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Original Article

New injury severity score (NISS) outperforms injury severity score (ISS) in the evaluation of severe blunt trauma patients

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ABSTRACT

Purpose: The injury severity score (ISS) and new injury severity score (NISS) have been widely used in trauma evaluation. However, which scoring system is better in trauma outcome prediction is still disputed. The purpose of this study is to evaluate the value of the two scoring systems in predicting trauma outcomes, including mortality, intensive care unit (ICU) admission and ICU length of stay.
Methods: The data were collected retrospectively from three hospitals in Zhejiang province, China. The comparisons of NISS and ISS in predicting outcomes were performed by using receiver operator characteristic (ROC) curves and Hosmer-Lemeshow statistics.
Results: A total of 1825 blunt trauma patients were enrolled in our study. Finally, 1243 patients were admitted to ICU, and 215 patients died before discharge. The ISS and NISS were equivalent in predicting mortality (area under ORC curve [AUC]: 0.886 *vs.* 0.887, $p = 0.9113$). But for the patients with ISS $\geq$25, NISS showed better performance in predicting mortality. NISS was also significantly better than ISS in predicting ICU admission and prolonged ICU length of stay.
Conclusion: NISS outperforms ISS in predicting the outcomes for severe blunt trauma and can be an essential supplement of ISS. Considering the convenience of NISS in calculation, it is advantageous to promote NISS in China's primary hospitals.

Introduction

Trauma scoring system is a common tool used in trauma clinical studies. It can facilitate the assessment of the severity of injury and the comparison of treatment outcomes.[1] ISS is the most widely used trauma scoring system based on the anatomy parameters and provides an overall evaluation for patients with multiple injuries. ISS was introduced in 1974,[2] and it has been one of the most widely used trauma scores. To compute ISS, the body is divided into six regions: head and neck, face, thorax, abdomen, extremities (including pelvis), and external. Each injury on the body is assigned an abbreviated injury scale (AIS) score and only the highest score in each region is used. ISS is calculated as the sum of the squares of the highest three AIS scores. The maximum score of ISS is 75. If a patient with AIS 6 in one body region, by convention, he is given an ISS of 75. However, ISS has limitations because multiple injuries within the same body region are only assigned a single score and this may underestimate the severity for the trauma patients.[3,4]

As a modification of ISS, NISS was proposed by Osler et al.[5] in 1997. NISS was defined as the sum of squares of the three most severe injuries regardless of body region injured. By definition, NISS is at least equal to ISS when the most severe injuries are located in different ISS regions. When NISS is used in evaluating multiple trauma patients, most of the time, the results may exceed ISS substantially.[1,6] In patients with multiple injuries in the same body region, ISS only considers the most severely injured site and may ignore the second most severe site. Therefore, NISS score is more in line with the surgeon's intuition about the injury severity.

As one of the most widely used trauma evaluation scores in China, ISS has been treated as the "gold standard" for trauma evaluation and also has long time been used for trauma research and benchmarking. However, in clinical use, ISS is more complicated than NISS.[1] Studies have shown that NISS score has a comparable ability in predicting trauma outcomes,[7–9] and even has advantages in some areas.[3,5,10] For the Chinese population, there are few studies about the predictive performance of the two scores, and it is unclear which one is more accurate. Considering that NISS

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is easy to calculate, if the NISS score has a similar or better predictive value, trauma evaluation based on scoring systems can be simpler and more reliable. In addition, this helps to promote the use of NISS in primary hospitals, making trauma evaluation based on trauma scoring system as a routine.

In China, the trauma scoring system is not well used in trauma evaluation, but changes may occur in the following years. In recent years, victims suffered from traffic and construction accidents continue to increase with the fast-growing car ownership and urbanization.[11] Trauma is the third leading cause of death in China.[12] From the beginning of 2018, as government directive, trauma centers based on emergency department or other relevant departments were established in most regions in China.[13] In this new situation, evaluation of the treatment based on the trauma scoring system will become an important work and can provide important quality control indicators.

