



Mortality prediction by 'Life Threat Index' compared to widely used trauma scoring systems

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Abstract

Introduction and objective. Injuries are an extremely important problem in public life and account for up to one-third of deaths in the entire human population. Available trauma scoring systems provide a good estimation of mortality; however, some factors affect their utility in daily practice. Therefore, a new easily applicable in any given country trauma scoring system has been developed and proposed in this study.

Materials and method. A retrospective study of the medical records of 485 patients were evaluated, together with diagnostic performance with regard to mortality, was calculated for the Revised Trauma Score (RTS), Injury Severity Score (ISS), The New Injury Severity Score (NISS), Trauma and Injury Severity Score (TRISS), International Classification based Injury Severity Score (ICISS) and the newly-developed Life Threat Index (LTI). Sensitivity, specificity, accuracy, PPV and NPV were calculated for each scoring system, and overall diagnostic performance was estimated with the use of ROC curves.

Results. Apart from RTS, all scoring systems showed similar performance regarding mortality prediction. TRISS and LTI showed the highest sensitivity reaching 0.998 and AUC of 0.89 and 0.87, respectively, which proved its usefulness in predicting mortality.

Conclusions. LTI proved to be one of the most sensitive in comparison with widely-used and recognized trauma scoring systems. Based on LTI methodology, it can be applied in any given country or region, even without a previously developed trauma database.

Key words

trauma, injury, mortality

INTRODUCTION

Injuries are an extremely important problem in public life, not only because of their medical impact, but also because they often considered as important economical and social factors. Injuries represent 8% of all deaths in the entire human population. They are, however, also one of the leading causes of death among younger patients, thus generating huge financial losses not only because of absence from work or costs of treatment, but also because of their consequence in the form of a disability or emotional distress, which strongly affects the quality of life [1–6]. Statistics for the global burden of disease (GBD) show that over 900 million people were affected by injury and that 4.8 million patients died in this group worldwide [7] in 2013. The most recent GBD also shows that injuries are responsible for 250 million disability-adjusted life years (DALY) [8].

During 2007–2015 in just one state in Australia, the costs related to high energy trauma reached over \$14 billion [9]. Deaths due to injuries make up about 10% of deaths registered worldwide, but because of the young age of the victims, potential years of life lost (PYLL) estimated due to

injuries is definitely the highest when compared to all other causes of deaths and disabilities [10] and, on average, in Western European countries reaches 1,061/100,000 person-years. Therefore, saving lives and preventing disability seems crucial in the economic and social aspects. However, special diagnostic and therapeutic difficulties occur in cases of severe, multiple and multi-organ injuries. This is due to the fact that these type of injuries manifest with numerous pathophysiological and metabolic effects, which are reflected in the general response of the body.

Numerous trauma scoring systems, such as Revised Trauma Score (RTS) [11], Injury Severity Score (ISS) [12], New Injury Severity Score (NISS) [13], Trauma and Injury Severity Score (TRISS) [14], and the International Classification based Injury Severity Score (ICISS) [15], are in used in clinical and academic practice. Each of these scoring systems has its own strengths and weaknesses. ICISS, proposed by Osler et al. [15], a scoring system based on the ICD-9 system, evaluated of over 300,000 patients in North Carolina, USA, and showed the viability of such an evaluation being performed for any given population or country which will be likely to be more objective. In 2008, as a continuation of the concept proposed by Osler et al., Nogalski proposed a Life Threat Index (LTI) (Wskaznik Zagrozenia Zycia – WZZ) [16], which relies on the ICD-10 classification system and validated on 92,000 patients. This scoring system has proved successful in regions where trauma a database and uniform injury classification

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are lacking, such as in Poland. Although to-date this scoring system has not been widely used, it has nevertheless proved its usefulness and reliability.

The aim of this study was to compare LTI with other injury scoring systems available in literature and in clinical practice, with regard to mortality prediction.

