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Using injury severity measures in trauma research:
a review from Low- and Middle-Income Countries

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Using injury severity measures in trauma research:

a review from Low- and Middle-Income Countries

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Using injury severity scores in trauma research

a review from Low- and Middle-Income Countries

ABSTRACT

Introduction:

Injury remains a major public health problem globally, but 90% of all trauma deaths occur in Low-and-Middle-Income-Countries (LMICs), where resources to deal with this crisis are inadequate. Characterization of injury severity is an important pillar of scientific research to measure and compare the outcomes. Although many injury severity measures were developed in high-income countries, many have been studied in LMICs. We conducted this study to identify and characterize all injury severity measures, describe how widely and frequently they are utilized in LMICs, and summarize the evidence on their performance based on empirical and theoretical validation analysis.

Methods:

First, a list of injury measures was identified through PubMed search. Subsequently, a systematic search of PubMed, Global Health, and EMBASE was undertaken, on LMIC trauma literature published from January 2006 through June 2016. To assess the application and performance of injury severity measures to predict in-hospital mortality, studies that applied one or more global injury severity measure(s) on all types of injuries were included, with the exception of war injuries and isolated organ injuries.

Results:

Over a span of 40 years, more than 55 injury severity measures were developed. Out of 3862 non-duplicate citations, 597 studies from 54 LMICs were listed as eligible studies. Full text review revealed 37 studies describing performance of injury severity measures for outcome prediction. Twenty-five articles from thirteen LMICs assessed the validity of at least one injury severity measure for in-hospital mortality.

Injury severity score was the most commonly validated measure in LMICs, with a wide range of performance (AUROC between 0.9-0.65). TRISS validation studies reported AUROC between 0.80-0.98.

Conclusion: Empirical studies from LMICs frequently utilize injury severity measures, however, no single injury severity measure has shown a consistent result in all settings or populations and thus warrants validation studies for the diversity of LMIC population.

Keywords: Injury severity measures; trauma score; injury severity scores; low- and middle-income countries; validation studies

Word Count:
Abstract: 300
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Article Summary with Strength and Weaknesses:

1. The study comprises of three parts: summary of all injury severity measures, description of their use in LMICs, and their performance to predict in-hospital mortality in LMIC settings

2. Injury severity measures, whether developed exclusively for characterizing trauma and injuries, or non-injury severity measures incorporated in trauma research, are both included in this study

3. A systematic electronic search of PubMed, Global Health, and EMBASE on literature published from January 2006 through June 2016.

4. Validation studies conducted in LMICs are used to estimate the performance of injury severity measures

5. Performance of injury severity measures to predict other outcomes such as blood transfusion requirement, ICU admission, or hospital length of stay, are not focus of this study

INTRODUCTION

Injury remains a major public health problem globally, causing significant death and disability across all

the age and sex spectrum.[1] A disproportionate share, 90%, of all trauma deaths occur in low- and

middle-income countries (LMICs), where resources to deal with this crisis are inadequate. An efficient

and effective trauma system has been found to be a key component. It is estimated that approximately

two million lives could be saved annually if LMICs could implement trauma systems comparable to

trauma care systems available in High- Income Countries (HICs).[2] However, this would require a careful

assessment of the gaps and planning to ensure the most efficient use of available resources. Injury

severity scoring systems can provide a foundation for benchmarking and performance improvement in

the arena of trauma care.[3] Characterization of injury severity is a critical pillar in the provision and

improvement of trauma care for key activities such as field triage, prognostication, prediction of risk-

adjusted outcomes, quality improvement, evaluation of cost and effectiveness of trauma service

delivery, planning of services and organization of resources.[4] Many injury measures have been

formulated over time with a wide range of methodologies.[5] While no single injury measure is

considered the best or the most comprehensive, assessment of injuries in a patient has been aided by

assigning numerical values to several indicators including physiological or biochemical parameters,

anatomical descriptors, age, etc., and combining these values to an overall measure of injury severity.[6,

7] While injury severity measures are most often used for the purpose as they were developed, such as

triage or mortality prediction, it is not uncommon to validate and use them for other functions.[8, 9]

There has been a proliferation of injury severity measures over the past few decades.[7, 10]

While a variety of injury severity measures have been developed exclusively for trauma and injuries,

other non-injury severity measures have also been incorporated in trauma research on many

occasions.[11-14] These severity measures use a range of clinical, biochemical, demographic, and

physical attributes to create indicators for prognostic predictions and performance evaluation.[4, 15]

However, both the utilization and validation of injury scores in clinical care or outcome research has been sparse in LMICs.[16] There are multiple reasons for this, but in many cases, especially for those injury severity measures developed in high-income settings, the information needs are challenging for a low-resource environment.[11, 15, 17-19] Many well-recognized injury measures were sometimes applied without being validated in the populations under study. One common example is the Trauma and Injury Severity Score (TRISS), which has been used widely for monitoring performance and benchmarking of observed versus expected survival outcomes in both HICs and LMICs.[20-22] TRISS coefficients were derived using the Major Trauma Outcome Study (MTOS), which was conducted in North American populations in the 1980s. The application of TRISS in other populations using the coefficients derived from the MTOS has thus often been questioned and debated.[22, 23] Similarly, some studies documented poor performance of other commonly used injury scores when applied to other populations.[24-26] However, there is a dearth in the literature on which injury severity measures were commonly used, whether those have been validated in such settings, and which of those show better performance in terms of validity and reliability to support their use in LMICs. This gap limits our ability to translate high quality injury research methods developed in HICs into effective decision support and quality improvement systems for LMICs. The aim of this study was therefore to fill this gap in the literature through a thorough review of the literature; specifically we sought to: (1) identify all the measures and scoring systems that were ever developed to measure injury severity, and summarize their characteristics; (2) describe how widely and frequently the key measures are utilized in LMICs; and (3) summarize the evidence on their measurement performance based on empirical validation analysis and theoretical analysis of their applicability.

METHODS

For our first aim, we conducted a literature search for terms "injury AND severity measures" OR "injury AND scores" OR "Injury AND scales", as well "Trauma AND severity measures" to include those that are not exclusive to injuries but have been utilized in trauma and injury research. A list of injury measures was identified through PubMed search. Subsequently, using bibliographies of the results of the primary search, a secondary search was performed to find the original literature of the injury measure development. Full text of all publications was reviewed to understand and describe the initial purpose and scope of development of the injury measure, its main components, year of first publication and country of development.

For the specific aims two and three, we conducted a detailed literature review to assess the application and performance of injury severity measures to predict in-hospital mortality, conducted in low- and middle-income countries. We included studies of global trauma populations and specific injury pathologies and used World Bank's classification for low- and middle-income countries (LMICs).

Eligibility Criteria:

For the purpose of determining the applications of different injury severity measures in LMICs, we included studies that applied one or more global injury severity measure(s) on any type of injury population, except for studies that focused only on poisoning, drowning, and ocular trauma. We excluded studies that applied exclusively organ specific injury severity measure(s), population from low income country treated in a high-income setting, as well as studies describing only combat injuries or those from military trauma registries due to the environment and contexts largely different from general LMICs settings.

Information Sources and Search Strategy:

We conducted a systematic electronic search of PubMed, Global Health, and EMBASE on literature published from January 2006 through June 2016. We used combinations of search terms including medical subject heading (MeSH) and keywords on two groups: "trauma or injury measures", and a list of "LMICs" (Supplemental file 1). We applied human subjects restrictions but language restrictions were not applied. All references were exported to Endnote version 7® and duplicated studies were excluded using Endnote before exporting them into an Excel spreadsheet.

Two authors (A.M. and S.A.) independently screened the titles and abstracts of all studies resulted from the above search strategy to identify the eligible studies for the applications of injury severity measures in LMICs. Full text version of all the eligible articles were sought and if full text was not available in English language, the abstracts were excluded from further analysis. All eligible full text articles were reviewed for relevance and data collection.

Data abstraction

Data were extracted from the selected studies using a pre-designed electronic data collection form. The studies were further categorized into validation studies or empirical/non-validation studies, or excluded if they did not match the inclusion criteria on full text review (Figure 1).

- Insert Figure 1-

To assess the performance of injury severity measures and prediction of in-hospital mortality, we selected studies that estimated the Area Under the Receiver Operating Characteristic (AUROC) curve or correlation between specific injury severity measure and in-hospital mortality, based on the studies identified with applications of injury severity measures in LMICs. Studies that did not specify the outcome of assessment or did not include any estimates of AUROC, correlation, or sensitivity and specificity were excluded. Three authors (A.M., H.H., and Y.W.H.) screened these identified studies for

the performance on predicting in-hospital mortality. Any disagreements were resolved by discussions among the three authors.

For the purpose of determining applications of different injury severity measures in LMICs, three authors (A.M., H.H., and Y.W.H.) extracted information on the injury severity measures used in each study, whether performance was assessed on in-hospital mortality prediction, and the country in which the study was conducted. The studies and corresponding injury measures were assessed in detail for study population, type of injury and injury mechanism, injury severity measures, study methods, in-hospital mortality prediction, and their corresponding performance in predicting in-hospital mortality. The performance of the injury severity measures is reported as Area Under Receiver Operating Characteristic (AUROC) curve and calibration as Hosmer-Lemeshow (H-L) goodness of fit test.

RESULTS

The results are described in order of specific objectives of the study. Our study demonstrates considerable growth in the science of injury severity measurement globally as well as in LMICs. Table 1 summarizes the search results of different injury measures, categorized according to the primary purpose of their development and their core components. It shows clearly that the science of injury severity measures had essentially taken off in early 1970s and it is still ongoing with similar enthusiasm. Almost sixty severity measures or scoring systems have been developed either exclusively for injury and trauma research or have been used in measuring the severity of injuries. Many injury severity measures were developed to support epidemiological research and performance evaluation; examples include, Abbreviated Injury Scale (AIS), Injury Severity Score (ISS) and New Injury Severity Scores (NISS), A severity categorization of trauma (ASCOT) and ICD-9-injury severity score (ICISS). Others, such as Revised trauma score (RTS), CRAMS, ABCD, and Kampala trauma scores (KTS) were developed to help in decision making, for example, pre-hospital triage, and in-hospital patient disposition. A number of injury

measures were developed for the purpose of outcome prediction; Trauma Mortality Prediction Model

(TMPM), Rapid Emergency Medicine score (REMS), and GAP are some examples.

Table 1: List of Injury Severity Measures, their purpose and components

	Measures	Year, Country	Components
	Primary purpose: Epidemiologic research and evaluation		
1	Abbreviated Injury Scale (AIS)[27]	1971, USA	Anatomic description of injuries
2	Comprehensive research injury scale (CRIS)[28]	1972, USA	Energy dissipation, threat-to-life, permanent impairment, treatment period, incidence
3	Injury Severity Score (ISS)[29]	1974, USA	AIS
4	Estimated survival probability (ESP) index[30]	1978, USA	International classification for disease (ICDA) codes
5	Penetrating and Blunt (PEBL) code[31]	1978, USA	Anatomic description of injuries with limited physiological responses
6	Wisconsin Trauma Index[17]	1980, USA	Involvement of different organ systems, burns, age, pre-existing condition
7	Anatomic Index (AI)[32]	1980, USA	Hospital Adaptation of the International Classification of Diseases Discharge Diagnosis
8	Revised estimated survival probability (RESP) score[33]	1982, USA	Hospital ICDA Discharge Diagnosis (HICDA), age
9	Probability of Death score (PODS)[34]	1983, Denmark	Re-categorization of AIS
10	Trauma Score – Injury Severity Score (TRISS)[23]	1987, USA	RTS, ISS, age, mechanism of trauma
11	Organ injury scale (OIS)[35-38]	1989, USA	Anatomic description, blood loss
12	Anatomic Profile (AP)[39]	1990, USA	AIS, Summary scores for body regions A through D
13	ASCOT (A severity categorization of trauma)[39]	1990, USA	ED RTS, patient age, AIS-85
14	Perceptron Neural Networks[40]	1993, USA	RTS, ISS, age
15	ICISS (ICD-9 Injury Severity Score)[41]	1996, USA	ISS, ICD-9 injury descriptors
16	New Injury Severity Score (NISS)[42]	1997, USA	AIS
17	MAX AIS[43]	2002, USA	Maximum AIS score
18	Trauma Registry Abbreviated Injury Scale Score (TRAIS)[44]	2003, USA	AIS derived survival risk ratio (SRR)
19	Turkish Injury scale (TIS)[45]	2003, Turkey	Injury severity according to Turkish Penal code
20	Revised Injury Severity Classification (RISC) Score[21]	2009, Germany	AIS, age, sex, head injury, biochemical and physiological parameters, cardiopulmonary resuscitation (CPR)
	Primary purpose: Triage and Decision Support		
21	Trauma index (TI)[46]	1971, USA	Region and type of injury, Cardiovascular, Central nervous system, Respiratory status
22	Glasgow coma scale (GCS)[47]	1974, UK	Eye opening, motor and verbal response
23	Illness-injury Severity index[48]	1979, USA	Physiological parameters, region and type of injury, pre-existing condition
24	Trauma Score[49]	1981, USA	Respiratory effort, Capillary refill, Respiratory rate (RR), Systolic Blood pressure (SBP), Glasgow Coma Scale (GCS)

