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Validation of trauma scales: ISS, NISS, RTS and TRISS for predicting mortality in a Colombian population

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Abstract

Background Our purpose was to validate the performance of the ISS, NISS, RTS and TRISS scales as predictors of mortality in a population of trauma patients in a Latin American setting.

Materials and methods Subjects older than 15 years with diagnosis of trauma, lesions in two or more body areas according to the AIS and whose initial attention was at the hospital in the first 24 h were included. The main outcome was inpatient mortality. Secondary outcomes were admission to the intensive care unit, requirement of mechanical ventilation and length of stay. A logistic regression model for hospital mortality was fitted with each of the scales as an independent variable, and its predictive accuracy was evaluated through discrimination and calibration statistics.

Results Between January 2007 and July 2015, 4085 subjects were enrolled in the study. 84.2% ($n = 3442$) were male, the mean age was 36 years (SD = 16), and the most common trauma mechanism was blunt type (80.1%; $n = 3273$). The medians of ISS, NISS, TRISS and RTS were: 14 (IQR = 10–21), 17 (IQR = 11–27), 4.21 (IQR = 2.95–5.05) and 7.84 (IQR = 6.90–7.84), respectively. Mortality was 9.3%, and the discrimination for ISS, NISS, TRISS and RTS was: AUC 0.85, 0.89, 0.86 and 0.92, respectively. No one scale had appropriate calibration.

Conclusion Determining the severity of trauma is an essential tool to guide treatment and establish the necessary resources for attention. In a Colombian population from a capital city, trauma scales have adequate performance for the prediction of mortality in patients with trauma.

Keywords Trauma Severity Indices · Multiple trauma · Mortality

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Background

Trauma associated mortality fluctuates and depends on diverse factors, such as: severity, patient's physiological reserve, transfer time from the trauma scene to care site and the available resources for treatment. Estimation of severity of trauma is a useful strategy not only to predict in-hospital mortality, but also to define the amount of technical and scientific resources that a patient may need during attendance. Thus, this strategy should reduce morbidity, mortality, as well as complications derived from trauma or health care itself [1].

Since the introduction of the Abbreviated Injury Scale (AIS) in 1971 by the Association for the Advancement of Automotive Medicine (AAAM) [2], at least 36 trauma scales for estimation of severity have been developed [3]. These scales have been divided into anatomical, physiological and combined [4]. The two anatomical scales most commonly used in the literature are the Injury Severity Score (ISS) [5] and the New Injury Severity Score (NISS) [6], both with varying discriminative performance according to the area under the receiver operating characteristic curve (AUC–ROC), ranging from 0.722 to 0.943 for ISS and from 0.785 to 0.831 for NISS [7]. The Revised Trauma Score (RTS) [8], a physiological scoring system most commonly used for triage in pre-hospital care, may be useful to predict mortality and to establish which more seriously injured patients require care in trauma centers. The Trauma and Injury Severity Score (TRISS) scale, described in 1983 by Champion et al. [9], combines the simplicity of RTS with the potential prediction of the ISS, and through a complex statistical method enables to predict the risk of death with an AUC–ROC from 0.82 to 0.96 [7]. All institutions dealing with trauma patients should evaluate their clinical outcomes based on trauma scales, which permit to create health policies for the care of severely traumatized patients.

An ideal scale should have a continuous evaluation process, which will assure its performance in discrimination, calibration and, ultimately, validation. Although there is no perfect trauma scale, the four mentioned above have the best evaluation processes published in the literature. Despite numerous studies that show different predictive performance with these scales according to the hospital or the country where they are applied [7], to the best of our knowledge there are no validation studies in our country or even in Latin America, which implies an important limitation to recommend widespread use. The purpose of this study is to validate the performance of the ISS, NISS, RTS and TRISS scales as predictors of mortality in a population of trauma patients treated at a high- complexity hospital in a Latin American setting.

Materials and methods

Design

A bidirectional cohort of consecutive cases are admitted to the emergency department of the Hospital Pablo Tobón Uribe (HPTU) in Medellin, Colombia. HPTU is a fourth-level complexity hospital, equivalent to a trauma center level 1 in the USA, with a total of 370 beds; 57 of them covering adult critical care. The average annual emergency department visits range from 60,000 to 65,000, of which 37–39% are trauma consultations. The protocol was approved by the ethical committee of the School of Medicine-University of Antioquia and the institutional review board of the HPTU.

