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ORIGINAL ARTICLE

Predictive capability of the injury severity score versus the new injury severity score in the categorization of the severity of trauma patients: a cross-sectional observational study

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Abstract

Purpose The AIS scale is a measurement tool for single injuries. The ISS is considered the gold standard for determining the severity of injured patients, and the NISS was developed to improve the ISS with respect to loss of information, as well as to facilitate its calculation. The aim of this study was to analyse what injury severity measure, calculated according to the Abbreviated Injury Scale (AIS), 1998 and 2005 (update 2008) versions, performs better with mortality, cost and hospital length of stay healthcare indicators.

Methods This cross-sectional observational study was carried out between February 1st 2012 and February 1st 2013. Inclusion criteria were injured patients due to external causes admitted to trauma service through the emergency department. Manual coding of all injuries was performed and ISS and NISS scores were calculated for both versions of the AIS scale. Severity was then compared to mortality (in-hospital and at 30 days), healthcare cost, and length of hospital stay.

Results The index with the best predictive capability for in-hospital mortality was NISS 05 (AUC = 0.811). There was a significant increase in hospital stay and healthcare cost in the most severe patients in all indexes, except for ISS 05.

Conclusions NISS is found to be an index with higher predictive capability for in-hospital mortality and correlates better to length of hospital stay and healthcare cost.

Keywords Abbreviated injury scale · Clinical coding · Injury severity score · Patient acuity · Trauma severity indexes

Introduction

Injury severity is a dynamic concept that changes over time, as the diagnosis, treatment, and outcome of the injury improve. It encompasses a series of dimensions according to which an injury can be considered more severe than others. These dimensions include: threat to life as a consequence of an injury, tissue damage, possibility of associated disability, amount of energy dissipated or absorbed depending on the injury mechanism, length of hospital stay, need for intensive care, cost of treatment, complexity, and duration of treatment and mortality involved [1, 2].

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A great scientific effort has been made in an attempt to achieve a valid and comparable system for the measurement of the severity of injuries. The Abbreviated Injury Scale (AIS) is the most widely used instrument to calculate the severity of traumatic injuries [1, 3]. The AIS was created by the Association for the Advancement of Automotive Medicine (AAAM) and is defined as “an anatomically based, consensus-derived, global severity scoring system that classifies an individual injury by body region according to its relative importance on a 6-point ordinal scale” [1].

The AIS scale is a measurement tool for single injuries. To assess the overall severity of a patient with multiple injuries, the Maximum Abbreviated Injury Scale (MAIS), the Injury Severity Score (ISS) [4], and the New Injury Severity Score (NISS) [5] were developed, based on the AIS.

The first of the three indexes to be used was MAIS, which is the maximum AIS of a patient. However, it could soon be appreciated that there was no linear correlation between mortality and MAIS, as this index only takes into account the injury with the highest AIS score and mortality for any given patient varies significantly depending on the number and severity of injuries sustained [6, 7]. As regards to the ISS, at present, it is considered the gold standard for determining the severity of injured patients [5, 8–11]. Finally, the NISS was developed to improve the ISS with respect to loss of information, as well as to facilitate its calculation [8].

The measurement of injury severity is a pending issue in many countries and we are beginning to work on it in Europe. In 2009, The World Health Organization (WHO), in its Global Status Report on Road Safety [12], encouraged countries to reach a consensus on the definition of seriously injured patient and to collect data on injury severity. As a consequence, in 2013, the European Commission defined a seriously injured patient as one with a score of 3 or higher on the AIS scale (MAIS $\geq$ 3). Translating this criterion to ISS and NISS indexes, in accordance with their calculation formulae, is the same as stating that seriously injured patients are those with, at least, an ISS or a NISS $\geq$ 9. Since 2016, all member states of the European Union must report all cases of serious patients [13].

Since its first publication in the 1970s, the AIS scale has undergone several revisions, in parallel to the evolution of the concept of severity. The most recent versions currently in use are the AIS 1998 and the AIS 2005 (update 2008). The existence of these different versions makes it necessary to monitor the modifications that each new version has introduced in the AIS scale, since, depending on the version used, the number of patients classified as seriously injured may vary [14]. For this reason, it is important to undertake studies on the relationship between injury severity indexes and the different healthcare indicators, for the different versions of the scale, and thus analyse which index is more valid.