25	CRAMS (Circulation, Respiration, Abdomen, Motor and Speech)[50]	1982, USA	Capillary refill, respiration, abdominal injuries, motor and verbal response
26	Prehospital Index (PHI)[8]	1986, USA	SBP, pulse, RR and level of consciousness
27	Rapid Acute Physiology score (RAPS)[51]	1987, USA	Truncated version of APACHE II- Pulse, BP
28	Revised Trauma Score (RTS)[52]	1989, USA	Sum of weighted values of GCS, BP, RR
29	Kampala Trauma Score (KTS)[53]	1996, Uganda	Age, number of serious injury, SBP, RR, neurologic status (AVPU)
30	FOUR (Full Outline of UnResponsiveness) score[54]	2005, USA	Physiological score consisting of eye, motor, brainstem and respiratory components
31	Trauma Associated Severe Hemorrhage Score (TASH)[55]	2006, Germany	SBP, hemoglobin, free peritoneal fluid, base excess, complex fractures, pulse, and sex
32	Prehospital pediatric trauma classification (PHPTC)[56]	2006, Brazil	Physiological status, trauma mechanism and anatomic injuries
33	Ganga Hospital Score[57]	2006, India	Severity of injury to the skin, bones and muscles of the limb; presence of co-morbids
34	Assessment of Blood Consumption (ABC) Score[58]	2008, USA	SBP, positive abdominal ultrasound, pulse, and penetrating injury
35	Emergency Trauma Score (EMTRAS)[59]	2009, Germany	Age, prehospital GCS, base excess, prothrombin time
36	Acidosis, Blood loss, Cold, Damage (ABCD)[60]	2012, USA	Acidosis, blood loss, temperature, NISS

Primary purpose: Outcome prediction

37	Glasgow outcome scale (GOS)[61]	1975, UK	Assessment of disability from recovery to death
38	Acute Physiology And Chronic Health Evaluation (APACHE) I[18]	1981, USA	Physiological variables, age, pre-admission health status; all disease categories
39	Penetrating Abdominal trauma index (PATI)[62]	1981, USA	Anatomical injury severity for each organ involved in penetrating trauma
40	Simplified Acute Physiology Score (SAPS or s-APACHE)[63]	1984, France	Abbreviated version of APACHE
41	APACHE II[64]	1985, USA	Physiological variables, age, chronic health; all disease categories
42	Pediatric Risk of Mortality (PRISM) score[65]	1988, USA	14 Physiological and biochemical parameters
43	Mangled extremity score (MESS)[66]	1990, USA	Composite score of tissue damage, ischemia, shock and age
44	APACHE III[67]	1991, USA	Acute physiologic abnormalities, age, preexisting functional limitations
45	Shock Index (SI)[68]	1992, USA	Ratio of pulse rate vs. SBP
46	Rixen Score[69]	1999, Germany	Age, GCS, ISS, base excess, prothrombin time
47	Glasgow coma scale Extended (GCS-E)[70]	2000, UK, S Africa	Eye, verbal, and motor response PLUS amnesia scale
48	KTS-II[71]	2002, Uganda	Age, SBP, RR on admission, Neurologic status (AVPU), number of serious injuries
49	Rapid Emergency Medicine score (REMS)[72]	2004, Germany	Coma, respiratory frequency, oxygen saturation, blood pressure, pulse rate and age
50	FLAMES Score[73]	2008, Canada	Age, APACHE II score, Extent of burn, and Sex

51	Trauma Mortality prediction model (TMPM) ICD 9[74]	2009, USA	ICISS, ICD 9
52	Mechanism, GCS, Age, Pressure (MGAP)[75]	2010, France	Mechanism (blunt vs. penetrating), GCS, age, SBP
53	Sequential trauma score[11]	2010, Germany	Age, mechanism, clinical interventions, biochemical and physiological parameters, AIS
54	GCS, Age, Pressure (GAP)[76]	2011, Japan	GCS, age, SBP
55	NORwegian survival prediction Model In Trauma (NORMIT)[77]	2014, Norway	NISS, RTS, age, pre-injury co-morbidity score
56	Exponential Injury Severity Score (EISS)[78]	2014, China	AIS derived injury score
57	Tangent injury severity score (TISS)[79]	2015, China	AIS derived injury score

AIS and its derivatives had long been the standard for measuring the anatomical injury severity, whereas a combination of neurological status and hemodynamic parameters help assess the physiological response to the injuries. However, table 1 also highlights that a number of empirically developed anatomic, physiological and composite measures such as AIS, or Glasgow Coma scale (GCS), later became the basis of more complex measures such as Revised Trauma Score (RTS), Injury severity score (ISS), and Revised Injury Severity Classification (RISC) score, and some of them (RTS, ISS, NISS) in turn became components of a more complex scoring system such TRISS, Sequential trauma score, etc. It is also noteworthy that many complex measures require a host of information, and therefore, data collection to calculate those scores starts from pre-hospital phase until the discharge from the hospital. The use of injury measures in studies published by different LMICs is depicted in figure 2. A total of 597 studies from 54 LMICs were listed as eligible studies between 2006 and 2016, which were a combination of empirical, epidemiological, review, and validation studies. China, Turkey, Iran, South Africa, Colombia, and Brazil are some of the upper-middle-income countries that contributed to the majority of injury literature published in the last ten years (figure 3), whereas India, Pakistan, Nigeria and Tanzania are some of the lower-middle-income and low-income countries that extensively used injury measures in a number of injury and trauma related publications. 31 publications described multi-country studies, which may also include a high-income country. Approximately 31% (n=186) of all studies were related to head or traumatic brain injuries.

- Insert Figure 2 here –

- Insert Figure 3 here –

Table 2 outlines different injury measures used in publications from 54 LMICs in injury-related research. GCS, ISS, TRISS and RTS are the most commonly used injury measures, however, some attempts have been made to develop new injury measures. Examples include Exponential Injury Severity score (EISS), Ganga hospital score for lower limb fractures, Tangent Injury severity score (TISS), and some novel biomarkers such as Lactate and serum acetylcholinesterase. Other scores that were not traditionally used in injury or trauma research such as McLaughlin, Modified Rankin, South African Triage score, Modified Early Warning System (MEWS), and Rwanda mortality prediction model have also been utilized for prediction of mortality in trauma populations. Glasgow outcome scale is widely used in documenting the outcomes of traumatic brain injuries (TBI), and Functional Independence measure (FIM) was used in some studies focusing on functional outcomes of injured patients. Some attempts have been made to modify existing injury measures; for example, in Simplified RTS, Glasgow coma score was replaced by five different levels of consciousness, or NISS was used instead of traditional ISS in TRISS method, etc.

Table 2: Injury measures used in last ten years' published literature from LMICs

Country	Injury measures
Algeria	GCS, ISS
Argentina	GCS, GOS-E, Modified Rankin scale
Bangladesh	GCS, GOS
Benin	GCS
Bosnia	ISS
Brazil	AIS, RTS, ISS, NISS, APACHE II, SAPS II, RAPS, REMS, GCS, MAIS, TRISS, FIM, Abdominal trauma index, OIS, MESS
Cambodia	GCS, GOS
Cameroon	ISS, TRISS, KTS, RTS, GCS, KTS II
China	AIS, ISS, TRISS, GCS, APACHE II, NISS, trauma index, Pre-hospital index, GOS, serum Acetylcholinesterase, Exponential injury severity score (EISS), Tangent ISS, FOUR score, SAPS II
Colombia	RTS, GCS, ISS, NISS, ABCD, ABC, McLaughlin, GOS, AIS
Croatia	GCS, GOS

Cuba	GCS, GOS
Egypt	GCS, APACHE II, GOS
Ethiopia	TRISS, GCS
Ghana	KTS II
Guinea	GCS
India	AIS, ISS, TRISS, KTS, RTS, GAP, MGAP, GCS, OIS, Pediatric Trauma Score (PTS), SOFA, NISS, ICISS, Ganga hospital score
Indonesia	ISS, AIS, TRISS, GCS, REMS,
Iran	AIS, ISS, TRISS, RTS, GCS, APACHE II, NISS, ASCOT, Modified ISS, APACHE III, GOS-E, Abdominal trauma index, Simplified RTS, MESS
Iraq	TRISS, PATI, ISS, Simplified RTS
Jamaica	ISS, GCS
Jordan	GCS, FIM, GOS
Kenya	GCS, GOS, ISS, TRISS
Lebanon	ISS, NISS
Malawi	KTS, RTS, MGAP, GCS
Malaysia	AIS, GOS, GCS, RTS, ISS
Mali	GCS
Mexico	OIS, APACHE II, ISS, PATI, AIS
Montenegro	ISS
Morocco	APACHE II, SAPS II
Mozambique	RTS, ISS,
Nepal	AIS, ISS, GCS, GOS
Niger	GCS
Nigeria	RTS, GCS, ISS, Facial injury severity, AIS, PTS, GOS, MESS
Pakistan	ISS, RTS, TRISS, GCS, OIS, GOS, Trauma Index
Papua N. Guinea	GCS, GOS
Paraguay	ISS
Rwanda	GCS, ISS, TRISS, Rwanda Mortality Probability Model
Senegal	GCS
Serbia	GCS, ISS, APACHE II, SOFAS, SAPS II
South Africa	AIS, ISS, RTS, GCS, NISS, MEWS, South African Triage Score, GOS, Lactate, s-APACHE, RAPS, REMS, APACHE II, OIS
Sri Lanka	ISS, GCS, GOS
Suriname	ISS
Tanzania	ISS, GCS, KTS, PTS, RTS, KTS II, OIS
Thailand	GCS, ISS, TRISS, APACHE II, ABCD, modified TRISS, GOS
Trinidad	TRISS

Tunisia	GCS, ISS, PTS, PRISM, GOS, FIM
Turkey	ISS, AIS, RTS, TRISS, GCS, Pediatric Trauma score, Organ specific scores, Lactate, GOS, PATI, NISS, Turkish penal code
Uganda	KTS, GCS, Lactate, KTS II
Ukraine	GCS
Uruguay	ISS, APACHE II, SAPS II, SOFA, GCS
Uzbekistan	GCS
Vietnam	SOFA score
Zambia	KTS, KTS II

Full text review of eligible articles was conducted to understand of validity of these new or existing injury measures and revealed that 37 studies examined the performance of injury severity measures for the prediction of hospital length of stay, in-hospital mortality, and functional outcome of injured patients. Supplemental file 2 details 25 of 37 validations studies, as the remaining 12 uses different outcomes (e.g. respiratory failure, ICU admission etc.) or use a different algorithm. These twenty-five articles from thirteen LMICs assessed the validity of at least one injury severity measure in hospital settings. ISS was the most commonly validated measure in LMICs in the past ten years, assessed in eleven studies. TRISS was the second most commonly validated injury severity measure in LMICS, followed by GCS, APACHE II, and NISS. GCS was more commonly assessed among head/traumatic brain injuries, while also validated among patients with general injuries. The majority of validation studies included all injury mechanisms, some studies included critically ill populations such as ICU patients, while others included patients admitted to the emergency room. The proportion of mortality also varied widely among different settings, ranging from 0.6% to 40%.

Among injury severity measures that were validated in multiple contexts, many presented a wide range of AUROC estimates. Out of the eleven validation studies on ISS, five estimated AUROC above 0.90, and two of the studies had AUROC below 0.70 with 95% CI overlapping 0.65. Similarly, as majority of the validation studies on TRISS reported AUROC between 0.80 and 0.98, three studies reported 95% CI of AUROC overlapping 0.70. More than a third of the validation studies did not present 95% CI estimates of AUROC, and more than half of the validation studies did not provide estimates on calibration (fifteen studies).