Methods

Study sample

This is a retrospective study with data reviewed from three hospitals in Zhejiang province. Hospital 1 is a teaching hospital with 2200 beds, Hospital 2 and Hospital 3 are both tertiary hospitals with 1500 and 950 beds respectively. All the patients (≥16 years) and sustained blunt trauma were included. The burn and penetrating patients were excluded. The data was collected through a dedicated website, and the following information was collected: demographic data, ISS, NISS, mechanism of injury, in-hospital mortality, ICU admission, and ICU length of stay (<15 days or ≥15 days).[14,15] Data were collected from March to October 2010, and ISS and NISS calculations were based on the AIS2005 version, with all raters trained before data entry.

Statistical analysis

The performance of the two injury scores was compared using the receiver operator characteristic (ROC) curve and the Hosmer-Lemeshow (H-L) statistic. The area under the ROC curve (AUC) ranged from 0.5 to 1, and a larger AUC represents better discrimination. Calibration was measured with the Hosmer-Lemeshow Chi-squared statistic and a low value indicates a well-calibrated model. We calculated the AUC with a 95% confidence interval (95% *CI*) and compared the two AUCs using the methods developed by Hanley and Mc Neil and this method had taken into account the correlation between the two curves based on the Z score.[16] In general, an ISS score greater than 16 is considered as severe multiple injuries,[1] while an ISS score greater than 25 can be regarded as profound injury.[2] To understand whether there is a difference in the predicting power of two scores in different injury severity groups, we also compared the performance of ISS and NISS in subgroup populations (ISS < or ≥ 16 and ISS < or ≥ 25). When predicting the ICU length of stay, patients who did not have ICU admission or died in the period of ICU stay were excluded. In addition, statistical comparisons between patients who have or have not admitted to ICU or stayed in ICU for more than 15 days were performed by an independent sample *t*-test. All statistical analyses were performed with the statistical package for social science for Windows, Version 22.0.

Results

Patients

During the study period of 12-month in 2009, 1825 blunt trauma patients (≥16 years) firstly diagnosed and treated consecutively in the emergency department of the three hospitals were enrolled in our study (Table 1). Approximately 77% of the population were male, and the mean age of this group was (44.73 ± 17.24) years. In Hospital 1, the mean age was (46.93 ± 16.52) years, older than Hospital 2 (43.68 ± 16.77) and Hospital 3 (43.44 ± 18.48). During the hospital stay, a total of 215 patients died with a mortality rate of 11.8%. The most frequent mechanisms of injury were traffic accidents and falls (54.0% and 18.5%, respectively). Finally, 1243 patients (68.1%) had been treated in the ICU. All patients had a mean ISS of 21.14 and a mean NISS of 22.38. There were 1104 severely injured patients with ISS≥16 and 639 patients with ISS≥25. The patients who admitted to ICU had much higher ISS than those who did not (23.83 ± 15.94 *vs.* 15.40 ± 14.36). Patients stayed in ICU ≥15 days also had significantly higher ISS than those stayed less than 15 days (Table 2).

Prediction of mortality

ISS and NISS had an equivalent ability in predicting mortality for the whole sample (AUC: 0.886 *vs*. 0.887, $p = 0.9113$; Table 3). The H-L statistic showed an improved calibration of ISS compared to NISS (19.22 *vs*. 27.13). In the three hospitals, the AUCs were similar for the two scoring systems, and ISS showed similar or better calibration (Table 3). We analyzed the subgroups with ISS<16 (distribution range, 1–15) and ISS≥16 (distribution range, 16–75). For patients in ISS<16 group, the AUCs of the two scores were quite similar, and the calibration of NISS was slightly better. For patients in ISS≥16 group, we found that the performance of NISS was also not significantly better than that of ISS (AUC: 0.788 *vs.* 0.756, $p = 0.1442$), but with better calibration (H-L: 10.25 *vs.* 13.89). However, for the subgroup with ISS≥25 (distribution range, 25–75), NISS was proved to be significantly superior to ISS in predicting mortality (AUC: 0.733 *vs.* 0.708, $p < 0.05$) and with better calibration (H-L: 4.56 *vs.* 4.86). In patients with ISS<25 (distribution range, 1–24), no significant difference was obtained.

Prediction of ICU admission

NISS had a better performance than ISS in predicting ICU admission (AUC: 0.727 *vs.* 0.713, $p = 0.0003$) with an improved calibration (H-L: 79.10 *vs.* 85.92) (Table 4).