Therefore, the objective of this study was to analyse the relationship between injury severity, measured through the ISS and NISS indexes based on AIS 98 and AIS 05 (update 2008), and the healthcare indicators of mortality, cost, and hospital stay.

Methods

A cross-sectional observational study at the Hospital Universitario Marqués de Valdecilla de Cantabria (HUMV) and the Complejo Hospitalario de Navarra (CHN), both in Spain, was designed.

The study has been approved by the Clinical Research Ethics Committee of Cantabria (reference number 2015.246).

A random sampling without replacement was used for the sample selection. Patients injured by external causes who were admitted to trauma services through the emergency department between February 2012 and February 2013 were included in the study. Patients who were readmitted to the trauma service, with injuries of unknown severity and whose medical records could not be reviewed were excluded from the study.

To ensure that the sample was representative, the size was calculated based on a target population of $n = 1116$ at HUMV and of $n = 1713$ at CHN, with a deviation of $Z = 1.96$, a margin of error of $e = 0.05$ (5%), a proportion of $p = 0.5$ (50%), and a possible loss of 10%. The necessary sample size was of $n = 309$ for HUMV and of $n = 342$ for CHN; however, 359 and 390, respectively, were finally included to ensure that the required sample size was reached after exclusions.

An AIS coding specialist, certified by the AAAM, and member of the International AIS Certification Board, manually coded injuries to determine their severity. ISS and NISS values were assigned for each case. The ISS was calculated as the sum of the squares of the highest AIS scores in each of the three most severely injured body regions (4): $A^2 + B^2 + C^2 = ISS$, where A, B, and C represent the three most severely injured regions of the body. The six body regions used in ISS are: head and neck, face, chest, abdominal and pelvic contents, extremities and pelvic girdle, and external. The NISS was computed as the sum of the squares of the three most severe AIS injuries, regardless of body region [5].

Once ISS and NISS variables were calculated, they were categorized as [15, 16]: minor (ISS 1–8), moderate (ISS 9–14), severe (ISS 16–24), and very severe (ISS > 24). Age, gender, hospital stay, healthcare cost (by means of the Diagnosis-Related Group [DRG]), and mortality (in-hospital and at 30 days) variables were also recorded.

For the statistical analysis, IBM SPSS program, version 22, was used.

Regarding the descriptive analysis of the sample, the mean and standard deviation of the quantitative variables (age, hospital stay, and healthcare cost) and the frequency and percentage of the qualitative variables (gender, ISS, and NISS) were calculated.

Contingency tables for ISS and NISS categories of patients who survived and patients who did not survive were developed by calculating the frequencies and the percentages associated to each category. To analyse the predictive capability of both indexes in relation with mortality (in-hospital and at 30 days), the logistic regression was used. The dependent variable was survival and the independent variable was injury severity, measured using ISS and NISS scores. The discriminatory capability of the models was calculated through the area under the receiver operating characteristic (ROC) curve (AUC) and the calibration by means of the statistical Hosmer–Lemeshow χ^2. Discrimination is the capacity of the tools (in this case, ISS and NISS) to discriminate between patients who survive and patients who die. Calibration is the accuracy of the risk predictions made by the models. The Lemeshow–Hosmer goodness-of-fit test resulting in lower χ^2 value would indicate better calibration for that index, and a p value > 0.05 would validate the model, indicating that no statistically significant differences between the observed and predicted values [17]. The discriminatory capability analysis compared values calculated for the area under the ROC curve for each model. The highest AUC value corresponds to the highest discriminatory capability.

To analyse the relation between ISS and NISS indexes and the healthcare indicators of length of stay (calculated in days) and cost (measured through the DRG weight), the Pearson correlation coefficient was calculated. In addition, to determine whether statistical differences between categories existed, the evaluation was done using the Kruskal–Wallis test, as the sample did not have a normal distribution. For the calculation of the mean stay, discharged patients were taken into account, excluding those who died while hospitalized, resulting in a total sample size of 672 patients.