A majority of the validation studies included only adults, and sometimes adolescents. A third of the validation studies included both adults and children, and one study included only pediatric injury population. Many of the validation studies also did not report proportion of missing data. Of those articles mentioned about missing data, all excluded records with missed information from analyses.

Besides using in-hospital death as outcome, other studies included morbidity outcomes such as length of hospitalization, damage control resuscitation, severe trauma, life-threatening injury, respiratory failure, and sepsis. These morbidity outcomes are less standardized and therefore limited the ability for comparison.

DISCUSSION

Our review points to an ongoing search for a comprehensive yet simple scoring system applicable to LMICs research and trauma care needs. While Glasgow coma scale, injury severity score and TRISS methodology have established themselves as gold standards in injury research, there seems to be a need for injury scoring systems that are reliable even in the light of the realities facing patient care systems in LMICs. Injuries and their physiological response are complex mechanisms, and the outcomes of injuries is frequently affected by a number of factors ranging from age and pre-existing conditions of the patient to biochemical response of the body. It is difficult to account for all factors in single a model

or severity measure; therefore, the use of non-injury-specific-measures such as APACHE II, SOFAS, and SAPS have gained traction in trauma research. Looking closely at the components of injury measures, it is also evident that resources required to document the anatomical and biochemical evidence of injury severity are easily available in high-income settings but may be difficult to obtain in resource constrained environments.

Composite but simple measures such as MGAP and KTS have become more popular, which have been widely used and validated in other settings across the globe.[9, 25, 26, 80] Our review demonstrated that, although a number of injury severity measures were developed during the 1990s and early 2000s, there have been limited applications and even less validations in LMICs. Furthermore, very few validation studies were conducted in low-income settings (Supplemental file 2). Over 70% of publications on injury research in LMICs have been published from only 11 countries (Figure 3), which is obviously incomparable with their burden of injuries; moreover, the body of research comprises of mostly descriptive or epidemiological studies. Comparison of the most commonly applied injury measures aligns with the most commonly validated injury severity measures, including GCS, ISS, TRISS, APACHE and KTS scores. It is important to note that the majority validation studies have been conducted in upper-middle-income countries such as China, Turkey, Brazil, and Thailand; involved single centers; or included specific study population such as head or abdominal injuries. New methods and models such as EISS, TISS and new TRISS have not been validated in other LMICs, outside of their origin.

A subset of studies found relatively low performance of injury severity measures, which demonstrates large deviation from studies conducted in predominantly high-income settings (e.g. TRISS, ISS). These differences may be due to a wide range of factors, such as the duration between injury and data collection, training of personnel administering AIS codes, resources and equipment available for diagnosis, missed injuries, etc. Some recent studies reveal that commonly used injury severity measures that depend on in-depth information may not perform well in mortality prediction, especially with

limited or incomplete data.[25, 26] Such differences underline the importance of assessing the performance and calibration of measures in specific contexts prior to their use in trauma registries or for outcome prediction. A review of publications on validation studies demonstrated that limited statistical analysis was performed in validation studies and the issue of missing data was not addressed. These may introduce bias in the estimates of performance of the injury severity measures. As mentioned before, many of the validation studies were limited with small sample size and single institutions, restricting to the specific setting and a lack of comparison among similar institutions within the country. Very often, the validation studies did not include statistical inference of the estimation, further restricting the ability to compare performance among injury severity measures inspected. Calibration is another feature of the measure that should be more commonly assessed.

Overall, our study has been able to highlight several important issues. First, the "10-90" funding and research gap is also quite evident for injury and trauma, and we have observed that the amount of injury research from LMICs is still far less than the burden of injuries faced by these countries.[81] The quality and depth of research is also not sufficient, being mostly limited to small empirical studies. The findings of validation studies focusing on mortality prediction highlight large variability in performance of commonly applied injury measures including GCS, ISS, RTS, TRISS and KTS. However, lack of large multicenter databases restricts the generalizability of results in large populations, even within a country. The results nevertheless corroborate the assumption that no single injury measure has shown a consistent result in all settings and thus underscores the importance of context specific validation studies. This has also been reported previously from systematic reviews for injury severity measures such as ISS, NISS, ICISS and TMPM, mainly featuring studies from high-income settings.[82, 83] Furthermore, application of injury measures in field triage or emergency room disposition is also heavily influenced by the system of trauma care delivery, and hence, their performance in terms of prediction

of survival, hospital length of stay or complications has to be tested and validated in specific settings where they are being used.

Our study has a few limitations. First, we conducted this literature review between 2006 and 2016, covering a ten-year period, and studies that were published outside of this timeframe are not included. Second, we have limited our literature search to three databases; nonetheless, inclusion of the Global Health database enabled us to review several Latin American publications that would have been otherwise missed. Third, we limited our detailed analysis of validation studies to those that focused on mortality prediction; this was due to a very limited number of studies focusing on a specific non-fatal outcome. We also did not focus on studies that used alternative coefficients for some of the established measures, as they were not consistently tested across settings.

CONCLUSION:

The science of injury severity measurement has been growing to predict injury outcomes, help in decision making and support epidemiological research. Empirical studies from upper- and lower-middle-income countries frequently utilize injury severity measures. However, there is still a lack of large multicenter validation studies. The evidence base from low-income countries is even less established, where most of the burden of injury and trauma lies. No single injury severity measure has shown a consistent result in all settings and thus underscores the importance of context specific validation studies.

List of Abbreviations:

AIS: Abbreviated Injury Scale

ABC: Assessment of Blood Consumption

ABCD: Acidosis, Blood loss, Cold, Damage

APACHE: Acute Physiology And Chronic Health Evaluation

ASCOT: A Severity Categorization Of Trauma

AUROC: Area Under Receiver Operating Characteristic

CRAMS: Circulation, Respiration, Abdomen, Motor and Speech

EISS: Exponential Injury Severity Score

FIM: Functional Independence measure

GAP: GCS, Age, Pressure

GCS: Glasgow Coma Scale

GCS-E: Glasgow Coma Scale- Extended

GOS: Glasgow Outcome Scale

H-L: Hosmer-Lemeshow

ICISS: ICD-9-Injury Severity Score

ISS: Injury Severity Score

KTS: Kampala Trauma Score

LISS: Logarithmic Injury Severity Score

MeSH: Medical Subject Heading

MEWS: Modified Early Warning System

MGAP: Mechanism, GCS, Age, Pressure

MTOS: Major Trauma Outcome Study

NISS: New Injury Severity Scores

REMS: Rapid Emergency Medicine score

RISC: Revised Injury Severity Classification

RTS: Revised Trauma Score

SAPS: Simplified Acute Physiology Score

SOFAS: Sequential Organ Failure Assessment Score

TBI: Traumatic Brain Injury

TISS: Tangent Injury severity score

TMPM: Trauma Mortality Prediction Model

TRISS: Trauma and Injury Severity Score

Figure 1: Flow diagram of search strategy and study selection according to Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) guidelines

Figure 2: LMIC publications using Trauma/ Injury severity measures

Figure 3: Top Ten countries with trauma/ injury publications

Supplemental file 1: Literature review search terms

Supplemental file 2: Validations studies describing performance of Injury severity measures to predict mortality

Declarations:

Ethics approval and consent to participate: Not applicable.

Consent for publication: Not applicable.

Availability of data and material: Please see supplemental files.

Competing Interest: The authors have no competing interests to declare

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I am one author signing on behalf of all co-owners of the Contribution.

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3862 Non-Duplicate Citations Screened

Inclusion/Exclusion Criteria Applied → 3062 Articles Excluded After Title/Abstract Screen

836 Articles Retrieved

Full text screening → 538 Empirical, review, or other non-validation studies   261 Articles Excluded During Data Extraction

37 Validation studies

Flow diagram of search strategy and study selection according to Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) guidelines

165x125mm (150 x 150 DPI)
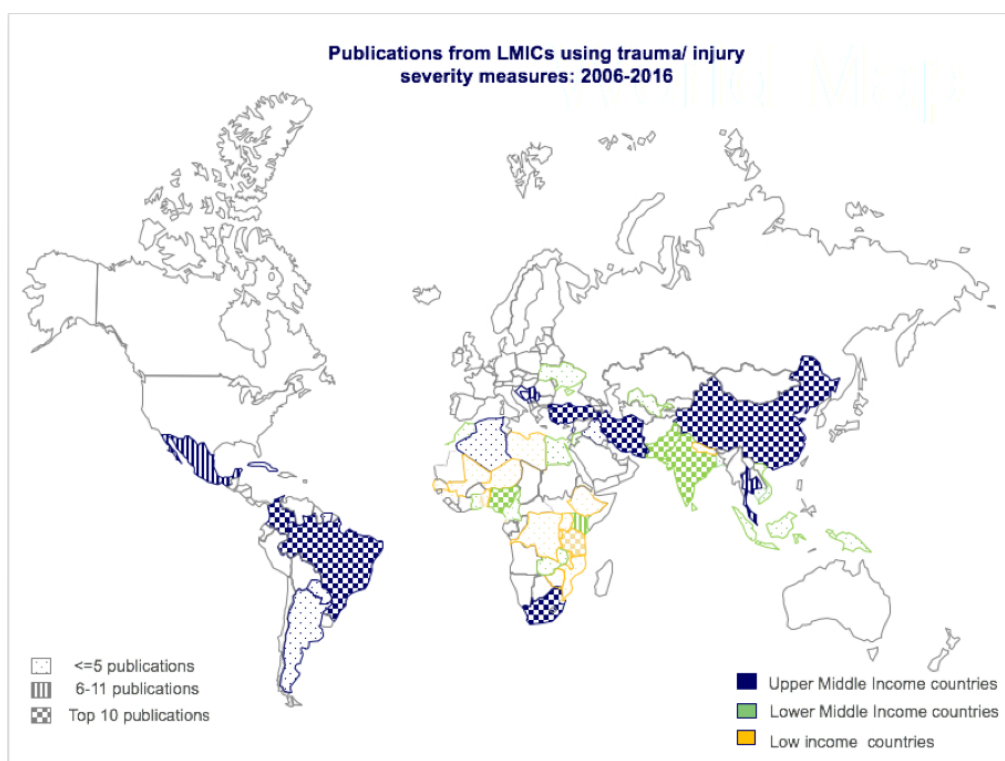
LMIC publications using Trauma/ Injury severity measures

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TOP TEN COUNTRIES

Country	Value
Tanzania	16
Colombia	16
Pakistan	24
Nigeria	27
South Africa	33
Turkey	55
Iran	56
India	66
Brazil	68
China	70
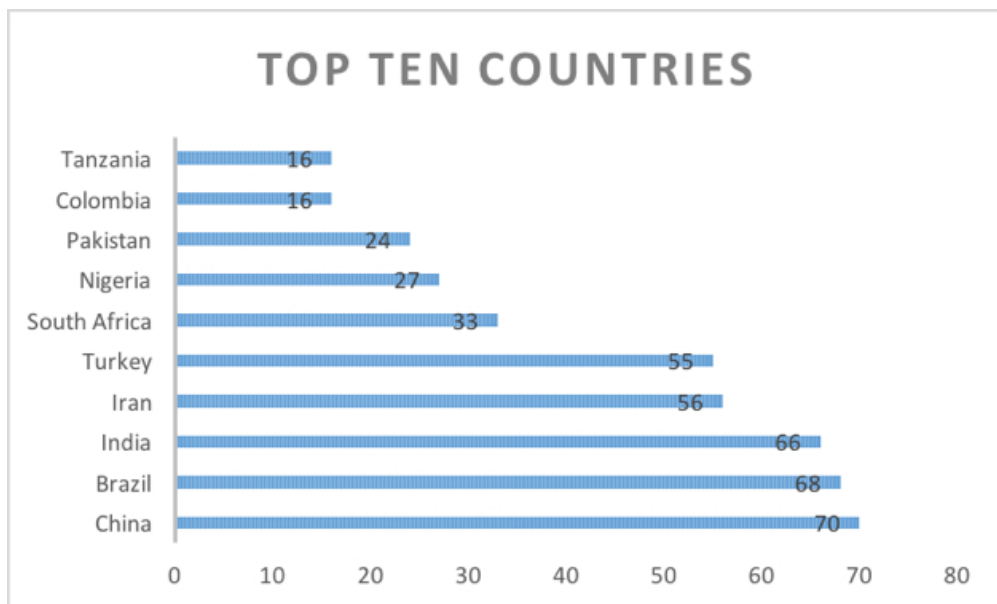
Top Ten countries with trauma/ injury publications

106x63mm (150 x 150 DPI)