Participants

All subjects older than 15 years who were admitted to the emergency room with a diagnosis of trauma were eligible. Were included those who had hospital stay over 24 h, showed lesions in two or more body areas according to the AIS definitions (head and neck, face, thorax, abdomen, extremities and external structures) and whose initial attention was held at the hospital in the first 24 h following trauma. Patients who received surgical care at another institution in the first 24 h post-trauma died before admission or prior to surgical procedures or diagnostic images that allowed verifying anatomical lesions were excluded; in the first case because mortality could be increased by inadequate treatment rather than by the severity of the trauma per se, and in the second case by the limitation to identify and classify lesions in the AIS.

Data source

For the retrospective cohort, electronic medical records of patients admitted to the emergency room between January 1, 2007, and October 31, 2013, were reviewed, whereas the prospective cohort examined electronic medical records of patients admitted to the emergency room between November 1, 2013, and July 31, 2015. For the retrospective cohort, a trained assistant search for trauma codes based on the international classification of diseases (ICD-10) discharge diagnosis (S02–S88, T01–T07, Y36), with posterior manual review of clinical records. For the prospective cohort, a trained research nurse checked daily admissions by the emergency department and concurrently collected data. Patient monitoring was carried out during hospital stay, as recorded in the initial trauma episode. Demographics, admittance physiological variables (heart rate, respiratory rate, blood pressure and Glasgow Coma Scale) and admission diagnoses confirmed through images and/or surgical findings in the first 24 h of all trauma patients were recorded on a special form predesigned with AIS diagnostic codes.

Outcome

The primary outcome was death during hospital stay related to the initial trauma. Secondary outcomes related to the utilization of health-care resources, such as admission to the intensive care unit (ICU), requirement of mechanical ventilation and hospital stay, were also evaluated.

Scale validation

Abbreviated injury scale (AIS)

In order to obtain the ISS and NISS scores, we used the AIS dictionary of anatomical lesions (version 2005) in accordance with the recommendations of the Association for the Advancement of Automotive Medicine (AAAM) [10]. For this purpose, a trained nurse with experience in trauma reviewed the full clinical records, recorded lesions detected in the first 24 h of admission and made the search for the codes in the AIS dictionary. Throughout all the study, the authors audited the quality of data regularly and verified the accuracy of the information from medical records. Since the retrospective cohort data could be subject to bias due to lack of information, a checklist was used for missing data, comparing the quality of data between retrospective and prospective cohort, without observing significant deviations.

Injury Severity Score (ISS)

In this scale, the three body areas (according to the AIS definitions of head and neck, face, thorax, abdomen, extremities and external structures) with major injury are selected and the injury with the highest AIS score (0–6) within each of these three areas is selected. The ISS is the sum of squares of the highest AIS score in these body regions, and the sum of them gives a score between 1 and 75 points. If a lesion is assigned an AIS score of 6, it automatically results in ISS 75 [5].

New Injury Severity Score (NISS)

This scale follows the same principle of the ISS, but it is modified to add the squares of the three highest scoring AIS injuries, independently of the affected body area. Consequently, the three most serious injuries could be in the same body area but also gives a score between 1 and 75 points [6].

Revised Trauma Score (RTS)

It uses three physiological variables: respiratory rate, systolic blood pressure and Glasgow Coma Scale, giving a score from 0 to 12. Patients with an RTS less than or equal to 11 should be transferred to a trauma center since the probability of survival is less than 90% [8].

Trauma and Injury Severity Score (TRISS)

It includes RTS and ISS using a statistical model to determine the probability of survival, adjusted for age and mechanism of trauma (penetrating or blunt). The likely result ranges from 0 to 7.841, and thus, the highest score has the highest chance of survival [9].

Sample size

As the investigation was conducted on a fixed and previously identified population, a formal sample size calculation was not made. However, sample size for validation studies in predictive models is not fully defined [11], and the options range from cohorts with a minimum of 100 outcomes until those with more than 250 outcomes [12].