Prediction of ICU length of stay

NISS was significantly better than ISS in predicting ICU length of stay for all the patients (AUC: 0.772 *vs.* 0.760, $p = 0.0460$), with a better calibration (H-L: 38.82 *vs.* 43.85). For the three hospitals, NISS was shown to be a better predictor than ISS in predicting ICU length of stay and with a significant *p* value except Hospital 2 (Table 5).

Discussion

ISS is the most commonly used method to assess trauma severity since on the one hand, people have got used to ISS habitually and on the other hand, many studies show no obvious difference in trauma outcome prediction between ISS and NISS.[7–9] We have found in this study that ISS and NISS have comparatively high consistency in mortality prediction. However, the subgroup analysis also indicates that NISS is more accurate in predicting mortality in severe trauma group (ISS ≥ 25). In addition, NISS has demonstrated an obvious superiority in predicting ICU admission and ICU length of stay.

We think that one important reason for this result is the inherent disadvantage of ISS.[3] Namely, among the six anatomic

Table 1
General data of the patients.

Patients' data	Total (n = 1825)	Hospital 1 (n = 626)	Hospital 2 (n = 692)	Hospital 3 (n = 507)
Age (mean ± SD)	44.73 ± 17.24	46.93 ± 16.52	43.68 ± 16.77	43.44 ± 18.48
Gender (n, %)				
Male	1405 (77.0)	497 (79.4)	523 (75.6)	385 (75.9)
Female	420 (23.0)	129 (21.6)	169 (24.4)	122 (24.1)
Mechanism (n, %)				
Traffic accident	985 (54.0)	409 (65.3)	377 (54.5)	199 (39.3)
Fall	337 (18.5)	147 (23.5)	112 (16.2)	78 (15.4)
Others	503 (27.5)	70 (11.2)	203 (29.3)	230 (45.3)
ISS (mean ± SD)	21.14 ± 15.94	29.96 ± 16.75	16.82 ± 9.96	16.15 ± 6.94
NISS (mean ± SD)	22.38 ± 16.28	31.33 ± 17.36	17.46 ± 10.42	17.32 ± 17.47
ICU admission (n, %)	1243 (68.1)	476 (76.0)	487 (70.4)	280 (55.2)

ISS: injury severity score; NISS: new injury severity score; ICU: intensive care unit; SD: standard deviation.

Table 2
Comparison of injury severity score between different subgroups.

Variables	Patients (n)	ISS (mean ± SD)	p value
ICU admission			<0.0001
No	582	15.40 ± 14.36	
Yes	1243	23.83 ± 15.94	
ICU length of stay			<0.0001
<15 days	966	21.05 ± 14.82	
≥15 days	277	33.55 ± 15.91	

ICU: intensive care unit; SD: standard deviation.

regions, only one highest score was rated. The severer a patient's injury is, the higher the risk for two or more organ injuries in one single region will be. Therefore, ISS may underestimate the injury in a single region in patients with severe trauma.[5] Patients who have two traumatic regions with AIS 4 points in their abdominal cavities have significantly higher severity of injury than those who have only one such traumatic region and the death risk is obviously higher. Based on our analysis, it can be discovered that the trend is gradually significant when these patients were divided into ≥16 and ≥ 25 by ISS, indicating that NISS considers the accumulative effect of multiple injuries in a single region. Since it is a subgroup

Table 3
Comparison of ISS and NISS in predicting mortality.

Mortality	ISS AUC (95% *CI*)	H-L (p value)	NISS AUC (95% *CI*)	H-L (p value)	p value
Total	0.886 (0.842–0.920)	19.22 (0.014)	0.887 (0.823–0.931)	27.13 (0.001)	0.9113
Hospital 1	0.847 (0.789–0.902)	12.48 (0.131)	0.865 (0.801–0.919)	26.33 (0.001)	0.7039
Hospital 2	0.806 (0.739–0.874)	14.54 (0.013)	0.803 (0.725–0.862)	14.32 (0.026)	0.8784
Hospital 3	0.946 (0.917–0.970)	12.82 (0.077)	0.935 (0.913–0.958)	21.91 (0.005)	0.8687
ISS<16	0.608 (0.529–0.689)	22.14 (0.001)	0.607 (0.530–0.685)	20.43 (0.005)	0.9235
ISS≥16	0.756 (0.717–0.795)	13.89 (0.085)	0.788 (0.755–0.812)	10.25 (0.115)	0.1442
ISS<25	0.619 (0.531–0.708)	37.57 (0.001)	0.607 (0.514–0.701)	23.11 (0.002)	0.9776
ISS≥25	0.708 (0.658–0.758)	4.86 (0.773)	0.733 (0.677–0.775)	4.56 (0.117)	0.0412