Supplemental file 1: Literature review search terms

PUBMED LMIC Filter

"Trauma Severity Indices"[Mesh] OR "Trauma Severity Indices/utilization"[Mesh] OR
"Injury severity measures" OR "Trauma Scores"[all fields] OR "Trauma Score"[all fields] OR "Injury
Scales"[all fields] OR "severity scores"[all fields] OR "Anatomic Profile"[all fields] OR "severity
classifications"[all fields] OR "severity classification"[all fields] OR "ISS"[all fields] OR "NISS" [all fields]
OR "ASCOT" [all fields] OR "RISC" [all fields] OR "MGAP" [all fields] OR "Probability of Death score"[all
fields] OR "TRISS"[all fields] OR "Trauma index" OR "Trauma indices"[all fields] OR "CRAMS" OR
"Circulation, Respiration, Abdomen, Motor, and Speech"[all fields] OR "Anatomic Index" OR "Anatomic
Indices" [all fields] OR "Injury severity score" [all fields]

"Trauma Severity Indices"[Mesh] OR "Trauma Severity Indices/utilization"[Mesh] OR
"Injury severity measures" OR"Trauma Scores"[tiab] OR "Trauma Score"[tiab] OR "Injury Scales"[tiab]
OR "severity scores"[tiab] OR "Anatomic Profile"[tiab] OR "severity classifications"[tiab] OR "severity
classification"[tiab] OR "ISS"[tiab] OR "NISS" [tiab] OR "ASCOT" [tiab] OR "RISC" [tiab] OR "MGAP" [tiab]
OR "Probability of Death score"[tiab] OR "TRISS"[tiab] OR "Trauma index" OR "Trauma indices"[tiab] OR
"CRAMS" OR "Circulation, Respiration, Abdomen, Motor, and Speech"[tiab] OR "Anatomic Index" OR
"Anatomic Indices" [tiab] OR "Injury severity score" [tiab] OR" Rapid Emergency Medicine score"[tiab]
OR "Acute Physiology and Chronic Health Evaluation" OR "APACHE"[tiab]

AND ("emerging country"[all fields] OR "emerging countries"[all fields] OR "emerging nation"[all fields]
OR "emerging nations"[all fields] OR "emerging population"[all fields] OR "emerging populations"[all
fields] OR "developing country"[tiab] OR "developing countries"[tiab] OR "developing nation"[tiab] OR
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"under served populations"[tiab] OR "under served world"[tiab] OR "deprived country"[tiab] OR "deprived countries"[tiab] OR "deprived nation"[tiab] OR "deprived nations"[tiab] OR "deprived population"[tiab] OR "deprived populations"[tiab] OR "deprived world"[tiab] OR "poor country"[tiab] OR "poor countries"[tiab] OR "poor nation"[tiab] OR "poor nations"[tiab] OR "poor population"[tiab] OR "poor populations"[tiab] OR "poor world"[tiab] OR "poorer country"[tiab] OR "poorer countries"[tiab] OR "poorer nation"[tiab] OR "poorer nations"[tiab] OR "poorer population"[tiab] OR "poorer populations"[tiab] OR "poorer world"[tiab] OR "developing economy"[tiab] OR "developing economies"[tiab] OR "less developed economy"[tiab] OR "less developed economies"[tiab] OR "lesser developed economy"[tiab] OR "lesser developed economies"[tiab] OR "under developed economy"[tiab] OR "under developed economies"[tiab] OR "underdeveloped economy"[tiab] OR "underdeveloped economies"[tiab] OR "middle income economy"[tiab] OR "middle income economies"[tiab] OR "low income economy"[tiab] OR "low income economies"[tiab] OR "lower income economy"[tiab] OR "lower income economies"[tiab] OR "low gdp"[tiab] OR "low gnp"[tiab] OR "low gross domestic"[tiab] OR "low gross national"[tiab] OR "lower gdp"[tiab] OR "lower gnp"[tiab] OR "lower gross domestic"[tiab] OR "lower gross national"[tiab] OR lmic[tiab] OR lmics[tiab] OR "third world"[tiab] OR "lami country"[tiab] OR "lami countries"[tiab] OR "transitional country"[tiab] OR "transitional countries"[tiab] OR Africa[tiab] OR Asia[tiab] OR Caribbean[tiab] OR West Indies[tiab] OR South America[tiab] OR Latin America[tiab] OR Central America[tiab] OR "Atlantic Islands"[tiab] OR "Commonwealth of Independent States"[tiab] OR "Pacific Islands"[tiab] OR "Indian Ocean Islands"[tiab] OR "Eastern Europe"[tiab] OR Afghanistan[tiab] OR Albania[tiab] OR Algeria[tiab] OR Angola[tiab] OR Antigua[tiab] OR Barbuda[tiab] OR Argentina[tiab] OR Armenia[tiab] OR Armenian[tiab] OR Aruba[tiab] OR Azerbaijan[tiab] OR Bahrain[tiab] OR Bangladesh[tiab] OR Barbados[tiab] OR Benin[tiab] OR Byelarus[tiab] OR Byelorussian[tiab] OR Belarus[tiab] OR Belorussian[tiab] OR Belorussia[tiab] OR Belize[tiab] OR Bhutan[tiab] OR Bolivia[tiab] OR Bosnia[tiab] OR Herzegovina[tiab] OR Hercegovina[tiab] OR Botswana[tiab] OR Brasil[tiab] OR Brazil[tiab] OR Bulgaria[tiab] OR Burkina Faso[tiab] OR Burkina Fasso[tiab] OR Upper Volta[tiab] OR Burundi[tiab] OR Urundi[tiab] OR Cambodia[tiab] OR Khmer Republic[tiab] OR Kampuchea[tiab] OR Cameroon[tiab] OR Cameroons[tiab] OR Cameron[tiab] OR Cape Verde[tiab] OR Central African Republic[tiab] OR Chad[tiab] OR Chile[tiab] OR China[tiab] OR Colombia[tiab] OR Comoros[tiab] OR Comoro Islands[tiab] OR Comores[tiab] OR Mayotte[tiab] OR Congo[tiab] OR Zaire[tiab] OR Costa Rica[tiab] OR Cote d'Ivoire[tiab] OR Ivory Coast[tiab] OR Croatia[tiab] OR Cuba[tiab] OR Cyprus[tiab] OR Czechoslovakia[tiab] OR "Czech Republic" [tiab] OR Slovakia[tiab] OR Slovak Republic[tiab] OR Djibouti[tiab] OR French Somaliland[tiab] OR Dominica[tiab] OR Dominican Republic[tiab] OR East Timor[tiab] OR East Timur[tiab] OR Timor Leste[tiab] OR Ecuador[tiab] OR Egypt[tiab] OR United Arab Republic[tiab] OR El Salvador[tiab] OR Eritrea[tiab] OR Estonia[tiab] OR Ethiopia[tiab] OR Fiji[tiab] OR Gabon[tiab] OR Gabonese Republic[tiab] OR Gambia[tiab] OR Gaza[tiab] OR Georgia Republic[tiab] OR Georgian Republic[tiab] OR Ghana[tiab] OR Gold Coast[tiab] OR Greece[tiab] OR Grenada[tiab] OR Guatemala[tiab] OR Guinea[tiab] OR Guam[tiab] OR Guiana[tiab] OR Guyana[tiab] OR Haiti[tiab] OR Honduras[tiab] OR Hungary[tiab] OR India[tiab] OR Maldives[tiab] OR Indonesia[tiab] OR Iran[tiab] OR Iraq[tiab] OR Jamaica[tiab] OR Jordan[tiab] OR Kazakhstan[tiab] OR Kazakh[tiab] OR Kenya[tiab] OR Kiribati[tiab] OR Korea[tiab] OR Kosovo[tiab] OR Kyrgyzstan[tiab] OR Kirghizia[tiab] OR Kyrgyz Republic[tiab] OR Kirghiz[tiab] OR Kirgizstan[tiab] OR "Lao PDR"[tiab] OR Laos[tiab] OR Latvia[tiab] OR Lebanon[tiab] OR Lesotho[tiab] OR Basutoland[tiab] OR Liberia[tiab] OR Libya[tiab] OR Lithuania[tiab]OR Macedonia[tiab] OR Madagascar[tiab] OR Malagasy Republic[tiab] OR Malaysia[tiab] OR Malaya[tiab] OR Malay[tiab] OR Sabah[tiab] OR Sarawak[tiab] OR Malawi[tiab] OR Nyasaland[tiab] OR Mali[tiab] OR Malta[tiab] OR Marshall Islands[tiab] OR Mauritania[tiab] OR Mauritius[tiab] OR Agalega Islands[tiab] OR "Melanesia"[tiab] OR Mexico[tiab] OR Micronesia[tiab] OR Middle East[tiab] OR Moldova[tiab] OR Moldovia[tiab] OR Moldovian[tiab] OR Mongolia[tiab] OR Montenegro[tiab] OR Morocco[tiab] OR Ifni[tiab] OR Mozambique[tiab] OR Myanmar[tiab] OR Myanma[tiab] OR Burma[tiab] OR Namibia[tiab]