MATERIALS AND METHOD

A retrospective cohort study was performed on a group of 485 patients admitted as emergency cases and hospitalized in the Department of Trauma Surgery and Emergency Medicine at the Medical University of Lublin, eastern Poland, during a period of one year. The main inclusion criteria were admission to the emergency department in less than 12 hours post injury, adult patients (over 18 years of age), and patients with injuries classified as S00-T19 accordingly to the ICD-10. The mechanism of injury was also classified with the ICD-10 in the range of V01–Y98. Patients were divided into 4 age groups: under 30-years-old, 31–50-years-old, 51–70 years old, and over 70-years-old.

The database used for analysis was prepared on medical documentation from the hospital Emergency Department, Department of Trauma Surgery and Emergency Medicine, Department of Anaesthesiology and Intensive Care in Independent Public Clinical Hospital No. 1 in Lublin, Poland.

The database created contained following information: Glasgow Coma Scale for neurological assessment, systolic blood pressure, heart rate, respiratory rate at the time of admission to the Emergency Department. Basic descriptive data, national identification number, age and gender, were collected at the time of admission for further processing. Each patient was then admitted to the hospital, where further diagnostics and treatment was performed. Retrospective analysis of individual medical documentation was performed to determine injury severity using the Abbreviated Injury Scale (AIS) [17], and the given injuries were assigned codes from range S–T (according to the ICD-10 classification), beginning with isolated injuries and ending with multiple injuries coded to fourth disease inclusive as well as the mechanism of the injury in the range V–Y (according to the ICD-10 classification). AIS score used for comparison was calculated as the single highest numerical value. The injuries were divided into blunt and penetrating. This data was used to assess severity of the injury in the following scales: Revised Trauma Score (RTS) [11], Injury Severity Score (ISS) [12], New Injury Severity Score (NISS) [13], Trauma and Injury Severity Score (TRISS) [14], International Classification based Injury Severity Score (ICISS) [15], and the newly-developed Life Threat Index (LTI) [16].

LTI such as ICISS is based on the ICD coding system, and the risk factors proposed and calculated by Nogalski assessed for the patients hospitalized in the Lublin Province between 2003–2009. The values of risk factors are provided in appendix 1. For each ICD-10 code corresponding to injuries (S–T), the injury risk factor (IRF) was calculated, for codes describing injury mechanism (V–Y), mechanism-related risk factor (MRF) was calculated. The age-related risk factor (ARF) was calculated for multiple age groups (0–14, 15–24, 25–34, 35–44, 45–54, 55–64, 65–74 and over 74-years-old)

$$IRF = \frac{(\text{number of patients with given S-T codes who survived})}{(\text{number of all patients with given S-T})}$$

$$MRF = \frac{(\text{number of patients with given V-Y codes who survived})}{(\text{number of all patients with given V-Y})}$$

$$ARF = \frac{(\text{number of patients with given age group who survived})}{(\text{number of all patients with given age group})}$$

$$LTI = MRF \times ARF \times IRF1 \times IRF2 \times IRF3 \dots IRFn$$

The lower the LTI score, the more severe the injury and the higher the mortality rate. Injury severity was divided into three trauma groups: trauma, moderate, and severe, with corresponding LTI, ICISS and TRISS scores: ≥ 0.9 ; 0.75–0.899 and 0–0.749.

Statistical analysis. Statistical analysis was performed by a statistic specialist using IBM SPSS ver. 14.0. For categorical variables, Pearson's Chi-square was used. Diagnostic performance of trauma severity score in predicting mortality was evaluated with the Receiver Operating Characteristic Curve (ROC). A predictive model was created for every trauma scoring system, which was then compared between scoring systems. During ROC evaluations, factors such as sensitivity and specificity were taken into consideration, which is easy to use in daily practice [18, 19], as the area under the curve (AUC) is a numerical presentation of diagnostic effectiveness. Positive predictive value (PPV) and negative predictive value (NPP) were calculated, where PPV indicates the probability of death and NPP probability of survival.

RESULTS

The study group consisted of 485 patients of whom a significant majority were males (58.85%; $p < 0.0001$). Patients ages ranged from 18–101 years. Patients aged over 70 constituted over 30% of the study group. Only 15% of patients were under 30 of age. Males in this age group sustained injury four times more frequently than females ($p < 0.0001$). Females had the highest injury rate in the over 70 age group. The demographic characteristics of the study group are presented in Table 1.