ISS: injury severity score; AUC: area under curve; H-L: Hosmer-Lemeshow; NISS: new injury severity score.

Table 4
Comparison of ISS and NISS in predicting ICU admission.

ICU admission	ISS AUC (95% *CI*)	H-L (p value)	NISS AUC (95% *CI*)	H-L (p value)	p value
Total	0.713 (0.685–0.738)	85.92 (0.001)	0.727 (0.690–0.743)	79.10 (0.001)	0.0003
Hospital 1	0.706 (0.657–0.783)	29.78 (0.001)	0.709 (0.627–0.731)	19.28 (0.006)	0.1310
Hospital 2	0.670 (0.623–0.727)	20.24 (0.001)	0.704 (0.538–0.731)	30.61 (0.001)	0.0001
Hospital 3	0.750 (0.707–0.793)	35.12 (0.001)	0.760 (0.717–0.802)	78.42 (0.001)	0.0001

ICU: intensive care unit;; ISS: injury severity score; AUC: area under curve; H-L: Hosmer-Lemeshow; NISS: new injury severity score.

Table 5
Comparison of ISS and NISS in predicting ICU length of stay.

ICU length of stay	ISS AUC (95% *CI*)	H-L (p value)	NISS AUC (95% *CI*)	H-L (p value)	p value
Total	0.760 (0.725–0.794)	43.58 (0.001)	0.772 (0.740–0.805)	38.82 (0.001)	0.0460
Hospital 1	0.644 (0.590–0.689)	18.75 (0.009)	0.663 (0.611–0.714)	19.56 (0.012)	0.0439
Hospital 2	0.765 (0.696–0.835)	9.03 (0.172)	0.777 (0.708–0.846)	5.11 (0.057)	0.0984
Hospital 3	0.757 (0.648–0.865)	7.95 (0.439)	0.804 (0.711–0.897)	5.41 (0.713)	0.0286

ICU: intensive care unit; ISS: injury severity score; AUC: area under curve; H-L:Hosmer-Lemeshow; NISS: new injury severity score.

analysis, the sample capacity will obviously decrease and the difference in outcomes affected by these small samples will become obvious. Therefore, NISS has demonstrated a higher mortality prediction performance on trauma patients. On the other hand, the results also show that NISS has a more accurate reflection of trauma severity than ISS.

Previous studies have indicated that NISS has a same or even better predictive value as ISS in the study of trauma patient outcomes.[3] In Eid's study,[3] NISS is a better predictor of mortality in trauma patients than that of ISS, suggesting that NISS can be a replacement of ISS. Sullivan[17] has also pointed out in his study on pediatric trauma patients that NISS shows a better death prediction value in patients with an ISS score greater than 25. We can believe in this study that NISS shows special advantages in adults with severe trauma, especially the group with an ISS greater than 25.

Our study has also found that NISS is obviously better than ISS in predicting the ICU admission of trauma patients. In a study including 23,909 patients, Lavoie et al.[18] found that NISS and ISS demonstrate a similar value in ICU admission prediction, but the latter shows a better calibration. In addition, NISS has showed a better performance in ICU admission prediction for patients with moderate to severe craniocerebral injury, suggesting that NISS may have an edge in prediction of severely traumatic treatment outcome. However, there are also a few studies with contrary conclusions. In Tamim's study,[19] ISS outperforms NISS, but the sample capacity of this study is too small. The combined sample size may bring in more credible results but there has been no meta-analysis on the outcomes of the ICU admission and length of stay.