OR Nepal[tiab] OR Netherlands Antilles[tiab] OR New Caledonia[tiab] OR Nicaragua[tiab] OR Niger[tiab] OR Nigeria[tiab] OR Northern Mariana Islands[tiab] OR Oman[tiab] OR Muscat[tiab] OR Pakistan[tiab] OR Palau[tiab] OR Palestine[tiab] OR Panama[tiab] OR Paraguay[tiab] OR Peru[tiab] OR Philippines[tiab] OR Philipines[tiab] OR Phillipines[tiab] OR Phillippines[tiab] OR Poland[tiab] OR Portugal[tiab] OR Puerto Rico[tiab] OR Romania[tiab] OR Rumania[tiab] OR Roumania[tiab] OR Russia[tiab] OR Russian[tiab] OR Rwanda[tiab] OR Ruanda[tiab] OR Saint Kitts[tiab] OR St Kitts[tiab] OR Nevis[tiab] OR Saint Lucia[tiab] OR St Lucia[tiab] OR Saint Vincent[tiab] OR St Vincent[tiab] OR Grenadines[tiab] OR Samoa[tiab] OR Samoan Islands[tiab] OR Navigator Island[tiab] OR Navigator Islands[tiab] OR Sao Tome[tiab] OR Saudi Arabia[tiab] OR Senegal[tiab] OR Serbia[tiab] OR Montenegro[tiab] OR Seychelles[tiab] OR Sierra Leone[tiab] OR Slovenia[tiab] OR Sri Lanka[tiab] OR Ceylon[tiab] OR Solomon Islands[tiab] OR Somalia[tiab] OR Sudan[tiab] OR Suriname[tiab] OR Surinam[tiab] OR Swaziland[tiab] OR Syria[tiab] OR Syrian[tiab] OR Tajikistan[tiab] OR Tadzhikistan[tiab] OR Tadjikistan[tiab] OR Tadzhik[tiab] OR Tanzania[tiab] OR Thailand[tiab] OR Togo[tiab] OR Togolese Republic[tiab] OR Tonga[tiab] OR Trinidad[tiab] OR Tobago[tiab] OR Tunisia[tiab] OR Turkey[tiab] OR Turkmenistan[tiab] OR Turkmen[tiab] OR Tuvalu[tiab] OR Uganda[tiab] OR Ukraine[tiab] OR Uruguay[tiab] OR USSR[tiab] OR Soviet Union[tiab] OR Union of Soviet Socialist Republics[tiab] OR Uzbekistan[tiab] OR Uzbek OR Vanuatu[tiab] OR New Hebrides[tiab] OR Venezuela[tiab] OR Vietnam[tiab] OR Viet Nam[tiab] OR West Bank[tiab] OR Yemen[tiab] OR Yugoslavia[tiab] OR Zambia[tiab] OR Zimbabwe[tiab] OR Rhodesia[tiab] OR Developing Countries[Mesh] OR Africa[Mesh:NoExp] OR Africa, Northern[Mesh:NoExp] OR Africa South of the Sahara[Mesh:NoExp] OR Africa, Central[Mesh:NoExp] OR Africa, Eastern[Mesh:NoExp] OR Africa, Southern[Mesh:NoExp] OR Africa, Western[Mesh:NoExp] OR Asia[Mesh:NoExp] OR Asia, Central[Mesh:NoExp] OR Asia, Southeastern[Mesh:NoExp] OR Asia, Western[Mesh:NoExp] OR Caribbean Region[Mesh:NoExp] OR West Indies[Mesh:NoExp] OR South America[Mesh:NoExp] OR Latin America[Mesh:NoExp] OR Central America[Mesh:NoExp] OR "Atlantic Islands"[Mesh:NoExp] OR "Commonwealth of Independent States"[Mesh:NoExp] OR "Pacific Islands"[Mesh:NoExp] OR "Indian Ocean Islands"[Mesh:NoExp] OR "Europe, Eastern"[Mesh:NoExp] OR Afghanistan[Mesh] OR Albania[Mesh] OR Algeria[Mesh] OR American Samoa[Mesh] OR Angola[Mesh] OR "Antigua and Barbuda"[Mesh] OR Argentina[Mesh] OR Armenia[Mesh] OR Azerbaijan[Mesh] OR Bahrain[Mesh] OR "Baltic States"[Mesh] OR Bangladesh[Mesh] OR Barbados[Mesh] OR Benin[Mesh] OR "Republic of Belarus"[Mesh] OR Belize[Mesh] OR Bhutan[Mesh] OR Bolivia[Mesh] OR Bosnia-Herzegovina[Mesh] OR Botswana[Mesh] OR Brazil[Mesh] OR Bulgaria[Mesh] OR Burkina Faso[Mesh] OR Burundi[Mesh] OR Cambodia[Mesh] OR Cameroon[Mesh] OR Cape Verde[Mesh] OR Central African Republic[Mesh] OR Chad[Mesh] OR Chile[Mesh] OR China[Mesh] OR Colombia[Mesh] OR Comoros[Mesh] OR Congo[Mesh] OR Costa Rica[Mesh] OR Cote d'Ivoire[Mesh] OR Croatia[Mesh] OR Cuba[Mesh] OR Cyprus[Mesh] OR Czechoslovakia[Mesh] OR Czech Republic[Mesh] OR Slovakia[Mesh] OR Djibouti[Mesh] OR "Democratic Republic of the Congo"[Mesh] OR "Democratic People's Republic of Korea"[Mesh] OR Dominica[Mesh] OR Dominican Republic[Mesh] OR East Timor[Mesh] OR Ecuador[Mesh] OR Egypt[Mesh] OR El Salvador[Mesh] OR Eritrea[Mesh] OR Estonia[Mesh] OR Ethiopia[Mesh] OR "Equatorial Guinea"[Mesh] OR Fiji[Mesh] OR "French Guiana"[Mesh] OR Gabon[Mesh] OR Gambia[Mesh] OR "Georgia (Republic)"[Mesh] OR Ghana[Mesh] OR Greece[Mesh] OR Grenada[Mesh] OR Guatemala[Mesh] OR Guinea[Mesh] OR Guinea-Bissau[Mesh] OR Guam[Mesh] OR Guyana[Mesh] OR Haiti[Mesh] OR Honduras[Mesh] OR Hungary[Mesh] OR "Independent State of Samoa"[Mesh] OR India[Mesh] OR Indonesia[Mesh] OR Iran[Mesh] OR Iraq[Mesh] OR Jamaica[Mesh] OR Jordan[Mesh] OR Kazakhstan[Mesh] OR Kenya[Mesh] OR Korea[Mesh] OR Kyrgyzstan[Mesh] OR Laos[Mesh] OR Latvia[Mesh] OR Lebanon[Mesh] OR Lesotho[Mesh] OR Liberia[Mesh] OR Libya[Mesh] OR Lithuania[Mesh] OR "Macedonia (Republic)"[Mesh] OR Madagascar[Mesh] OR Malawi[Mesh] OR Malaysia[Mesh] OR Mali[Mesh] OR Malta[Mesh] OR Mauritania[Mesh] OR Mauritius[Mesh] OR "Melanesia"[Mesh] OR Mexico[Mesh] OR Micronesia[Mesh] OR Middle East[Mesh:NoExp] OR

Moldova[Mesh] OR Mongolia[Mesh] OR Montenegro[Mesh] OR Morocco[Mesh] OR Mozambique[Mesh] OR Myanmar[Mesh] OR Namibia[Mesh] OR Nepal[Mesh] OR Netherlands Antilles[Mesh] OR New Caledonia[Mesh] OR Nicaragua[Mesh] OR Niger[Mesh] OR Nigeria[Mesh] OR Oman[Mesh] OR Pakistan[Mesh] OR Palau[Mesh] OR Panama[Mesh] OR Papua New Guinea[Mesh] OR Paraguay[Mesh] OR Peru[Mesh] OR Philippines[Mesh] OR Poland[Mesh] OR Portugal[Mesh] OR Puerto Rico[Mesh] OR "Republic of Korea"[Mesh] OR Romania[Mesh] OR Russia[Mesh] OR "Russia (Pre-1917)"[Mesh] OR Rwanda[Mesh] OR "Saint Kitts and Nevis"[Mesh] OR Saint Lucia[Mesh] OR "Saint Vincent and the Grenadines"[Mesh] OR Samoa[Mesh] OR Saudi Arabia[Mesh] OR Senegal[Mesh] OR Serbia[Mesh] OR Montenegro[Mesh] OR Seychelles[Mesh] OR Sierra Leone[Mesh] OR Slovenia[Mesh] OR Sri Lanka[Mesh] OR Somalia[Mesh] OR South Africa[Mesh] OR Sudan[Mesh] OR Suriname[Mesh] OR Swaziland[Mesh] OR Syria[Mesh] OR Tajikistan[Mesh] OR Tanzania[Mesh] OR Thailand[Mesh] OR Togo[Mesh] OR Tonga[Mesh] OR "Trinidad and Tobago"[Mesh] OR Tunisia[Mesh] OR Turkey[Mesh] OR Turkmenistan[Mesh] OR Uganda[Mesh] OR Ukraine[Mesh] OR Uruguay[Mesh] OR USSR[Mesh] OR Uzbekistan[Mesh] OR Vanuatu[Mesh] OR Venezuela[Mesh] OR Vietnam[Mesh] OR Yemen[Mesh] OR Yugoslavia[Mesh] OR Zambia[Mesh] OR Zimbabwe[Mesh] OR "Southern African Development Community"[all fields] OR "East African Community"[all fields] OR "West African Health Organisation"[all fields] OR "Sub Saharan Africa "[all fields] OR "SubSaharan Africa "[all fields])

Global Health Search terms:

trauma severity indices OR trauma severity indices OR injury severity measures OR trauma scores OR trauma score OR injury scales OR injury severity scores OR anatomic profile OR injury severity classification OR ISS OR NISS OR ASCOT OR RISC OR MGAP OR probability of death score OR TRISS OR trauma index OR trauma indices OR CRAMS OR anatomic index OR injury severity score OR rapid emergency medicine score OR acute physiology and chronic health evaluation OR APACHE

(emerging country OR emerging countries OR emerging nation OR emerging nations OR emerging population OR emerging populations developing country OR developing countries OR developing nation OR developing nations OR developing population OR developing populations OR developing world OR less developed country OR less developed countries OR less developed nation OR less developed nations OR less developed population OR less developed populations OR less developed world OR lesser developed country OR lesser developed countries OR lesser developed nation OR lesser developed nations OR lesser developed population OR lesser developed populations OR lesser developed world OR under developed country OR under developed countries OR under developed nation OR under developed nations OR under developed population OR under developed populations OR under developed world OR underdeveloped country OR underdeveloped countries OR underdeveloped nation OR underdeveloped nations OR underdeveloped population OR underdeveloped populations OR underdeveloped world OR middle income country OR middle income countries OR middle income nation OR middle income nations OR middle income population OR middle income populations OR low income country OR low income countries OR low income nation OR low income nations OR low income population OR low income populations OR lower income country OR lower income countries OR lower income nation OR lower income nations OR lower income population OR lower income populations OR underserved country OR underserved countries OR underserved nation OR underserved nations OR (underserved population OR underserved populations OR underserved world OR under served country OR under served countries OR under served nation OR under served nations OR under served population OR under served populations OR under served world OR deprived country OR deprived countries OR deprived nation OR deprived nations OR deprived population OR deprived populations OR deprived world OR poor country OR poor countries OR poor nation OR poor nations OR poor population OR poor populations OR poor world OR poorer country OR poorer countries OR poorer nation OR poorer nations OR poorer population OR poorer populations OR poorer world OR developing economy OR developing economies OR less developed economy OR less developed economies OR lesser developed economy OR lesser developed economies OR under developed economy OR under developed economies OR underdeveloped economy OR underdeveloped economies OR middle income economy OR middle income economies OR low income economy OR low income economies OR lower income economy OR lower income economies OR low gdp OR low gnp OR low gross domestic OR low gross national OR lower gdp OR lower gnp OR lower gross domestic OR lower gross national OR lmic OR lmics OR third world OR lami country OR lami countries OR transitional country OR transitional countries OR Africa OR Asia OR Caribbean OR West Indies OR South America OR Latin America OR Central America OR Atlantic Islands OR Pacific Islands OR Indian Ocean Islands OR Eastern Europe OR Afghanistan OR Albania OR Algeria OR Angola OR Antigua OR Barbuda OR Argentina OR Armenia OR Armenian OR Aruba OR Azerbaijan OR Bahrain OR Bangladesh OR Barbados OR Benin OR Byelarus OR Byelorussian OR Belarus

OR Belorussian OR Belorussia OR Belize OR Bhutan OR Bolivia OR Bosnia OR Herzegovina OR Hercegovina OR Botswana OR Brasil OR Brazil OR Bulgaria OR Burkina Faso OR Burkina Fasso OR Upper Volta OR Burundi OR Urundi OR Cambodia OR Khmer Republic OR Kampuchea OR Cameroon OR Cameroons OR Cameron OR Camerons OR Cape Verde OR Central African Republic OR Chad OR Chile OR China OR Colombia OR Comoros OR Comoro Islands OR Comores OR Mayotte OR Congo OR Zaire OR Costa Rica OR Cote d'Ivoire OR Ivory Coast OR Croatia OR Cuba OR Cyprus OR Czechoslovakia OR Czech Republic OR Slovakia OR Slovak Republic OR Djibouti OR French Somaliland OR Dominica OR Dominican Republic OR East Timor OR East Timur OR Timor Leste OR Ecuador OR Egypt OR United Arab Republic OR El Salvador OR Eritrea OR Estonia OR Ethiopia OR Fiji OR Gabon OR Gabonese Republic OR Gambia OR Gaza OR Georgia Republic OR Georgian Republic OR Ghana OR Gold Coast OR Greece OR Grenada OR Guatemala OR Guinea OR Guam OR Guiana OR Guyana OR Haiti OR Honduras OR Hungary OR India OR Maldives OR Indonesia OR Iran OR Iraq OR Jamaica OR Jordan OR Kazakhstan OR Kazakh OR Kenya OR Kiribati OR Korea OR Kosovo OR Kyrgyzstan OR Kirghizia) OR (Kyrgyz Republic OR Kirghiz OR Kirgizstan OR Lao PDR OR Laos OR Latvia OR Lebanon OR Lesotho OR Basutoland OR Liberia OR Libya OR LithuaniaOR Macedonia OR Madagascar OR Malagasy Republic OR Malaysia OR Malaya OR Malay OR Sabah OR Sarawak OR Malawi OR Nyasaland OR Mali OR Malta OR Marshall Islands OR Mauritania OR Mauritius OR Agalega Islands OR Melanesia OR Mexico OR Micronesia OR Middle East OR Moldova OR Moldovia OR Moldovian OR Mongolia OR Montenegro OR Morocco OR Ifni OR Mozambique OR Myanmar OR Myanma OR Burma OR Namibia OR Nepal OR Netherlands Antilles OR New Caledonia OR Nicaragua OR Niger OR Nigeria OR Northern Mariana Islands OR Oman OR Muscat OR Pakistan OR Palau OR Palestine OR Panama OR Paraguay OR Peru OR Philippines OR Philipines OR Phillipines OR Phillippines OR Poland OR Portugal OR Puerto Rico OR Romania OR Rumania OR Roumania OR Russia OR Russian OR Rwanda OR Ruanda OR Saint Kitts OR St Kitts OR Nevis OR Saint Lucia OR St Lucia OR Saint Vincent OR St Vincent OR Grenadines OR Samoa OR Samoan Islands OR Navigator Island OR Navigator Islands OR Sao Tome OR Saudi Arabia OR Senegal OR Serbia OR Montenegro OR Seychelles OR Sierra Leone OR Slovenia OR Sri Lanka OR Ceylon OR Solomon Islands OR Somalia OR Sudan OR Suriname OR Surinam OR Swaziland OR Syria OR Syrian OR Tajikistan OR Tadzhikistan OR Tadjikistan OR Tadzhik OR Tanzania OR Thailand OR Togo OR Togolese Republic OR Tonga OR Trinidad OR Tobago OR Tunisia OR Turkey OR Turkmenistan OR Turkmen OR Tuvalu OR Uganda OR Ukraine OR Uruguay OR USSR OR Soviet Union OR Soviet Socialist Republics OR Uzbekistan OR Uzbek OR Vanuatu OR New Hebrides OR Venezuela OR Vietnam OR Viet Nam OR West Bank OR Yemen OR Yugoslavia OR Zambia OR Zimbabwe OR Rhodesia OR Developing Countries OR Africa OR Asia OR Caribbean Region OR West Indies OR South America OR Latin America OR Central America OR Atlantic Islands OR Pacific Islands OR Indian Ocean Islands OR Europe, Eastern OR Afghanistan OR Albania OR Algeria OR American Samoa OR Angola OR Antigua and Barbuda OR Argentina OR Armenia OR Azerbaijan OR Bahrain OR Baltic States OR Bangladesh OR Barbados OR Benin OR Belarus OR Belize OR Bhutan OR Bolivia OR Bosnia-Herzegovina OR Botswana OR Brazil OR Bulgaria OR Burkina Faso OR Burundi OR Cambodia OR Cameroon OR Cape Verde OR Central African Republic OR Chad OR Chile OR China OR Colombia OR Comoros OR Congo OR Costa Rica OR Cote d'Ivoire OR Croatia OR Cuba OR Cyprus OR Czechoslovakia OR Czech Republic OR Slovakia OR Djibouti OR Congo OR Korea OR Dominica OR Dominican Republic OR East Timor OR Ecuador OR Egypt OR El Salvador OR Eritrea OR Estonia OR Ethiopia OR Equatorial Guinea OR Fiji OR French Guiana OR Gabon OR Gambia OR Georgia OR Ghana OR Greece OR Grenada OR Guatemala OR Guinea OR Guinea-Bissau OR Guam OR Guyana OR Haiti OR Honduras OR Hungary OR Samoa OR India OR Indonesia OR Iran OR Iraq OR Jamaica OR Jordan OR Kazakhstan OR Kenya OR Korea OR Kyrgyzstan

