	**0.004**
Risk of death — APACHE II	20.9 ± 15.0	45.2 ± 22.0	**<0.001**
Risk of death — SAPS II	16.5 ± 16.6	50.1 ± 24.8	**<0.001**
Risk of death — LODS	15.8 ± 13.6	43.8 ± 26.8	**<0.001**
ISS	18.7 ± 8.6	21.8 ± 10.5	0.110
NISS	25.8 ± 8.7	32.6 ± 12.4	**<0.001**
Number of significant injuries (AIS ≥3)	2.9 ± 1.7	4.0 ± 2.0	**<0.001**

Bold values highlight the variables that were different between the groups, considering the significance level equals or less than 5%.
[a] Mann—Whitney test.

Table 3 Logistic regression model of the risk factors for the mortality of trauma victims who were hospitalised in the ICU in São Paulo, Brazil from 2010 to 2011.

Variable	β	Exp(β)	IC 95% Exp(β)	*P*-value
Length of ICU stay	−0.04	0.96	0.92—0.99	**0.025**
NISS	0.06	1.06	1.02—1.12	**0.010**
Risk of death — SAPS II	0.07	1.07	1.05—1.09	**<0.001**

Bold values highlight the variables that were different between the groups, considering the significance level equals or less than 5%.

predictors of mortality; these scores predict mortality better than trauma severity scores (Nogueira et al., 2009; Ulvik et al., 2007).

Some studies have utilised the area under the curve (AUC) of Receiver Operating Characteristic (ROC) to identify the accuracy of severity indexes in the prediction of mortality. A Norwegian study showed that the accuracy of the SAPS II (AUC 0.91) is superior to those of the maximum Sequential Organ Failure Assessment (SOFA) score (AUC 0.84) and the ISS (AUC 0.61) (Ulvik et al., 2007). Furthermore, a Brazilian study found that the AUCs of the SAPS II and LODS (0.85 and 0.83, respectively) were greater than those of the ISS and NISS (0.58 and 0.63, respectively) and thus the discriminatory capacities of the SAPS II and LODS were better than those of the trauma indexes in the prediction of the mortality of ICU patients (Nogueira et al., 2009).

In our study, the severity of trauma was associated with an increased mortality as identified by the highest NISS and the number of injuries with AIS scores ≥3. Additionally, the worst physiologic conditions as indicated by the APACHE II, SAPS II and LODS scores and the presence of multi-organ failure also exhibited this association. However, considering all of the variables, the risk of death was better portrayed by the SAP II and NISS. Ulvik et al. (2007) also demonstrated that the SAPS II is a better predictor of 30-day mortality compared with the maximum SOFA score, ISS, age, gender and severity of head injury.

The SAPS II was created to predict mortality in ICU patients and exhibited a better fit to the regression model in our study than did the other indicators of physiologic changes that were developed for the same purpose.

Regarding the trauma severity indicators, we unexpectedly found no significant differences in mortality between the survivors and non-survivors in terms of ISS scores. This finding is in contrast to the findings of other studies (Brattström et al., 2010; Serviá et al., 2012; Ulvik et al., 2007) that have reported that ISS scores are significantly higher among non-survivor groups but that ISS scores is not an independent risk factor for mortality in multivariable analyses. Researchers have attributed these results to the lack of physiological data in the ISS (Ulvik et al., 2007) and to the severity of the injuries to patients who have been included in ICU studies (Hefny et al., 2013). It is possible that the inclusion of only very severely injured patients reduced the ability of the logistic regression model to detect these factors.

However, in our study, the score on the NISS, which is another indicator of trauma severity that is based on the codification system of AIS and does not include physiological data, was an independent risk factor for mortality. It is possible that the adjustment of the NISS calculation in relation to the ISS as explained by Osler et al. (1997) and the distribution of the injuries to the participants in this study contributed to the association of the NISS with mortality.

Studies that have evaluated ICU patients according to NISS scores are scarce in the scientific literature; however, Swedish researchers tested ISS and NISS in multivariable logistic regression analyses and found that the results for the NISS were largely similar to those for the ISS. However, the ISS was tested with two categories, >24 and <25. When the ISS was replaced with the NISS, the cutoff used in the formulation of the groups was 29 (Brattström et al., 2010).

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Based on the discussion above, the following conclusions can be reached: the severity indicators of physiological changes are important instruments for the identification of trauma victims with an elevated risk of dying in the ICU; the SAPS II excelled among these indicators; the ISS exhibited fragility as a predictor of the mortality of ICU trauma victims; and the substitution of the NISS for the ISS has certain advantages when various severe injuries are observed within a single body region. Therefore, these findings suggest that the SAPS II and NISS should be used for risk adjustment for this subset of trauma patients.

In our study, the survivors had longer lengths of stay (LOS) than did the non-survivors, and this finding supports those of other international studies (Auñón Martín et al., 2012; Chalya et al., 2011; Serviá et al., 2012). Furthermore, in the multivariate analysis of our data, the LOS proved to be a predictor of mortality, but increases in LOS scores were associated with decreased risks of death in the ICU.

Acosta et al. (1998) analysed the time of death following ICU trauma admission and identified the first 24 h as the lethal period within which the main cause of death was central nervous system (CNS) injury. After this period, the incidence of these deaths declines, but the main cause of death continues to be CNS involvement between 24 and 72 h after admission to the hospital; after 72 h, death is primarily associated with inflammatory processes.

Research has identified severe head injury as a strong predictor of mortality (Serviá et al., 2012; Ulvik et al., 2007); however this significant injury has been defined by AIS scores for the head $\geq$4. The results of our study were based on analyses in which the significant injuries to the affected regions were determined based on AIS scores $\geq$3, and the anatomical locations of the injuries were not associated with mortality.

Our study has some limitations. The inclusion of other variables, either due to a different method of inclusion in the logistic regression model or the inclusion of variables that were not initially considered in our study, might have changed the interpretation of our results and our conclusions. Furthermore, this study was performed in a single ICU and was therefore subject to the specific characteristics of this specific hospital.

Despite the limitations of our study, it contributes to the understanding of the roles that trauma severity scores and physiological changes play in determining the outcomes of the trauma victims admitted to the ICU. Furthermore, our results might help to improve the quality of clinical practice by aiding the identification of victims with higher risks of death and the recognition of preventable deaths (i.e., deaths occurred in patients with lower risks of death). The retrospective analysis of causes of preventable deaths allows identifying inadequate care management of injured patients and is essential to ensure the quality of care and safety of trauma victims admitted in ICU.

Conclusions

Mortality among trauma patients primarily occurred during the first days of ICU admission, and the risk of dying decreased with each day of hospitalisation. The SAPS II and NISS scores were risk factors for mortality in this group of patients; higher values on these indexes indicated greater risks of death in the ICU. The SAPS II performed better than the APACHE II and LODS in the identification of this outcome. The ISS was not related to ICU mortality however, the NISS was important in identifying the risk of death.

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Conflict of interest

The authors have no conflict of interest to declare.

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