Statistical analysis

Descriptive statistics were means, medians and proportions for demographic variables and characteristics of trauma. A logistic regression model for hospital mortality as the outcome was conducted with each one of the scales as independent variables, and its predictive accuracy was evaluated through discrimination and calibration statistics. Discrimination was determined by the area under the curve of the receiver operating characteristic (AUC–ROC), with values close to 1 understood as perfect discrimination and those close to 0.5 as no discrimination [13]. The calibration of the models was assessed by the degree of correspondence between the estimated and observed probability of death through deciles of risk. The correspondence of both mortalities was determined graphically and with Hosmer–Lemeshow goodness-of-fit test, considering that the model was calibrated with a p value greater than 0.05 [14]. We used STATA 13.0 (StataCorp, College Station, Texas 77845, USA) for all analyses.

Results

Between January 2007 and July 2015, a total of 138,455 emergency department visits were registered, with 112,291 patients corresponding to a traumatic etiology. After an exhaustive review of the inclusion criteria, 4085 subjects were eligible for enrolling in the study (Fig. 1). Eighty-four percent ($n = 3442$) of the patients were male, and the mean age was 36 years ($SD = 16$). The most common trauma mechanism was blunt type (80.1%; $n = 3273$), mostly from motor vehicle accidents (74.7%; $n = 2445$). The medians of ISS, NISS, TRISS and RTS were: 14 ($IQR = 10–21$), 17 ($IQR = 11–27$), 4.21 ($IQR = 2.95–5.05$) and 7.84 ($IQR = 6.90–7.84$), respectively. Mortality for the entire cohort was 9.3% (381 of 4085 individuals). Table 1 shows population characteristics according to the vital status at hospital discharge. The elapsed time between trauma occurrence and emergency admittance is almost doubled for in-hospital patient dead ($p = 0.013$). Table 2 displays the outcomes related to health-care resource utilization and trauma severity according to the vital status at hospital discharge. A significant number of individuals (40.7%, $n = 1663$) had an ISS greater than or equal to 16, which represents a high proportion of multiple trauma; 36% ($n = 1470$) were admitted to the ICU, and most of them (88%, $n = 1290$) required mechanical ventilation. Severe trauma of the head and neck anatomical area, defined as an AIS greater than or equal to 3, occurred in 35% ($n = 1427$) of the cohort and was present in the majority of deceased subjects (82%; $n = 312$). The group of patients who died had a short