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OR Laos OR Latvia OR Lebanon OR Lesotho OR Liberia OR Libya OR Lithuania OR Macedonia OR Madagascar OR Malawi OR Malaysia OR Mali OR Malta OR Mauritania OR Mauritius OR Melanesia OR Mexico OR Micronesia OR Middle East OR Moldova OR Mongolia OR Montenegro OR Morocco OR Mozambique OR Myanmar OR Namibia OR Nepal OR Netherlands Antilles OR New Caledonia OR Nicaragua OR Niger OR Nigeria OR Oman OR Pakistan OR Palau OR Panama OR Papua New Guinea OR Paraguay OR Peru OR Philippines OR Poland OR Portugal OR Puerto Rico OR Romania OR Russia OR Russia OR Rwanda OR Saint Kitts and Nevis OR Saint Lucia OR Grenadines OR Samoa OR Saudi Arabia OR Senegal OR Serbia OR Montenegro OR Seychelles OR Sierra Leone OR Slovenia OR Sri Lanka OR Somalia OR South Africa OR Sudan OR Suriname OR Swaziland OR Syria OR Tajikistan OR Tanzania OR Thailand OR Togo OR Tonga OR Trinidad and Tobago OR Tunisia OR Turkey OR Turkmenistan OR Uganda OR Ukraine OR Uruguay OR USSR OR Uzbekistan OR Vanuatu OR Venezuela OR Vietnam OR Yemen OR Yugoslavia OR Zambia OR Zimbabwe OR Southern African Development Community OR East African Community OR West African Health Organisation)

EMBASE Search Terms

'Trauma Severity Indices':ab,ti OR 'Trauma Severity Indices/utilization':ab,ti OR
'Injury severity measures':ab,ti OR 'Trauma Scores':ab,ti OR 'Trauma Score':ab,ti OR 'Injury Scales':ab,ti OR
'injury severity scores':ab,ti OR 'Anatomic Profile':ab,ti OR 'injury severity classification':ab,ti OR 'ISS':ab,ti
OR 'NISS':ab,ti OR 'ASCOT':ab,ti OR 'RISC':ab,ti OR 'MGAP':ab,ti OR 'Probability of Death score':ab,ti OR
'TRISS':ab,ti OR 'Trauma index':ab,ti OR 'Trauma indices':ab,ti OR 'CRAMS':ab,ti OR 'Circulation,
Respiration, Abdomen, Motor, and Speech':ab,ti OR 'Anatomic Index':ab,ti OR 'Anatomic Indices':ab,ti OR
'Injury severity score':ab,ti OR 'Rapid Emergency Medicine score':ab,ti OR 'Acute Physiology and Chronic
Health Evaluation':ab,ti OR 'APACHE':ab,ti

Low and Middle Income Terms – Adapted from Norwegian Cochran Centers Developing Country filter
and Johns Hopkins filters. (Both filters based on World Bank LMIC country classification).

'developing country':ab,ti OR 'developing countries':ab,ti OR 'developing nation':ab,ti OR 'developing nations':ab,ti
OR 'developing population':ab,ti OR 'developing populations':ab,ti OR 'developing world':ab,ti OR 'less developed
country':ab,ti OR 'less developed countries':ab,ti OR 'less developed nation':ab,ti OR 'less developed nations':ab,ti
OR 'less developed population':ab,ti OR 'less developed populations':ab,ti OR 'less developed world':ab,ti OR
'lesser developed country':ab,ti OR 'lesser developed countries':ab,ti OR 'lesser developed nation':ab,ti OR 'lesser
developed nations':ab,ti OR 'lesser developed population':ab,ti OR 'lesser developed populations':ab,ti OR 'lesser
developed world':ab,ti OR 'under developed country':ab,ti OR 'under developed countries':ab,ti OR 'under
developed nation':ab,ti OR 'under developed nations':ab,ti OR 'under developed population':ab,ti OR 'under
developed populations':ab,ti OR 'under developed world':ab,ti OR 'underdeveloped country':ab,ti OR
'underdeveloped countries':ab,ti OR 'underdeveloped nation':ab,ti OR 'underdeveloped nations':ab,ti OR
'underdeveloped population':ab,ti OR 'underdeveloped populations':ab,ti OR 'underdeveloped world':ab,ti OR
'middle income country':ab,ti OR 'middle income countries':ab,ti OR 'middle income nation':ab,ti OR 'middle
income nations':ab,ti OR 'middle income population':ab,ti OR 'middle income populations':ab,ti OR 'low income
country':ab,ti OR 'low income countries':ab,ti OR 'low income nation':ab,ti OR 'low income nations':ab,ti OR 'low
income population':ab,ti OR 'low income populations':ab,ti OR 'lower income country':ab,ti OR 'lower income
countries':ab,ti OR 'lower income nation':ab,ti OR 'lower income nations':ab,ti OR 'lower income population':ab,ti
OR 'lower income populations':ab,ti OR 'underserved country':ab,ti OR 'underserved countries':ab,ti OR
'underserved nation':ab,ti OR 'underserved nations':ab,ti OR 'underserved population':ab,ti OR 'underserved
populations':ab,ti OR 'underserved world':ab,ti OR 'under served country':ab,ti OR 'under served countries':ab,ti
OR 'under served nation':ab,ti OR 'under served nations':ab,ti OR 'under served population':ab,ti OR 'under served
populations':ab,ti OR 'under served world':ab,ti OR 'deprived country':ab,ti OR 'deprived countries':ab,ti OR
'deprived nation':ab,ti OR 'deprived nations':ab,ti OR 'deprived population':ab,ti OR 'deprived populations':ab,ti OR
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Supplemental file 2: Validations studies describing performance of Injury severity measures to predict mortality

Injury severity measure	Country	Year	Number of hospital	Specific injury mechanism	Study population	Age included	Sample size	% mortality	Missing data %	Performance		Calibration	
										AUROC	95% CI	H-L	p-value
APACHE II	Turkey[1]	2011	1	All injuries	Injury patients admitted to ICU in a tertiary referral hospital	>=15	100	14%	NR*	0.92	NA‡	NA	NA
	Thailand[2]	2012	1	All injuries	Injury patients admitted to surgical ICU, neurosurgical ICU or burn unit in a tertiary referral hospital	Adult (not specified)	132	20%	NR	0.89	NA	NA	NA
	Iran[3]	2012	1	Head injuries	Head injury associated with systemic trauma admitted to neurosurgical ICU	>=14	93	19.5%	NR	0.892	NA	NA	NA
	Morocco[4]	2014	1	Moderate and severe traumatic brain injuries	Injury patients admitted to medical and surgical ICU due to TBI	>=16	225	40.0%	7.6%	0.92	(0.837-0.982)	NA	NA

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	Country	Year	N	Injury type	Inclusion criteria	ISS	Sample size	Mortality		AUC	95% CI		
	Brazil[5]	2014	1	All injuries	Injury patients admitted for more than 24 hours in ER or ICU at a regional reference hospital	>12	163	10.4%	15.5%	0.777	(0.705-0.838)	NA	NA
	China[6]	2014	1	All injuries	Emergency ICU patients arrived within 24 h of injury, with ISS >16 in a university hospital	>18	81	30.9%	NR	Day 1: 0.926; day 3: 0.967; day 7: 0.936	NA	NA	NA
APACHE III	Iran[7]	2016	2	Multiple injuries from road traffic injuries	Injury patients admitted to ICU and survived for at least 4 hours upon arrival in ICU in two hospitals	>14	152	31.6%	NR	0.797	(0.652-0.901)	NA	NA
EISS	China[8]	2014	2	Moderate and severe injuries	Injury patients admitted to two tertiary hospitals	>=15	8040	6.2%	Excluded from analysis	Zhejiang: 0.949; Liaoning: 0.942	Zhejiang: (0.937-0.961); Liaoning: (0.930-0.955)	Zhejiang: 13.52; Liaoning: 15.55	Zhejiang: 0.0604; Liaoning: 0.0164

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GAP	India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.85	(0.80-0.90)	NA	NA
	Turkey[10]	2006	1	Falls	Injury pediatric patients due to specified mechanism admitted to ER in a university hospital	<14	749	3.6%	1.74%	0.975	(0.961-0.985)	NA	NA
GCS	Indonesia[11]	2009	1	Traumatic brain injury with severe or multi-trauma	Injury patients of specified mechanism with severe or multi-trauma to the university hospital (level 2 trauma center)	>=12	48	37.0%	Excluded from analysis	0.756	NA	NA	NA

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Brazil[12]	2011	1	Blunt traumatic brain injury	Injury patients of specified mechanism hospitalized at a trauma referral center	>14	277	19.1%	NR	First care: 0.747; best score: 0.791; worst score: 0.782	First care: (0.675-0.819); best score: (0.735-0.848); worst score: (0.724-0.839)	NA	NA
Iran[3]	2012	1	Head injuries	Head injury associated with systemic trauma admitted to neurosurgical ICU	>=14	93	19.5%	NR	0.621	NA	NA	NA
Morocco[4]	2014	1	Moderate and severe traumatic brain injuries	Injury patients admitted to medical and surgical ICU due to TBI	>=16	225	40.0%	7.6%	0.862	(0.823-0.893)	NA	NA
Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7525; severe injuries: 0.9658	All injuries: (0.6184-0.8866); severe injuries: (0.9301-1.000)	NA	NA

ISS	Turkey[10]	2006	1	Falls	Injury pediatric patients due to specified mechanism admitted to ER in a university hospital	<14	749	3.6%	1.74%	0.962	(0.945-0.974)	NA	0.37
	Iran[14]	2007	3	All injuries	Injury patients admitted to the hospitals	All	4096	6%	NR	>0.93	NA	NA	NA
	Lebanon[15]	2008	1	All injuries	Injury patients admitted in a major tertiary care referral hospital	All	891	3.6%	NR	0.881	(0.816-0.945)	2.97	0.70
	China[16]	2008	1	All injuries	Patients with multiple injuries admitted to Emergency ICU in a university hospital	>=16	2110	NR	NR	0.943	(0.922-0.949)	6.25	Compared with NISS: 0.052
	Turkey[17]	2009	1	Firearm injury	Firearm Injury patients admitted to ER in a level-1 trauma center	All	135	12.6%	NR	0.964	NA	1.908	0.965