Table 1. Demographic characteristic of the study group

		Age				Total
		< 30- years- old	31–50- years- old	51–70- years- old	70- years- old	
Gender	N	13	33	47	106	199
	Gender %	6.5%	16.6%	23.6%	53.3%	100%
	Age %	17.6%	25.0%	36.2%	71.1%	41.0%
	Total %	17.6%	25.0%	36.2%	71.1%	41.0%
Males	N	61	99	83	43	286
	Sex %	21.3%	34.6%	29.0%	15.0%	100.0%
	Age %	82.4%	75.0%	63.8%	28.9%	59.0%
	Total %	12.6%	20.4%	17.1%	8.9%	59.0%
Total	N	74	132	130	149	485
	Total %	15.3%	27.2%	26.8%	30.7%	100.0%

Over 90% of all traumas were blunt injuries, which was consistent for all age groups. However, males were more susceptible to penetrating injuries (12.6%), compared to 3.5% of females in all age groups. The mortality rate in the study group was 4.52% (n=22), and was significantly higher in males – 3.08% (n=15) vs. females – 1.44% (n=7; p<0.001). The distribution of injuries and the results of mean scores in each scoring system are presented in Table 2.

Table 2. Distribution of injuries depending on gender and age

		Sex		Total			
		Females	Males				
Injury mechanism	Penetrating	N	7	36	43		
		Injury mechanism %	16.3%	83.7%	100.0%		
		Sex %	3.5%	12.6%	8.9%		
	Blunt	Total %	1.4%	7.4%	8.9%		
		N	192	250	442		
		Injury mechanism %	43.4%	56.6%	100.0%		
Total	Sex %	96.5%	87.4%	91.1%			
	Total %	39.6%	51.5%	91.1%			
	N	199	286	485			
Total	Total %	41.0%	59.0%	100.0%			
		Age				Total	
		< 30-years-old	31 – 50-years-old	51 – 70-years-old	70-years-old		
Injury mechanism	Penetrating	N	11	11	15	6	43
		Injury mechanism %	25.6%	25.6%	34.9%	14.0%	100.0%
		Sex %	14.9%	8.3%	11.5%	4.0%	8.9%
	Blunt	Total %	2.3%	2.3%	3.1%	1.2%	8.9%
		N	63	121	115	143	442
		Injury mechanism %	14.3%	27.4%	26.0%	32.4%	100.0%
Total	Sex %	85.1%	91.7%	88.5%	96.0%	91.1%	
	Total %	13.0%	24.9%	23.7%	29.5%	91.1%	
	N	74	132	130	149	485	
Total	Total %	15.3%	27.2%	26.8%	30.7%	100.0%	

Table 3. Mean range of injury severity scoring systems point value

	Mean	SD
RTS	11.73	1.213
AIS	2.79	0.776
ISS	9.33	6.7
NISS	10.35	8.721
TRISS	0.9872	0.08098
ICISS	0.94	0.092
LTI	0.9	0.099

Analysis of predictive values of all scoring systems showed that RTS did not reach AUC of 0.8, which shows significantly inferior diagnostic performance on any evaluated scale in this study, with p value ranging from 0.006 – <0.001, depending on the scoring system. TRISS reached the highest AUC of 0.89, followed by LTI 0.87. AIS and ISS showed lower predictive values, respectively, 0.81 and 0.84. No significant difference was noted between the diagnostic performance of LTI and TRISS (p=0.445), and both systems showed the highest diagnostic performance among the evaluated scoring systems. Regarding PPV and NPV, TRISS also showed to be most efficient scoring system. Positive prognostic value for TRISS reached 0.971 and NPV 0.889. The sensitivity of LTI was comparable with TRISS and NISS; however, LTI showed higher specificity. (Tab. 4; Fig. 1–2).

Table 4. Comparison of diagnostic accuracy, sensitivity, specificity, PPV, NPV and AUC of evaluated trauma scoring systems.