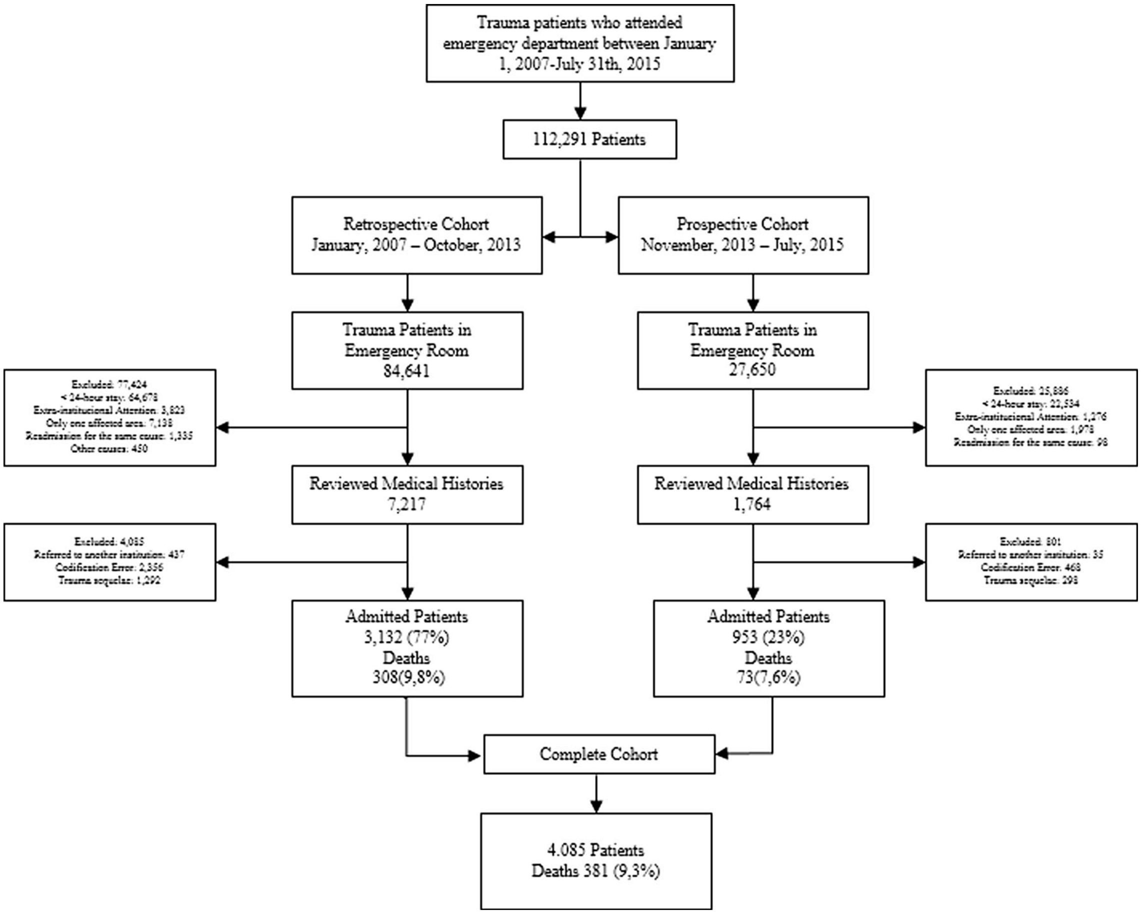

Fig. 1 Patient admission flow chart

Table 1 General characteristics of the study population according to the vital status at discharge

Variable	All (n = 4085)	Living (n = 3704)	Dead (n = 381)
Male sex [n (%)]	3442 (84.2%)	3112 (84%)	330 (87%)
Age (median—SD)	36 (16)	35 (16)	41 (20)
Time between trauma and income[a] (Medium—IQR)	76 (39–256)	74 (39–250)	120 (41–324)
Blunt trauma [n (%)]	3273 (80.1%)	2994 (81%)	279 (73%)
Traffic accident [n (%)]	2445 (74.7%)	2244 (75%)	201 (72%)
Motorcycle [n (%)]	1942 (79.4%)	1802 (80%)	140 (70%)
Automobile [n (%)]	414 (16.9%)	359 (16%)	55 (27%)
Other [n (%)]	89 (3.6%)	83 (4%)	6 (3%)
Penetrating trauma [n (%)]	812 (19.9%)	710 (19%)	102 (27%)
Firearm [n (%)]	543 (66.9%)	454 (64%)	89 (87%)
Edged weapon [n (%)]	223 (27.4%)	213 (30%)	10 (10%)
Anti-personnel mine [n (%)]	14 (1.7%)	13 (2%)	1 (1%)
ISS (median—IQR)	14 (10–21)	12 (9–18)	26 (20–33)
NISS (median—IQR)	17 (11–27)	17 (10–27)	41 (34–50)
RTS (median—IQR)	7.84 (6.90–7.84)	7.84 (7.55–7.84)	5.03 (4.09–6.82)
TRISS (median—IQR)	4.21 (2.95–5.05)	4.46 (3.31–5.05)	0.73 (−0.36–2.05)

% percentage, *SD* standard deviation, *n* number of patients, *ISS* Injury Severity Score, *NISS* New Injury Severity Score, *RTS* Revised Trauma Score, *TRISS* Trauma and Injury Severity Score, *IQR* interquartile range