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Brazil[18]	2009	1	All injuries	Injury patients hospitalized at ICU for >24 hours and within 48 hours in a university hospital	>=18	185	21.1%	NR	0.63	(0.52-0.72)	NA	0.636
Turkey[1]	2011	1	All injuries	Injury patients admitted to ICU in a tertiary referral hospital	>=15	100	14%	NR	0.878	NA	NA	NA
China[6]	2014	1	All injuries	Emergency ICU patients arrived within 24 h of injury, with ISS >16 in a university hospital	>18	81	30.9%	NR	0.804	NA	NA	NA
Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7183; severe injuries: 0.7521	All injuries: (0.5491-0.8885); Severe injuries: (0.4925-1.000)	NA	NA

Pakistan[19]	2015	1	Abdominal gunshot injury	Injury patients admitted to a university hospital with the specified mechanism	>=16	70	15.7%	Excluded from analysis	0.952	(0.902-1.000)	NA	NA
India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.69	(0.62-0.76)	NA	NA
Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7784; severe injuries: 0.9820	All injuries: (0.6285-0.9212), severe injuries: (0.9585-1.000)	NA	NA
India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.86	(0.81-0.91)	NA	NA
Malawi[20]	2015	1	All injuries	Injury patients treated in a tertiary care referral hospital	Adults (not specified)	All: 15617; admitted:2811	5%	Excluded from analysis	All patients: 0.6904; admitted patients: 0.5929;	NA	NA	NA

MGAP	India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.84	(0.79-0.89)	NA	NA
LISS	China[21]	2012	3	Major injuries	Patients with major injury (AIS>3 in a single body region) admitted in tertiary hospitals	>=15	12238 (3,784, 4,436, and 4,018 patients)	5.9%	NR	Hangzhou: 0.949; Zhejiang: 0.935; Shenyang: 0.936	Hangzhou: (0.938-0.959); Zhejiang: (0.921-0.953); Shenyang: (0.921-0.953)	Hangzhou: 13.79; Zhejiang: 18.43; Shenyang: 17.45	Hangzhou: 0.055; Zhejiang: 0.005; Shenyang: 0.008
LODS	Brazil[18]	2009	1	All injuries	Injury patients hospitalized at ICU for >24 hours and within 48 hours in a university hospital	>=18	185	21.1%	NR	0.83	(0.72-0.89)	NA	0.0596
NISS	China[16]	2008	1	All injuries	Patients with multiple injuries admitted to Emergency ICU in a university hospital	>=16	2110	NR	NR	0.938	(0.922-0.949)	7.36	Compared with ISS: 0.052

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Turkey[17]	2009	1	Firearm injury	Firearm Injury patients admitted to ER in a level-1 trauma center university hospital	All	135	12.6%	NR	0.98	NA	1.4	0.994
Brazil[18]	2009	1	All injuries	Injury patients hospitalized at ICU for >24 hours and within 48 hours in a university hospital	>=18	185	21.1%	NR	0.58	(0.47-0.67)	NA	0.1683
China[21]	2012	3	Major injuries	Patients with major injury (AIS>3 in a single body region) admitted in tertiary hospitals	>=15	12238 (3,784, 4,436, and 4,018 patients)	5.9%	NR	Hangzhou: 0.931; Zhejiang: 0.911; Shenyang: 0.918	Hangzhou: (0.918-0.944); Zhejiang: (0.890-0.931); Shenyang: (0.904-0.932)	Hangzhou: 15.76; Zhejiang: 22.70; Shenyang: 28.97	Hangzhou: 0.027; Zhejiang: 0.001; Shenyang: <0.001
China[22]	2015	2	Serious injury (exclude isolated minor or moderate injuries to a single body region)	Injury patients except those with minor injury, admitted to two level-3 first-class hospitals	>18	8079	6%	NR	Hangzhou: 0.929; Shenyang: 0.924	Hangzhou: (0.916-0.943); Shenyang: (0.910-0.938)	Hangzhou: 29.71; Shenyang: 33.49	Hangzhou: <0.001; Shenyang: <0.001

RAPS	Brazil[5]	2014	1	All injuries	Injury patients admitted for > 24 hours in ER or ICU at regional reference hospital	>12	163	10.4%	15.5%	0.806	(0.737-0.864)	NA	NA
REMS	Brazil[5]	2014	1	All injuries	Injury patients admitted for more than 24 hours in ER or ICU at a regional reference hospital	>12	163	10.4%	15.5%	0.761	(0.688-0.824)	NA	NA
RTS	Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7341; severe injuries: 0.9674	All injuries: (0.5896-0.8786); severe injuries: (0.9330-1.000)	NA	NA
	India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.85	(0.80-0.90)	NA	NA

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	Malawi[20]	2015	1	All injuries	Injury patients treated in a tertiary care referral hospital	Adults (age not specified)	All: 15617; admitted:2811	5%	Excluded from analysis	All patients: 0.6703; admitted patients: 0.6371	NA	NA	NA
SAPS II	Brazil[18]	2009	1	All injuries	Injury patients hospitalized at ICU >24 hours and <48 hours in a university hospital	>=18	185	21.1%	NR	0.85	(0.76-0.91)	NA	0.887
	Morocco[4]	2014	1	Moderate and severe traumatic brain injuries	Injury patients admitted to medical and surgical ICU due to TBI	>=16	225	40.0%	7.6%	0.843	(0.795-0.898)	NA	NA
s-APACHE II	Brazil[5]	2014	1	All injuries	Injury patients admitted for more than 24 hours in ER or ICU at a regional reference hospital	>12	163	10.4%	15.5%	0.788	(0.717-0.848)	NA	NA

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	Country	Year		Inclusion	Population	Age	N	Mortality					
TISS	China[22]	2015	2	Serious injury (exclude isolated minor or moderate injuries to a single body region)	Injury patients except those with minor injury, admitted to two level-3 first-class hospitals	>18	8079	6%	NR	Hangzhou: 0.949; Shenyang: 0.942	Hangzhou: (0.939-0.959); Shenyang: (0.931-0.954)	Hangzhou: 19.59; Shenyang: 21.19	Hangzhou: 0.003; Shenyang: 0.002
	Indonesia[11]	2009	1	Traumatic brain injury with severe or multi-trauma	Injury patients of specified mechanism with severe or multi-trauma to the university hospital (level 2 trauma center)	>=12	48	37.0%	Excluded from analysis	0.796	NA	NA	NA
TRISS	Trinidad[23]	2009	3	All injuries	Injury patients admitted in the three tertiary care teaching hospitals	All	326	4.30%	NR	0.82	(0.69-0.96)	NA	NA
	Turkey[1]	2011	1	All injuries	Injury patients admitted to ICU in a tertiary referral hospital	>=15	100	14%	NR	0.926	NA	NA	NA

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Country	Year		Injury type	Setting	Age	N			Score			
Brazil[24]	2011	1	All injuries	Injury patients admitted to ER at the level I trauma center	>=18	533	24.1%	2.8%	TRISS: 0.9; NTRISS: 0.92	NA	0.0000 for the TRISS; 0.0002 for NTRISS.	0.0012
Thailand[25]	2012	1	Blunt injuries	Injury patients registered in the Regional Hospital	All	6411	4.1%	Excluded from analysis	Modified version 1: 0.9619, version 2: 0.9601, version 3: 0.9115	NA	NA	NA
Thailand[2]	2012	1	All injuries	Injury patients admitted to surgical ICU, neurosurgical ICU or burn unit in tertiary referral hospital	Adult (not specified)	132	20%	NR	0.83	NA	NA	NA
China[6]	2014	1	All injuries	Emergency ICU patients arrived within 24 h of injury, with ISS >16 in a university hospital	>18	81	30.9%	NR	0.974	NA	NA	NA

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Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7117; severe injuries: 0.9386	All injuries: (0.5346-0.8888); severe injuries: (0.8566-1.000)	6.17	0.62
Iran[7]	2016	2	Multiple injuries from road traffic injuries	Injury patients admitted to ICU and survived for at least 4 hours upon arrival in ICU in two hospitals	>14	152	31.6%	NR	0.806	(0.663-0.908)	NA	NA

*Not reported; ‡Not applicable

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a literature review and validation analysis of studies from Low- and Middle-Income Countries

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a literature review and validation analysis of studies from Low- and Middle-Income Countries

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Performance of injury severity scores in trauma research:

a literature review and validation analysis of studies from Low- and Middle-Income Countries

ABSTRACT

Introduction:

Characterization of injury severity is an important pillar of scientific research to measure and compare the outcomes. Although majority of injury severity measures were developed in high-income countries, many have been studied in Low- and Middle-Income Countries (LMICs). We conducted this study to identify and characterize all injury severity measures, describe how widely and frequently they are utilized in trauma research from LMICs, and summarize the evidence on their performance based on empirical and theoretical validation analysis.

Methods:

First, a list of injury measures was identified through PubMed search. Subsequently, a systematic search of PubMed, Global Health, and EMBASE was undertaken on LMIC trauma literature published from January 2006 through June 2016, in order to assess the application and performance of injury severity measures to predict in-hospital mortality. Studies that applied one or more global injury severity measure(s) on all types of injuries were included, with the exception of war injuries and isolated organ injuries.

Results:

Over a span of 40 years, more than 55 injury severity measures were developed. Out of 3862 non-duplicate citations, 597 studies from 54 LMICs were listed as eligible studies. Full text review revealed 37 studies describing performance of injury severity measures for outcome prediction. Twenty-five articles from thirteen LMICs assessed the validity of at least one injury severity measure for in-hospital mortality.

Injury severity score was the most commonly validated measure in LMICs, with a wide range of

performance (AUROC between 0.9-0.65). TRISS validation studies reported AUROC between 0.80-0.98.

Conclusion: Empirical studies from LMICs frequently utilize injury severity measures, however, no single

injury severity measure has shown a consistent result in all settings or populations and thus warrants

validation studies for the diversity of LMIC population.

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Article Summary with Strength and Weaknesses:

1. The study comprises of three parts: summary of all injury severity measures, description of their use in LMICs, and their performance to predict in-hospital mortality in LMIC settings

2. Injury severity measures, whether developed exclusively for characterizing trauma and injuries, or non-injury severity measures incorporated in trauma research, are both included in this study

3. A systematic electronic search of PubMed, Global Health, and EMBASE on literature published from January 2006 through June 2016.

4. Validation studies conducted in LMICs are used to estimate the performance of injury severity measures

5. Performance of injury severity measures to predict other outcomes such as blood transfusion requirement, ICU admission, or hospital length of stay, are not focus of this study

INTRODUCTION

Injury remains a major public health problem globally, causing significant death and disability across all the age and sex spectrum.[1] A disproportionate share, 90%, of all trauma deaths occur in low- and middle-income countries (LMICs), where resources to deal with this crisis are inadequate. An efficient and effective trauma system has been found to be a key component. It is estimated that approximately two million lives could be saved annually if LMICs could implement trauma systems comparable to trauma care systems available in High- Income Countries (HICs).[2] However, this would require a careful assessment of the gaps and planning to ensure the most efficient use of available resources. Injury severity scoring systems can provide a foundation for benchmarking and performance improvement in the arena of trauma care.[3] Characterization of injury severity is a critical pillar in the provision and improvement of trauma care for key activities such as field triage, prognostication, prediction of risk-adjusted outcomes, quality improvement, evaluation of cost and effectiveness of trauma service delivery, planning of services and organization of resources.[4] Many injury measures have been formulated over time with a wide range of methodologies.[5] While no single injury measure is considered the best or the most comprehensive, assessment of injuries in a patient has been aided by assigning numerical values to several indicators including physiological or biochemical parameters, anatomical descriptors, age, etc., and combining these values to an overall measure of injury severity.[6, 7] Although injury severity measures are most often used for the purpose as they were developed, such as triage or mortality prediction, it is not uncommon to validate and use them for other functions.[8, 9]

There has been a proliferation of injury severity measures over the past few decades.[7, 10] While a variety of injury severity measures have been developed exclusively for trauma and injuries, other non-injury severity measures have also been incorporated in trauma research on many occasions.[11-14] These severity measures use a range of clinical, biochemical, demographic, and physical attributes to create indicators for prognostic predictions and performance evaluation.[4, 15]

However, both the utilization and validation of injury scores in clinical care or outcome research has been sparse in LMICs.[16] There are multiple reasons for this, but in many cases, especially for those injury severity measures developed in high-income settings, the information needs are challenging for a low-resource environment.[11, 15, 17-19] Many well-recognized injury measures were sometimes applied without being validated in the populations under study. Subsequently, studies have documented poor performance of injury severity measures such as Trauma and Injury Severity Score (TRISS), when applied to other populations using the coefficients derived from the Major Trauma Outcome Study.[20-26] However, there is a dearth in the literature on utilization of common injury severity measures, and which of those show better performance in terms of validity and reliability to support their use in LMICs. This gap limits our ability to translate high quality injury research methods developed in HICs into effective decision support and quality improvement systems for LMICs. The aim of this study was therefore to fill this gap in the literature through a thorough review of the literature; specifically we sought to: (1) identify all the measures and scoring systems that were ever developed to measure injury severity, and summarize their characteristics; (2) describe how widely and frequently the key measures are utilized in LMICs; and (3) summarize the evidence on their measurement performance based on empirical validation analysis and theoretical analysis of their applicability.