	AUC	95% CI LO	95% CI HI	Sensitivity	Specificity	PPV	NPV	Accuracy
RTS	0.75	0.64	0.86	0.996	0.682	0.968	0.778	0.965
AIS	0.81	0.74	0.88	0.978	0.727	0.966	0.375	0.946
ISS	0.84	0.77	0.92	1.000	0.954	1.000	0.957	0.957
NISS	0.83	0.75	0.91	0.998	0.909	0.959	0.667	0.957
ICISS	0.86	0.78	0.94	0.994	0.818	0.962	0.571	0.957
TRISS	0.89	0.84	0.95	0.998	0.636	0.971	0.889	0.969
LTI	0.87	0.80	0.94	0.998	0.909	0.959	0.667	0.957

The study also shows that all evaluated scoring systems have a high capacity for estimating mortality; however, estimation of survival rate is relatively lower when based on PPV and NPV.

The results show that all the scoring systems are comparable; however, physiological- based scoring systems such as RTS are least accurate in predicting mortality. Also, anatomical systems represented by AIS and ISS showed inferior results to the more developed systems such as TRISS, TLI or ICISS. This shows that the introduction of parameters such as injury mechanism or age increases the predictive values of the scoring systems, although this is not a statistically significant improvement.

DISCUSSION

In the injury databases and injury severity scales, AIS, ISS, NISS and TRISS are widely used [20, 21]. Their big advantage is data collected regarding this particular group of patients, and provide the possibility of fully assessing the severity of injury. However, there is no uniform system for patient assessment after injury [22]. Almost any trauma centre anywhere in the world can choose an injury scale which is most convenient, popular, or known in a particular country or region, which often does not permit comparison of results of treatment between trauma centres and makes it difficult to create uniform procedures and algorithms.

Scoring systems derived from AIS, such as ISS, NISS or TRISS, are the most popular in literature. However, none of the mentioned systems is uniformly accepted worldwide as the gold standard, and new scoring systems are introduced into literature [23] to provide more accurate and detailed descriptions of patient status.

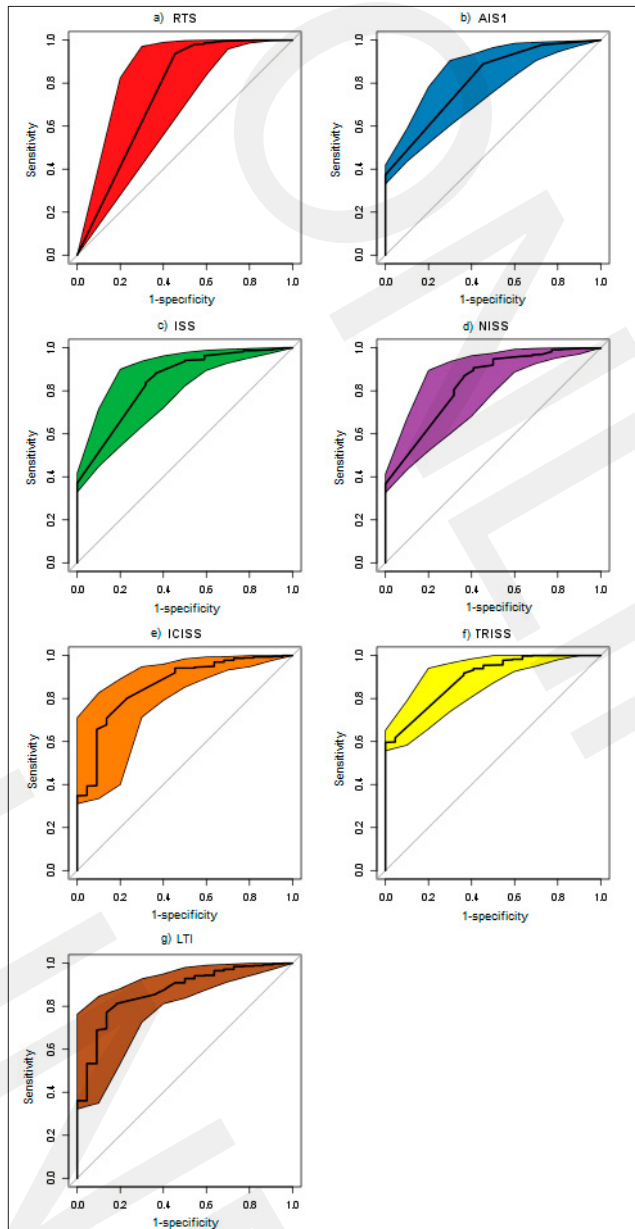


Figure 1. ROC curves for RTS (a), AIS (b), ISS (c), NISS (d), ICISS (e), TRISS (f) and LTI (g) with 95% CI