[a] Time in minutes, data are available for 3153 patients

Table 2 Clinical Outcomes and severity of trauma

Variable	All ($n = 4085$)	Living ($n = 3704$)	Dead ($n = 381$)
Admission to ICU [*n* (%)]	1470 (36%)	1112 (30%)	358 (94%)
Mechanical ventilation requirement [*n* (%)]	1290 (31.6%)	934 (25%)	356 (93%)
Hospital stay (Median—IQR)	7 (4–15)	8 (4–17)	2 (1–6)
ISS $\geq$ 16 [*n* (%)]	1663 (40.7%)	1315 (35%)	348 (91%)
GCS $\leq$ 8 (*n* (%))	709 (17.3%)	442 (12%)	267 (71%)
Shock on admission[a] [*n* (%)]	413 (10.1%)	331 (9%)	82 (22%)
Severe head and neck trauma (AIS $\geq$ 3) [*n* (%)]	1427 (35%)	1155 (31%)	312 (82%)
Serious face trauma (AIS $\geq$ 3) [*n* (%)]	34 (0.8%)	29 (0.8%)	5 (1.3%)
Severe chest trauma (AIS $\geq$ 3) [*n* (%)]	841 (20.6%)	732 (20%)	109 (29%)
Severe abdominal trauma (AIS $\geq$ 3) [*n* (%)]	488 (12%)	432 (12%)	56 (15%)
Severe limb trauma (AIS $\geq$ 3) [*n* (%)]	1042 (25.5%)	970 (26%)	72 (19%)

% percentage, *n* number of patients, *IQR* interquartile range, *ISS* Injury Severity Score, *GCS* Glasgow Coma Scale, *AIS* Abbreviated Injury Scale

[a] Systolic blood pressure $\leq$90 mmHg on admission

Table 3 Logistic regression models with discrimination and calibration for each scale

Scale	OR	*p* value	95% CI	AUC	HL	Prob > χ^2
(a) Complete cohort results ($n = 4085$)						
ISS	1.13	0.000	1.12–1.14	0.85	45.5	0.000
NISS	1.13	0.000	1.12–1.14	0.89	15.8	0.045
RTS	0.39	0.000	0.36–0.42	0.86	24.8	0.000
TRISS	0.39	0.000	0.36–0.42	0.92	16.5	0.035
(b) Blunt trauma mechanism results ($n = 3273$)						
ISS	1.13	0.000	1.12–1.15	0.86	28.1	0.002
NISS	1.13	0.000	1.11–1.14	0.89	20.4	0.009
RTS	0.37	0.000	0.34–0.41	0.86	26.3	0.000
TRISS	0.36	0.000	0.33–0.40	0.92	13.5	0.095
(c) Penetrating trauma mechanism results ($n = 812$)						
ISS	1.11	0.000	1.09–1.14	0.81	15.4	0.031
NISS	1.12	0.000	1.10–1.15	0.87	9.3	0.316
RTS	0.45	0.000	0,39–0,51	0.86	10.2	0.017
TRISS	0.46	0.000	0.40–0.52	0.90	7.9	0.443

ISS Injury Severity Score, *NISS* New Injury Severity Score, *RTS* Revised Trauma Score, *TRISS* Trauma and Injury Severity Score, *OR* odds ratio for each point, *CI* confidence interval, *AUC* area under curve, *HL* Hosmer–Lemeshow

hospital length of stay, with a median of two days and an interquartile range from one to six, which shows that most of the deaths occurred in the first week of trauma.

Table 3 exhibits the results of the logistic regression models for each one of the evaluated scales with its corresponding discrimination (AUC–ROC) and calibration (Hosmer–Lemeshow goodness-of-fit test). Figure 2 presents the ROC curves for each of the assessed scales, and Fig. 3 shows models' calibration according to the correspondence between the observed and expected probability of death from risk deciles. We highlight the discriminating power of all analyzed indices, exhibiting TRISS the best performance (AUC = 0.92). None of the scoring systems showed good calibration. When the groups were compared by mechanism of trauma (blunt vs. penetrating), discrimination remained at similar values; however, calibration was adequate for the NISS and TRISS indices in the group of penetrating trauma.

Discussion

ISS, NISS, RTS and TRISS trauma scales demonstrated an acceptable performance for discrimination of mortality in a population of Latin American patients with trauma, with an apparent superiority of TRISS due to its higher AUC (0.9167). However, model's calibration did not prove to be adequate, although the combined scale TRISS seems to generally show a better prediction, except at the end of increased risk of death (Fig. 3). Similarly, regression models suggest a better calibration for TRISS and NISS in the group of patients with penetrating trauma. This is consistent with previously published studies evaluating this scale [15, 16].