Results

Out of the 749 cases initially reviewed, 50 were excluded; therefore, the sample was finally composed of 699 cases. The reasons for exclusion of those cases are detailed in Fig. 1. Thus, in the final sample, 49.3% (n = 344) of the patients were from HUMV and 50.7% (n = 355) from CHN (Table 1). Of these, 388 were males (55.5%) and 311 females (44.4%). The mean age was 52.7 years (SD = 29.2), ranging from 0 to 98 years. The mean length of hospital stay was 8.5 days (SD = 16.3), with a range of 0–311 days. The mean DRG weight in the final sample was of 2.5 (SD = 5.6). Twenty-seven patients (3.9%) died in hospital, and mortality at 30 days was 36 (5.2%) patients (Table 1). When comparing the two hospitals, no significant differences were observed in any variable, showing that the sample was homogeneous in both centres.

The most frequent causes of injury were falls (60.4%, n = 422), followed by exposure to inanimate mechanical

Fig. 1 Flow diagram of the sample selection process

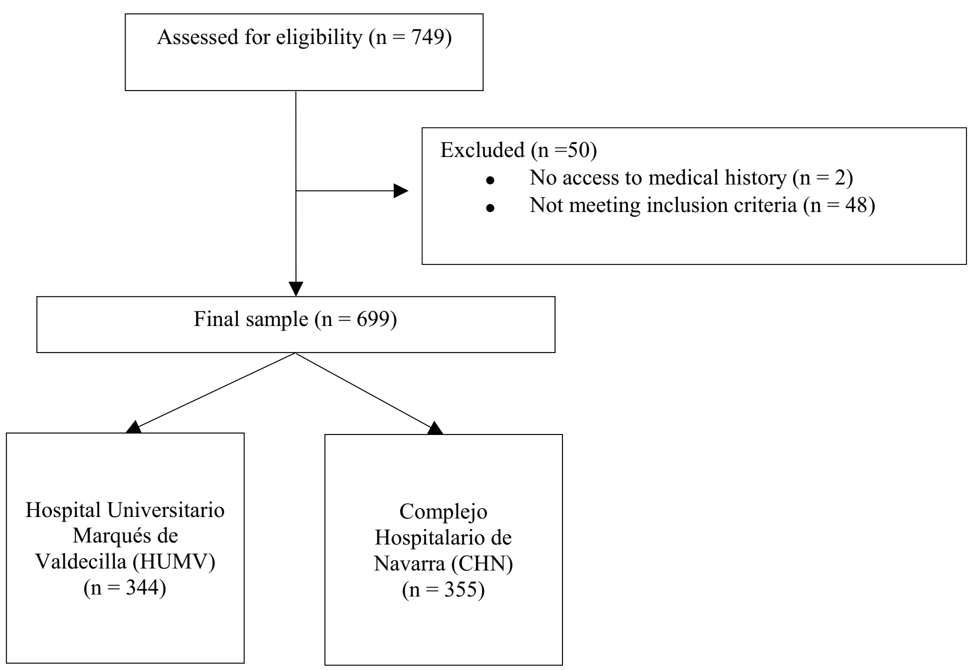

Table 1 Descriptive analysis (sex, age, length of stay, mortality, and cause of injury variables) of the total sample and by centre

Variables	Total		HUMV		CHN		p
	n = 699		n = 344		n = 355		
	M	SD	M	SD	M	SD	
Age (years)	52.66	29.21	53.17	29.17	52.16	29.27	0.82
Stay (days)	8.66	16.46	9.44	19.10	7.92	13.50	0.30
DRG weight	2.52	5.57	3.11	3.23	2.74	1.43	0.16
	n	%	n	%	n	%	p
Sex							
Male	388	55.5	198	57.7	190	53.5	0.21
Female	311	44.4	146	42.3	165	46.5	
In-hospital mortality							
Yes	27	3.86	18	5.23	9	2.5	0.14
No	672	96.14	326	94.77	346	97.5	
Mortality at 30 days							
Yes	36	5.2	22	6.4	14	3.9	0.14
No	663	94.8	322	93.6	341	96.1	
Causes							
Falls	422	60.4	209	60.9	213	60.0	
Transport accidents	83	11.9	52	15.1	31	8.8	
Exposure to inanimate mechanical forces	114	16.2	47	13.5	67	18.9	
Accidental exposure to other and unspecified factors	49	7.0	23	6.7	26	7.3	
Assaults	16	2.3	6	1.7	10	2.8	
Intentional self-harm	6	0.90	3	0.90	3	0.80	0.142
Contact with heat and hot substances	3	0.40	–	–	3	0.80	
Exposure to animate mechanical forces	2	0.30	1	0.30	1	0.30	
Other accidental threats to breathing	2	0.30	1	0.30	1	0.30	
Exposure to electric current, radiation and extreme ambient air temperature and pressure	2	0.30	2	0.60	–	–	