The greatest disadvantage of the above-mentioned scoring systems is believed to be the cost of their use due to several factors. First of all, the copyrights to the AIS classification are owned by the Association for the Advancement of Automotive Medicine. In order to use any of the subsequent editions of AIS classification, copyrights have to be bought. The second issue is the coding problem, where coders can code similar injuries differently, and the coding in this system is a dynamic process and emergency department evaluation is not the end of the coding process. Additional conditions during hospitalization or surgery can also be observed which influence the end-point value of the system; intra-observer agreement is low without special training [24]. These facts render the AIS scale and its derivatives to be unsuitable for use as a diagnostic tool in the pre-hospital period; its complexity requires a certain way of training the coders which significantly increases the costs of its use, especially in middle to low income countries.

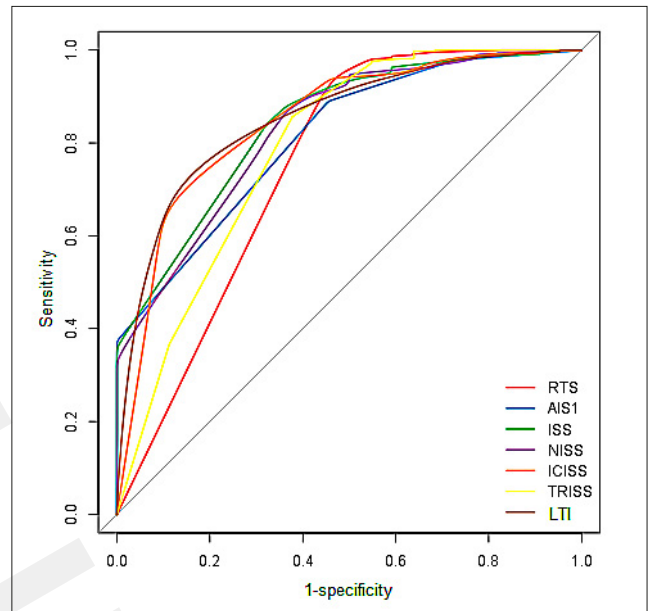


Figure 2. Collective ROC graph presenting results of all evaluated trauma scoring systems

LTI and ICISS have a significant advantage in this respect as they consider all injuries that occurred and multiple injuries are taken under consideration.

When considering point distribution of ISS and NISS in the studied group of patients, it can be noticed that while in scoring according to ISS, the maximum result was 48 points, while the maximum score according to NISS was 66 in the same study group. In addition to the value 48, which was a maximum for ISS, there were other results, such as 50, 57, 66, appearing in NISS for the same group of patients. This shows that grading according to NISS is more detailed, precise, and describes the results of injury in a better way; however, the most recent meta-analysis shows that there is no significant difference between NISS and ISS in predicting mortality [25]. Another drawback of the system based on AIS is the fact that the age of the patient is not taken into consideration in the calculations. This is the factor which was of critical importance in some cases, such as peritrochanteric fractures where age is widely recognized risk factor [26], but is not included in trauma scoring systems.

TRISS results are dependent on GCS score, which are often changed between EMS and Emergency Departments, which is rather caused by dynamic changes appearing after initial trauma, while GCS showed good inter-observer agreement [27]; therefore, it should be proposed that in TRISS evaluation only one predetermined GCS score should be used, such as GCS evaluation in the Emergency Department. Additionally, RTS which also relies on GCS and other physiological parameters, is susceptible to inappropriate scoring due to changes in a patient's status, or coding differences between coders, and major trauma definitions based on newly-proposed methodology or scales are introduced [28].