Anatomical scales based on the AIS, as the ISS and NISS, have shown different results in the literature, according to the mechanism of trauma (blunt vs. penetrating) [17]. It has been reported that the ISS ignores the serious injuries that occur in the same anatomical area, suggesting to apply the NISS scale in cases of penetrating trauma by firearms or sharps weapons, which allows to include the most serious injuries regardless of the anatomical area [17]. However, the results in this respect are inconclusive, and so far there is no unified recommendation on which of these two scales would be the best

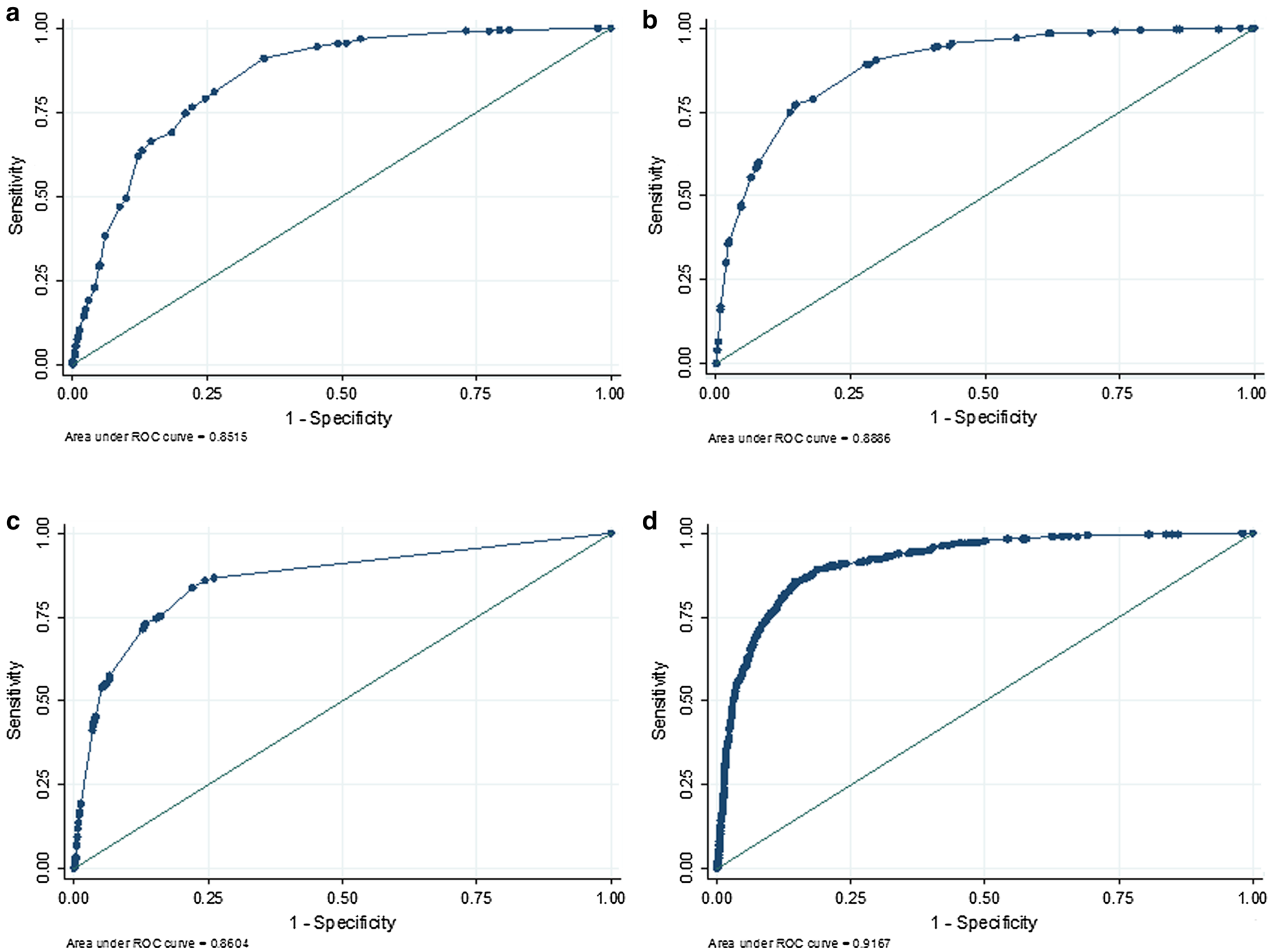

Fig. 2 Areas under the curve for assessed scales: ISS (**a**); NISS (**b**); RTS (**c**); TRISS (**d**)