forces (16.2%, $n = 114$) and transport accidents (11.9%, $n = 83$) (Table 1).

As regards to the analysis of mortality (in-hospital and at 30 days), an exponential increase in the percentage of deaths was observed as the severity of the patient increased. Considering ISS < 15 and ISS > 15 severity categories, it could be observed that the percentage of in-hospital and at 30 days deaths ranged between 2.5 and 3.7% for the ISS < 15 category and from 16.9 to 25.5% for the ISS > 15 category (Table 2). In addition, when NISS < 15 and NISS > 15 severity categories were taken into account, the study showed that the percentage of in-hospital and at 30 days deaths ranged from 2.4 to 3.6% for the NISS < 15 category and from 12.9 to 19.2% for the NISS > 15 category (Table 2).

The analysis of the predictive capability of both indexes in relation with mortality showed that, with respect to in-hospital mortality, the NISS 05 index discriminated better among surviving and non-surviving patients than ISS 98, ISS 05 and NISS 98 (AUC = 0.811). In addition, an adequate model fit was obtained (Hosmer–Lemeshow $\chi^2 = 8.76$; $p > 0.05$). However, this index lost its discriminatory capability in mortality at 30 days (Table 3).

Regarding the mean length of hospital stay according to ISS and NISS categories, an exponential increase was obtained, with the length of hospital stay being longer for patients in the most severe categories, except for the ISS 05 index, in which the length of stay was longer for the 16–24 category than for the > 24 category (Fig. 2). Such differences in the mean length of hospital stay between categories were statistically significant for ISS 98 (Kruskal Wallis $\chi^2 = 112.37$; $df = 2$; $p < 0.000$), NISS 98 (Kruskal Wallis $\chi^2 = 115.56$; $df = 2$; $p < 0.000$), ISS 05 (Kruskal Wallis $\chi^2 = 158.58$; $df = 2$; $p < 0.000$), and NISS 05 (Kruskal Wallis $\chi^2 = 155.52$; $df = 2$; $p < 0.000$). The correlation between ISS and NISS values in both versions of the scale with hospital stay was positive and statistically significant ($p < 0.001$). In other words, there is a correlation between the severity of the injury and the days of hospitalization, which is higher for the NISS index in both versions of the scale (Table 4).

Table 2 Contingency tables for the prediction of in-hospital and at 30 day mortality according to ISS and NISS of both versions of the scale