The above-mentioned factors speak in favour of trauma scoring systems although they are of an experimental character, e.g. ICISS or LTI, where no acute physiological changes are taken into consideration and cannot influence the end result. In the current study, it was found that LTI is comparable with TRISS, ISS or NISS in predicting mortality [25, 29]. However, in this study, the mean ISS reached 9.33,

which shows that the majority of evaluated patients suffered minor trauma, which could have influenced the overall results, and suggests that further larger studies in this aspect should be conducted prior to introducing LTI into wider use around the world.

The current study also showed that, apart from RTS, all scoring systems showed similar diagnostic performance, as also shown by other researchers [30], and ways to improve this scoring system are proposed in literature [31]. The above-mentioned factors affecting the widely-used scoring systems outline the need for creating a uniform scoring system which can be introduced worldwide in any given country or region.

The LTI in its original and first form was based on risk factors in the Lublin Province in eastern Poland which are also characteristic for this strictly defined area, and which were used in this study to calculate the value of LTI. Naturally, in order to transfer the LTI methodology, a database of risk factors characteristic for each region or country needs to be developed. This would be relatively easy to achieve without vast additional financing. Moreover, due to fact that LTI is based on the ICD scoring system and shows high sensitivity, it can be applied as a simple triage mechanism for patients with multiple injuries.

The main limitation of ISS is that it is not capable of coding multiple injuries affecting one anatomical location. To avoid this problem, an NISS was proposed where multiple injuries can be assigned to one anatomical location, but no more than three. Some studies show superior diagnostic performance of NISS over ISS in predicting mortality [32]. Nevertheless, in the current study, the same as in a recent meta-analysis by Deng et al [25], the diagnostic performance of ISS and NISS is comparable, regardless of the fact that NISS can include more than one injury in a given anatomical location. This phenomenon does not occur in ICISS and LTI where multiple injuries are included, which results in a higher mortality prognostic value. According to Osler, in the ICISS such factors can be considered. As proven, the more the co-factors considered, the greater the significance of the predictive value in scale improves [15, 33]. In the current study ICD-10 classification for ICISS calculation was applied which showed a high diagnostic performance with AUC of 0.86. This corresponds with other researchers showing AUC of 0.852–0.868 in ICD-10 based ICISS [34–36] with regard to mortality, and 0.815 with regard to ICU admission [35]. Such a high diagnostic performance can be only obtained if survival risk ratios (SRR) are correctly adopted for high, middle or low income countries, as shown by Claeson et al. [37].

It is worth remembering that the ICISS predicting value is only based on SRR calculated for a given ICD code, without taking into consideration other factors that may affect its diagnostic performance. LTI, which incorporates risk factors describing age or injury mechanism, provide a higher diagnostic performance. Also, the amount of risk factors representing specific injuries used to calculate LTI is unlimited, and multiple injuries can be evaluated in a single patient, through which, diagnostic accuracy increases.

The obtained results show that injury severity scales used in the study, such as AIS or ISS, based only on anatomical deviations from the norm in the injury examination, as well as physiological response of the organism to injury such as RTS, proved to be inferior in predicting mortality or patient survival, than much more complicated scales such as TRISS, LTI or ICISS.

Taking the results of this study into consideration, it is proposed that in the setting of an Emergency Department, the teams of emergency medics and areas of the hospital Emergency Department, the Revised Trauma Score, Glasgow Coma Scale, and assessment of basic physiological parameters, should be used, as well as additional tests to provide a basis for making the decision about admitting patient to the hospital or not. When the patient arrives in the hospital and is fully diagnosed, it is proposed that prognostic scales such as LTI or TRISS. RTS and GCS should be used by the teams of emergency medics and the hospital Emergency Department, due to little amount of time needed for collection of all necessary data and ease of data collection for evaluation. More detailed and time-consuming scoring systems, such as LTI or TRISS, seem most applicable in the next step of treatment due to their good diagnostic and predictive properties.

CONCLUSIONS

LTI proved to be an effective tool compared to other widely-used and recognized trauma scoring systems. All evaluated injury scales, apart from RTS, showed high and similar accuracy in predicting mortality. The methodology of LTI enabling inclusion of multiple factors such as the injury mechanism or patients age, as well as multiple ICD based codes, provide adequate diagnostic accuracy and the ability to implement this system in any given region or country.

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