in this type of trauma. Smith et al. [18] described the NISS has a better discrimination for mortality than ISS in penetrating trauma, with AUC of 0.93 versus 0.88 ($p = 0.008$). On the contrary, Zhao et al. [19] found no differences between these two scales and suggested that in the penetrating trauma NISS could be more sensitive but less specific for predicting death. Husum and colleagues [20] found a similar performance in terms of discrimination to define mortality in patients with penetrating trauma and suggest that higher-quality studies are required to resolve this uncertainty.

Several studies have evaluated the calibration of these scales to predict mortality with different results, although most of them show a lack of calibration [19, 21, 22]. It is likely that for the evaluation of calibration in such scales, the Hosmer–Lemeshow test does not be appropriate, since it has been argued its lack of power to assess a poor calibration and being very sensitive to large sample sizes [23]. Consequently, we also evaluated graphically the calibration of the scales and the results appear more accurate for NISS and TRISS score systems.

The demographic characteristics of this cohort differ from previous reports of trauma in Colombia [24] and other Latin American countries [25], where a higher mortality associated with penetrating injury is described. In this cohort, we found that 80.1% of trauma was blunt, mostly from motor vehicle traffic accidents (60% of the cohort), while in another Colombian cohort, traffic accidents accounted for only 20.7% [24] and in a Brazilian cohort was 38.2% [25]. In addition, our study population was mainly male (84%) and with a mean age of 36 years, representing the most economically active population group. Blunt trauma was the most frequent in the group of deceased patients in our cohort (73%), while in the research published by Ordoñez et al. [24], the penetrating mechanism produced by firearms and sharp weapons accounted for 50% of deaths. These demographics indicate an evolution in trauma mechanisms that is closer to developed countries, but it may not represent the whole population with trauma in Colombia, since it is a private hospital in a city with high motorcycle traffic fatalities.