As we know, higher ISS and NISS are significant factors in ICU length of stay. The longer the ICU stay is, the severer the trauma often will be, the more medical resources will be consumed. Based on previous studies, 15 days were selected as the cut-off point for prolonged ICU stay. The results suggest that NISS has a significant advantage in predicting prolonged ICU length of stay in trauma patients. In Harwood's study,[21] NISS shows a better predictive value in patients with prolonged ICU length of stay and the results are consistent with ours. There are fewer studies on the prolonged ICU length of stay, but those studies on hospital length of stay have also found that NISS has a better prediction.[20,21]

Our results indicate that NISS is more accurate than ISS in the ICU admission and ICU length of stay prediction in trauma patients, which may be relevant to the composition of the patient admitted to ICU. Generally, patients with prolonged ICU stay ($\geq$15 days) may have a higher injury severity. In our study, the mean ISS score of patients admitted to ICU is 23.83, significantly higher than patients not admitted to ICU (15.40, $p < 0.0001$); the ISS of patients with ICU stay $\geq$ 15 days are also significantly higher than patients with ICU stay less than 15 days (33.55 *vs.* 21.05, $p < 0.0001$). It is easy to understand since the severer the trauma for surviving patients is, the longer the ICU length of stay will be. It also shows that NISS is more valuable for the outcome prediction in patients with severe trauma, which is consistent with NISS's performance in mortality prediction in the severely injured patients. A multiple-organ injury in one ISS scoring region often has a superimposed effect on patients' ICU length of stay. The severer the trauma in a single region is, the more organs may be injured in that region, the greater the disruption to physiology will be and the longer it will take for patients to recover to the normal physiological state. Patients who suffer more from respiratory and circulatory injuries are more likely to be admitted to ICU and the ICU length of stay is usually positively correlated with the injury severity. Since more than one injury in each scoring region can be involved in NISS, the scoring can better predict which patients need longer ICU length of stay by more accurate reflection in injury severity.

From Table 1, it can be found that the proportions of patients admitted to ICU in Hospital 1 and Hospital 2 are higher than that in Hospital 3 (476, 76.0% and 487, 70.4%, respectively *vs*. 280, 55.2%). Both Hospital 1 and Hospital 2 have trauma ICUs, mainly used to treat patients with multiple injuries. Compared with Hospital 3, Hospital 2 may have a lower ICU admission requirement. The predictive value of ISS and NISS on ICU admission in Hospital 3 is higher than that of Hospital 2 (Table 4). Although the differences between ISS and NISS were significant, the value of the two anatomical-based scores in predicting ICU admission in Hospital 2 declined. There was no significant difference between the two scores in predicting ICU length of stay in Hospital 2 (Table 5), which may be related to a higher proportion of ICU admission and the total length of ICU stay. However, most of the patients in Hospital 1 were transferred from primary hospitals. The patients' condition was more severe and complicated, and hence the influencing factors on ICU admission were more diverse. Thus, there was no significant difference between the two scores in predicting ICU admission in Hospital 1.

Traditional Chinese trauma treatment relies on each specialized department, so most hospitals lack professional trauma treatment teams except for a few teaching hospitals with independent traumatology department.[22] However, this situation has been changed since 2018. National Health Commission of The People's Republic of China has required all provinces and municipalities to establish specialized trauma centers to improve the successful rate on trauma treatment, especially multiple injuries.[13] The trauma scoring system has then become an important assessment tool to be popularized urgently. Currently, ISS is an essential tool for trauma evaluation internationally. It is regarded as the "golden standard" and has long been used in trauma research and benchmarking.[10] It is difficult to replace the most commonly adopted ISS with NISS.[1,6] However, as there is no need to consider the region division, the calculation of NISS is much simpler, making it more advantageous to promote and apply in primary hospitals. Many studies have found that NISS has a similar or even better predictive value than ISS,[5,8–10,21,23] so there is no significant impact on the study on trauma outcomes.

This study demonstrated that ISS and NISS are equivalent in predicting mortality; however, NISS begins to play its advantages when the injury severity increases. Also, NISS is superior in predicting ICU admission and ICU length of stay, especially in severely injured patients. Considering its certain value in trauma severity evaluation and easy calculation, NISS will be more likely to use in primary hospitals in China.

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Ethical statement

This study was approved by the Ethics Committee of the Second Affiliated Hospital of Zhejiang University School of Medicine.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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