$n=699$	ISS 98						NISS 98					
	1–8	9–14	16–24	> 24	< 15	> 15	1–8	9–14	16–24	> 24	< 15	> 15
In-hosp	*n* (%)											
No	338 (99.1)	279 (95.5)	30 (90.9)	24 (75)	618 (97.5)	54 (83.1)	319 (99.4)	271 (95.4)	41 (93.2)	40 (81.6)	591 (97.5)	81 (87.1)
Yes	3 (0.9)	13 (4.5)	3 (9.1)	8 (25)	16 (2.5)	11 (16.9)	2 (0.6)	13 (4.6)	3 (6.8)	9 (18.4)	15 (2.5)	12 (12.9)
Total	341	292	33	32	634	65	321	284	44	49	606	93
$n = 699$	ISS 05						NISS 05					
	1–8	9–14	16–24	> 24	< 15	> 15	1–8	9–14	16–24	> 24	< 15	> 15
In-hosp	*n* (%)											
No	395 (99.2)	241 (94.9)	15 (78.9)	21 (75)	636 (97.5)	36 (76.6)	370 (99.5)	241 (94.9)	33 (91.7)	28 (75.7)	611 (97.6)	61 (83.6)
Yes	3 (0.8)	13 (5.1)	4 (21.1)	7 (25)	16 (2.5)	11 (23.4)	2 (0.5)	13 (5.1)	3 (8.3)	9 (24.3)	15 (2.4)	12 (16.4)
Total	398	254	19	28	652	47	372	254	36	37	626	73
$n=699$	ISS 98						NISS 98					
	1–8	9–14	16–24	> 24	< 15	> 15	1–8	9–14	16–24	> 24	< 15	> 15
30 days	*n* (%)											
No	338 (99.1)	279 (93.2)	30 (87.9)	24 (71.9)	611 (94.4)	52 (80)	319 (99.4)	264 (93)	41 (93.2)	38 (77.6)	584 (96.4)	79 (84.9)
Yes	3 (0.9)	13 (6.8)	3 (12.1)	8 (28.1)	23 (3.6)	13 (20)	2 (0.6)	20 (7)	3 (6.8)	11 (22.4)	22 (3.6)	14 (15.1)
Total	341	292	33	32	634	65	321	284	44	49	606	93
$n=699$	ISS 05						NISS 05					
	1–8	9–14	16–24	> 24	< 15	> 15	1–8	9–14	16–24	> 24	< 15	> 15
30 days	*n* (%)											
No	395 (99.2)	233 (91.7)	15 (78.9)	20 (71.4)	628 (99.3)	35 (74.5)	370 (99.5)	234 (92.1)	32 (88.9)	27 (73)	604 (96.5)	59 (80.8)
Yes	3 (0.8)	21 (8.3)	4 (21.1)	8 (28.6)	24 (3.7)	12 (25.5)	2 (0.5)	20 (7.9)	4 (11.1)	10 (27)	22 (3.5)	14 (19.2)
Total	398	254	19	28	652	47	372	254	36	37	626	73

Table 3 Comparison of ISS and NISS in both versions of the scale using AUC with a confidence interval of 95% and the statistical interval of Hosmer–Lemeshow χ^2 for the prediction of in-hospital and at 30 day mortality

	ISS 98		NISS 98		ISS 05		NISS 05	
	AUC (CI)	H–L (*p*)	AUC (CI)	H–L (*p*)	AUC (CI)	H–L (*p*)	AUC (CI)	H–L (*p*)
In-hospital	0.780 (0.685; 0.876)	2.23 (0.82)	0.784 (0.693; 0.875)	7.62 (0.18)	0.806 (0.715; 0.896)	3.58 (0.47)	0.811 (0.724; 0.898)	8.76 (0.19)
30 days	0.780 (0.703; 0.856)	5.88 (0.32)	0.773 (0.698; 0.848)	11.09 (0.063)	0.804 (0.732; 0.875)	9.17 (0.076)	0.804 (0.734; 0.874)	14.79 (0.055)

AUC area under the receiver operating characteristic (ROC) curve, *H–L* Hosmer–Lemeshow χ^2, *IC* confidence interval, *p* associated probability