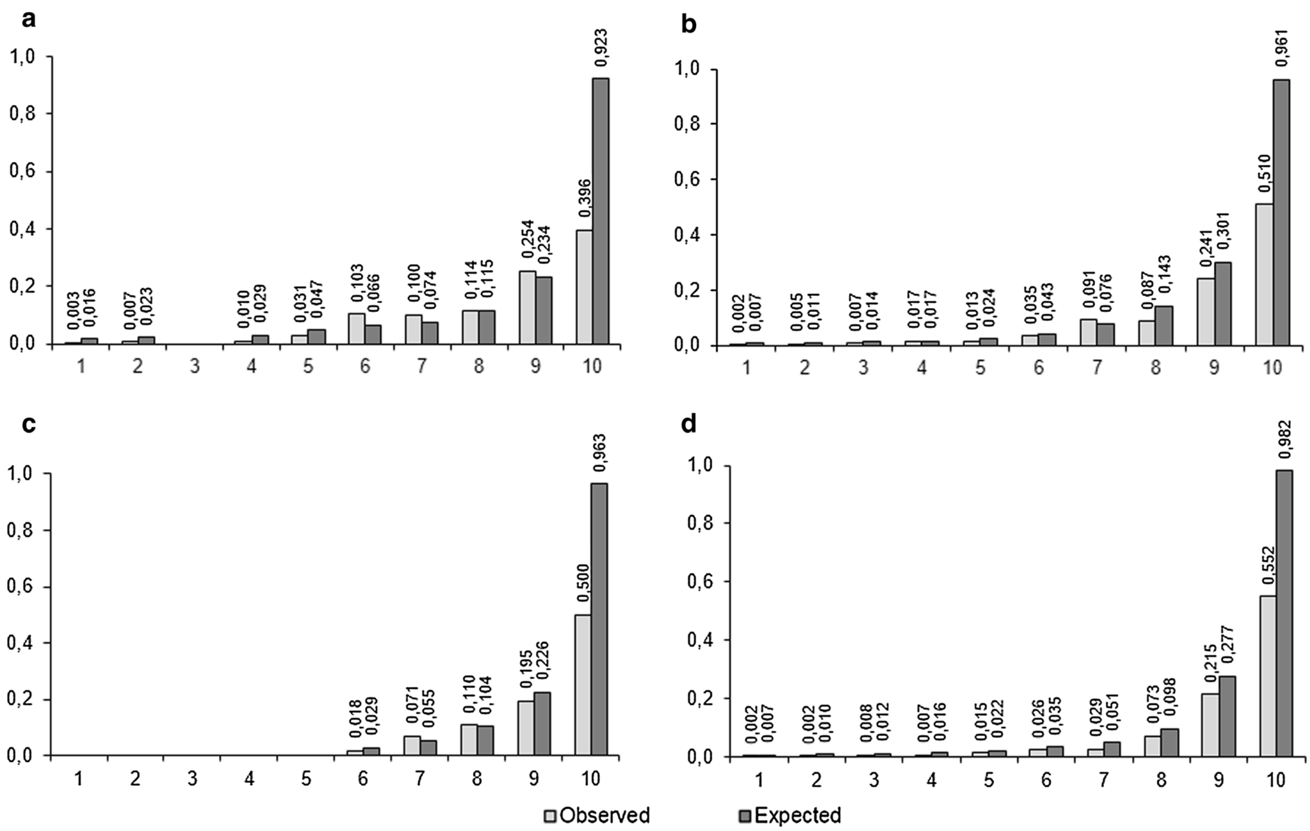

Fig. 3 Observed and expected probability of death according to assessed scales: ISS (**a**); NISS (**b**); RTS (**c**); TRISS (**d**). The *Y*-axis corresponds to death probability and the *X*-axis to deciles

The overall mortality was 9.3%, comparable to that reported in other studies with similar characteristics [26, 27]. However, in patients with multiple trauma, defined as an ISS greater than or equal to 16, mortality was 21%. One possible explanation for the higher mortality in this set of patients could be the longest time from trauma occurrence until admission to the institution (2 h). It is common in our medical practice that subjects are initially taken by teams of pre-hospital care to low-complexity care levels that do not have the resources to attend the most severely injured patients. We also observed a large proportion of individuals with severe cranioencephalic trauma (CET), defined as an AIS greater than or equal to 3 in head area; and in the group of patients who died the majority (82%) had severe traumatic brain injury (TBI), indicating that this might be an independent factor for mortality. The high prevalence of motorcycle traffic accidents, in an environment where it is common to avoid mandatory protection elements as the helmet, provides an opportunity for transit regulators in our country to conduct massive campaigns aimed to improve adhesion to usage of protective elements and to responsible driving.

The present study has several limitations. The sample size is small compared to other studies with large databases of trauma in the USA [28] and Germany [29]; however, it is similar to other database of developed countries like Switzerland [30] and Australia [31]. The retrospective nature of most of the information makes it difficult to collect it appropriately. There is no national or institutional database for gathering information of trauma patients, so that accurate anatomical diagnosis and to standardize them to the AIS dictionary was a hard task. While research has been conducted to use the International Classification of Diseases coding system (ICD-9 and 10) [28] to obviate the difficulty of using the AIS codes, in our hospital this information is not consistent in medical records and this possibility was not considered.

Determining the severity of trauma is an essential tool to guide treatment, establish the necessary resources for attention and allow comparison of clinically important outcomes between different institutions providing health services. Since ISS introduction in 1974, there have been described in the literature almost 50 scales aimed to establish the magnitude of injury and helping to predict mortality. Many of these prediction tools have undergone validation processes worldwide but, to our knowledge, there is no similar research in Latin America with an appropriate statistical method. Considering the performance of the RTS scoring system found in the present study, we could suggest that, in the setting of pre-hospital care in Colombia, the application of this scale for triage should be mandatory to ensure a timely transfer to hospitals that have the necessary resources to care for these patients. This proposal has been evaluated in multiple studies worldwide, and it is necessary to establish a public health policy in our country to implement and verify compliance with these strategies.

Conclusion

We concluded that in a Colombian population from a capital city, the most common trauma scales have adequate performance for the prediction of mortality in patients with trauma.

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Compliance with ethical standards

Conflict of interest None.

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