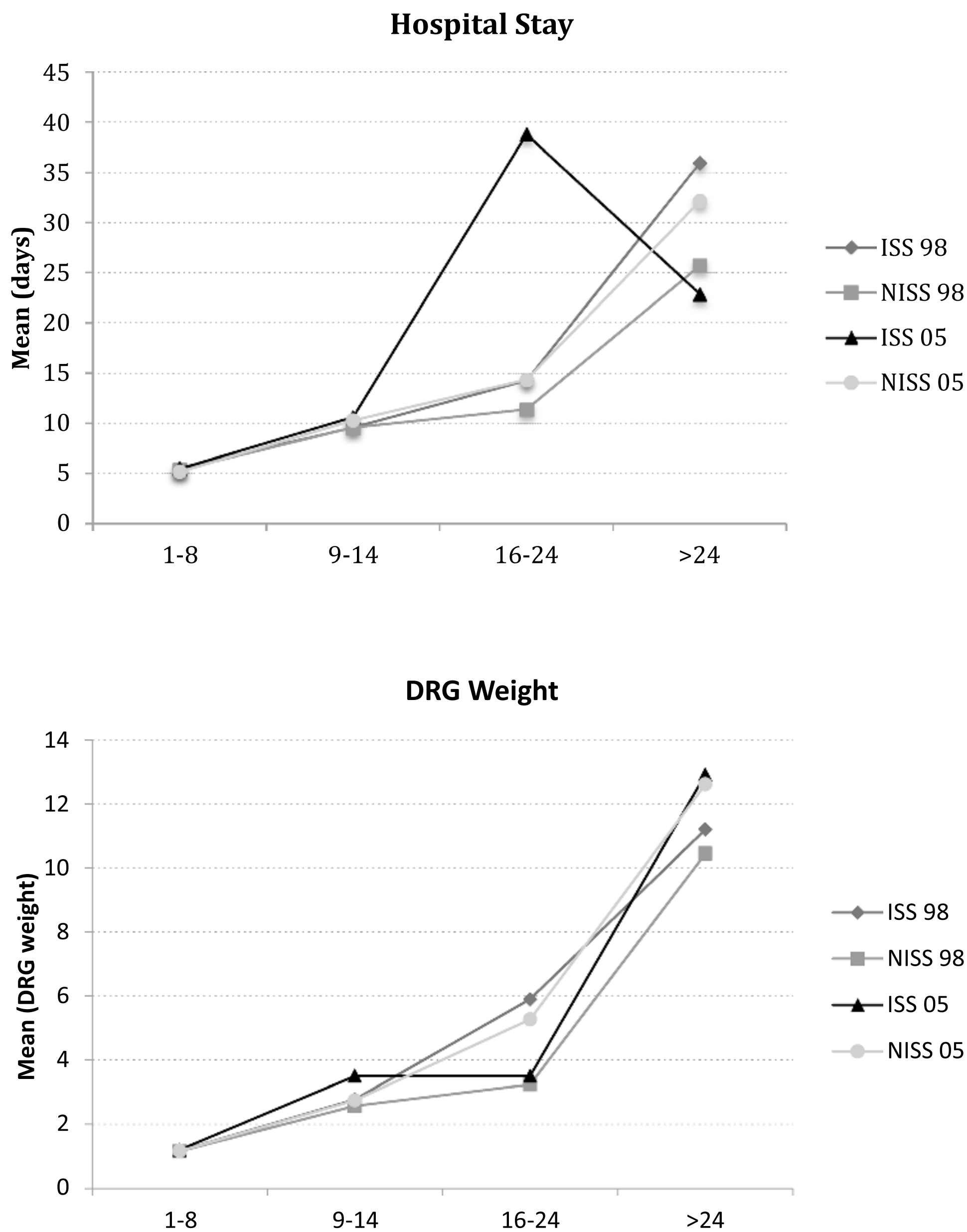

Fig. 2 Mean patient hospital stay and DRG weight for ISS and NISS categories in AIS 98 and AIS 05 versions

Table 4 Correlation coefficient between ISS and NISS values of both versions of the scale and length of stay and DRG weight healthcare indicators

	Hospital stay	DRG weight
ISS 98	0.439**	0.526**
NISS 98	0.516**	0.587**
ISS 05	0.432**	0.465**
NISS 05	0.516**	0.541**

**$p < 0.001$

Finally, with respect to cost, the increase in the DRG weight according to ISS and NISS categories was also exponential, showing higher DRG weight as the severity of patients increased, except for the ISS 05 index, in which the same DRG weight in 9–14 and 16–24 categories was obtained (Table 4; Fig. 2). These differences in the mean DRG weight values between the distinct categories were statistically significant for ISS 98 (Kruskal Wallis χ^2 = 145.66; $df = 2$; $p < 0.000$), NISS 98 (Kruskal Wallis χ^2 = 148.13; $df = 2$; $p < 0.000$), ISS 05 (Kruskal Wallis χ^2 = 190.41; $df = 2$; $p < 0.000$), and NISS 05 (Kruskal Wallis χ^2 = 178.06; $df = 2$; $p < 0.000$).

Discussion

Numerous authors claim that in-hospital mortality is an incomplete measure of injury mortality, as patients also die once they have been discharged as a consequence of the same injuries [18–20]. The criterion for mortality at 30 days is, in addition, that proposed by the United Nations Economic Commission for Europe to define mortality due to road traffic crashes [21].

This study analysed mortality associated with injuries according to their severity when death occurs in the hospital itself (in-hospital mortality) and at 30 days. The results show that mortality at 30 days and in-hospital mortality increased at an exponential rate in accordance with severity of the patient.

In our sample, the predictive capability of ISS 05 and NISS 05 with respect to mortality at 30 days was the same. However, for in-hospital mortality, the index that presented the best predictive capability was NISS 05 (AUC = 0.811), in line with other studies [8]. Conversely, a recent investigation [11] on in-hospital mortality showed a higher predictive capability of ISS with respect to NISS. The fact that the severity index was obtained via an automatic conversion program from ICD-9 codes, rather than using manual coding, could be the reason for the differences between our results and the aforementioned study.

Other studies, such as that of Tohira et al. 2012, concluded that NISS could be a better predictor of mortality, but more studies reporting injury mechanism and type of injury coding would be necessary [22]. In addition, the revision of the Utstein Template for Uniform Reporting of Data following Major Trauma, considered that NISS is preferable to ISS for reporting data after major trauma. The expert panel included in the study concluded that an NISS > 15 should be used as a single inclusion criterion [23].

Regarding length of hospital stay, we observed that it increased exponentially with severity, measured with ISS and NISS for the two versions of the scale, being the longest for the most severe categories. In our study, the best correlation to hospital stay was observed with NISS 98, followed by NISS 05. Some authors [24] have described a higher predictive capability of NISS for length of hospital stay. Other studies on the predictive capabilities of NISS compared to ISS for length of hospital stay [8] have also found a higher predictive capability of NISS compared to ISS, especially for patients in the most severe categories, as these are found to be more faithfully represented by NISS, and therefore, its use is recommended.

On the other hand, it is surprising that version 98 is the one that presents better correlation to length of hospital stay. Mortality is not the only indicator of severity, but it is a very important factor in its determination. Advances in trauma patient care have resulted in a decrease in mortality, but this does not necessarily result in a reduction in the length of hospital stay or resources used.

Another factor to bear in mind when analysing the length of hospital stay is that the revised literature is primarily North American, where they have a fundamentally private healthcare system. On the contrary, in our sample, all cases are covered by a national healthcare system, where the criteria of universal access and guaranteed care can have a significant impact, increasing hospital stay duration. More studies on the possible differences in length of hospital stay according to the type of healthcare system would be necessary.

Finally, the results of the present study show that the correlation between healthcare costs was positive and statistically significant for all severity indexes, but again, in this case, NISS 98 presented a higher correlation in all indexes, followed by NISS 05, ISS 98, and ISS 05. The possible loss of information associated with ISS could explain why NISS correlates better to costs than ISS, in both versions of the scale. Besides this, and as mentioned previously, advances in healthcare system result in a decrease in mortality, but this does not necessarily imply a decrease in healthcare costs.

Limitations

The study presents a series of limitations. First, the column of AIS 05 (update 2008) dictionary that shows the correlation between AIS 98 codes and each AIS 05 (update 2008) code was eliminated to avoid coding bias. Second, given the unavailability of another Spanish-speaking coder accredited as an AIS expert, it was not possible to perform double manual coding to check the inter-coder reliability.

Conclusion

In this study, NISS is shown to be a more precise index than ISS. This makes sense, because from a practical point of view, it is easier to calculate, and from a logical point of view, it assigns the same priority to all injuries, regardless of the body region in which they are found [8]. In the end, NISS is an update that was carried out to improve ISS.

Although any authors recognize the higher predictive capability of NISS over ISS for distinct healthcare indicators (mortality, length of hospital stay and cost) [2, 5, 8, 25, 26] and that the inherent imperfections of ISS as a severity indicator are well known [8, 27, 28], ISS remains the gold standard in the measurement of injury severity [5, 8–11].

In light of the results obtained in this study, we recommend the use of NISS over ISS in the characterization of the severity of patients with multiple injuries.

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Compliance with ethical standards

Conflict of interest The authors declare that we have no conflict of interest.

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