METHODS

For our first aim, we conducted a literature search for terms "injury AND severity measures" OR "injury AND scores" OR "Injury AND scales", as well "Trauma AND severity measures" to include those that are not exclusive to injuries but have been utilized in trauma and injury research. A list of injury measures was identified through PubMed search. Subsequently, using bibliographies of the results of the primary search, a secondary search was performed to find the original literature of the injury measure development. Full text of all publications was reviewed to understand and describe the initial purpose

and scope of development of the injury measure, its main components, year of first publication and country of development.

For the specific aims two and three, we conducted a detailed literature review to assess the application and performance of injury severity measures to predict in-hospital mortality, conducted in low- and middle-income countries. We included studies of global trauma populations and specific injury pathologies and used World Bank's classification for low- and middle-income countries (LMICs) in year 2016.

Eligibility Criteria:

For the purpose of determining the applications of different injury severity measures in LMICs, we included studies that applied one or more global injury severity measure(s) on any type of injury population, except for studies that focused only on poisoning, drowning, and ocular trauma. We excluded studies that applied exclusively organ specific injury severity measure(s), population from low income country treated in a high-income setting, as well as studies describing only combat injuries or those from military trauma registries due to the environment and contexts largely different from general LMICs settings.

Information Sources and Search Strategy:

We conducted a systematic electronic search of PubMed, Global Health, and EMBASE on literature published from January 2006 through June 2016. We used combinations of search terms including medical subject heading (MeSH) and keywords on two groups: "trauma or injury measures", and a list of "LMICs" (Supplemental file 1). We applied human subjects restrictions but language restrictions were not applied. All references were exported to Endnote version 7® and duplicated studies were excluded using Endnote before exporting them into an Excel spreadsheet.

Two authors (A.M. and S.A.) independently screened the titles and abstracts of all studies resulted from the above search strategy to identify the eligible studies for the applications of injury severity measures in LMICs. Full text version of all the eligible articles were sought and if full text was not available in English language, the abstracts were excluded from further analysis. All eligible full text articles were reviewed for relevance and data collection.

Data abstraction

Data were extracted from the selected studies using a pre-designed electronic data collection form. The studies were further categorized into validation studies or empirical/non-validation studies, or excluded if they did not match the inclusion criteria on full text review (Figure 1).

- Insert Figure 1-

To assess the performance of injury severity measures and prediction of in-hospital mortality, we selected studies that estimated the Area Under the Receiver Operating Characteristic (AUROC) curve or correlation between specific injury severity measure and in-hospital mortality, based on the studies identified with applications of injury severity measures in LMICs. Studies that did not specify the outcome of assessment or did not include any estimates of AUROC, correlation, or sensitivity and specificity were excluded. Three authors (A.M., H.H., and Y.W.H.) screened these identified studies for the performance on predicting in-hospital mortality. Any disagreements were resolved by discussions among the three authors.

For the purpose of determining applications of different injury severity measures in LMICs, three authors (A.M., H.H., and Y.W.H.) extracted information on the injury severity measures used in each study, whether performance was assessed on in-hospital mortality prediction, and the country in which the study was conducted. The studies and corresponding injury measures were assessed in detail for study population, type of injury and injury mechanism, injury severity measures, study methods, in-

hospital mortality prediction, and their corresponding performance in predicting in-hospital mortality.

The performance of the injury severity measures is reported as Area Under Receiver Operating

Characteristic (AUROC) curve and calibration as Hosmer-Lemeshow (H-L) goodness of fit test.

Patient and Public Involvement

This study did not involve patients or human subjects directly or indirectly and the results of the analysis

were solely based on the previously published literature.

RESULTS

The results are described in order of specific objectives of the study. Our study demonstrates

considerable growth in the science of injury severity measurement globally as well as in LMICs. Table 1

summarizes the search results of different injury measures, categorized according to the primary

purpose of their development and their core components. It shows clearly that the science of injury

severity measures had essentially taken off in early 1970s and it is still ongoing with similar enthusiasm.

Almost sixty severity measures or scoring systems have been developed either exclusively for injury and

trauma research or have been used in measuring the severity of injuries. Many injury severity measures

were developed to support epidemiological research and performance evaluation; examples include,

Abbreviated Injury Scale (AIS), Injury Severity Score (ISS) and New Injury Severity Scores (NISS), A

severity categorization of trauma (ASCOT) and ICD-9-injury severity score (ICISS). Others, such as Revised

trauma score (RTS), CRAMS, ABCD, and Kampala trauma scores (KTS) were developed to help in decision

making, for example, pre-hospital triage, and in-hospital patient disposition. A number of injury

measures were developed for the purpose of outcome prediction; Trauma Mortality Prediction Model

(TMPM), Rapid Emergency Medicine score (REMS), and GAP are some examples.

Table 1: List of Injury Severity Measures, their purpose and components

	Measures	Year, Country	Components
	Primary purpose: Epidemiologic research and evaluation		
1	Abbreviated Injury Scale (AIS)[27]	1971, USA	Anatomic description of injuries
2	Comprehensive research injury scale (CRIS)[28]	1972, USA	Energy dissipation, threat-to-life, permanent impairment, treatment period, incidence

3	Injury Severity Score (ISS)[29]	1974, USA	AIS
4	Estimated survival probability (ESP) index[30]	1978, USA	International classification for disease (ICDA) codes
5	Penetrating and Blunt (PEBL) code[31]	1978, USA	Anatomic description of injuries with limited physiological responses
6	Wisconsin Trauma Index[17]	1980, USA	Involvement of different organ systems, burns, age, pre-existing condition
7	Anatomic Index (AI)[32]	1980, USA	Hospital Adaptation of the International Classification of Diseases Discharge Diagnosis
8	Revised estimated survival probability (RESP) score[33]	1982, USA	Hospital ICDA Discharge Diagnosis (HICDA), age
9	Probability of Death score (PODS)[34]	1983, Denmark	Re-categorization of AIS
10	Trauma Score – Injury Severity Score (TRISS)[23]	1987, USA	RTS, ISS, age, mechanism of trauma
11	Organ injury scale (OIS)[35-38]	1989, USA	Anatomic description, blood loss
12	Anatomic Profile (AP)[39]	1990, USA	AIS, Summary scores for body regions A through D
13	ASCOT (A severity categorization of trauma)[39]	1990, USA	Emergency Department RTS, patient age, AIS-85
14	Perceptron Neural Networks[40]	1993, USA	RTS, ISS, age
15	ICISS (ICD-9 Injury Severity Score)[41]	1996, USA	ISS, ICD-9 injury descriptors
16	New Injury Severity Score (NISS)[42]	1997, USA	AIS
17	MAX AIS[43]	2002, USA	Maximum AIS score
18	Trauma Registry Abbreviated Injury Scale Score (TRAIS)[44]	2003, USA	AIS derived survival risk ratio (SRR)
19	Turkish Injury scale (TIS)[45]	2003, Turkey	Injury severity according to Turkish Penal code
20	Revised Injury Severity Classification (RISC) Score[21]	2009, Germany	AIS, age, sex, head injury, biochemical and physiological parameters, cardiopulmonary resuscitation (CPR)
Primary purpose: Triage and Decision Support			
21	Trauma index (TI)[46]	1971, USA	Region and type of injury, Cardiovascular, Central nervous system, Respiratory status
22	Glasgow coma scale (GCS)[47]	1974, UK	Eye opening, motor and verbal response
23	Illness-injury Severity index[48]	1979, USA	Physiological parameters, region and type of injury, pre-existing condition
24	Trauma Score[49]	1981, USA	Respiratory effort, Capillary refill, Respiratory rate (RR), Systolic Blood pressure (SBP), Glasgow Coma Scale (GCS)
25	CRAMS (Circulation, Respiration, Abdomen, Motor and Speech)[50]	1982, USA	Capillary refill, respiration, abdominal injuries, motor and verbal response
26	Prehospital Index (PHI)[8]	1986, USA	SBP, pulse, RR and level of consciousness
27	Rapid Acute Physiology score (RAPS)[51]	1987, USA	Truncated version of APACHE II- Pulse, BP, GCS , RR
28	Revised Trauma Score (RTS)[52]	1989, USA	Sum of weighted values of GCS, BP, RR
29	Kampala Trauma Score (KTS)[53]	1996, Uganda	Age, number of serious injury, SBP, RR, neurologic status (AVPU)
30	FOUR (Full Outline of UnResponsiveness) score[54]	2005, USA	Physiological score consisting of eye, motor, brainstem and respiratory components

31	Trauma Associated Severe Hemorrhage Score (TASH)[55]	2006, Germany	SBP, hemoglobin, free peritoneal fluid, base excess, complex fractures, pulse, and sex
32	Prehospital pediatric trauma classification (PHPTC)[56]	2006, Brazil	Physiological status, trauma mechanism and anatomic injuries
33	Ganga Hospital Score[57]	2006, India	Severity of injury to the skin, bones and muscles of the limb; presence of co-morbids
34	Assessment of Blood Consumption (ABC) Score[58]	2008, USA	SBP, positive abdominal ultrasound, pulse, and penetrating injury
35	Emergency Trauma Score (EMTRAS)[59]	2009, Germany	Age, prehospital GCS, base excess, prothrombin time
36	Acidosis, Blood loss, Cold, Damage (ABCD)[60]	2012, USA	Acidosis, blood loss, temperature, NISS
Primary purpose: Outcome prediction			
37	Glasgow outcome scale (GOS)[61]	1975, UK	Assessment of disability from recovery to death
38	Acute Physiology And Chronic Health Evaluation (APACHE) I[18]	1981, USA	Physiological variables, age, pre-admission health status; all disease categories
39	Penetrating Abdominal trauma index (PATI)[62]	1981, USA	Anatomical injury severity for each organ involved in penetrating trauma
40	Simplified Acute Physiology Score (SAPS or s-APACHE)[63]	1984, France	Abbreviated version of APACHE
41	APACHE II[64]	1985, USA	Physiological variables, age, chronic health; all disease categories
42	Pediatric Risk of Mortality (PRISM) score[65]	1988, USA	14 Physiological and biochemical parameters
43	Mangled extremity score (MESS)[66]	1990, USA	Composite score of tissue damage, ischemia, shock and age
44	APACHE III[67]	1991, USA	Acute physiologic abnormalities, age, preexisting functional limitations
45	Shock Index (SI)[68]	1992, USA	Ratio of pulse rate vs. SBP
46	Rixen Score[69]	1999, Germany	Age, GCS, ISS, base excess, prothrombin time
47	Glasgow coma scale Extended (GCS-E)[70]	2000, UK, S Africa	Eye, verbal, and motor response PLUS amnesia scale
48	KTS-II[71]	2002, Uganda	Age, SBP, RR on admission, Neurologic status (AVPU), number of serious injuries
49	Rapid Emergency Medicine score (REMS)[72]	2004, Germany	Coma, respiratory frequency, oxygen saturation, blood pressure, pulse rate and age
50	FLAMES Score[73]	2008, Canada	Age, APACHE II score, Extent of burn, and Sex
51	Trauma Mortality prediction model (TMPM) ICD 9[74]	2009, USA	ICISS, ICD 9
52	Mechanism, GCS, Age, Pressure (MGAP)[75]	2010, France	Mechanism (blunt vs. penetrating), GCS, age, SBP
53	Sequential trauma score[11]	2010, Germany	Age, mechanism, clinical interventions, biochemical and physiological parameters, AIS
54	GCS, Age, Pressure (GAP)[76]	2011, Japan	GCS, age, SBP
55	NORwegian survival prediction Model In Trauma (NORMIT)[77]	2014, Norway	NISS, RTS, age, pre-injury co-morbidity score
56	Exponential Injury Severity Score (EISS)[78]	2014, China	AIS derived injury score

57   Tangent injury severity score (TISS)[79]   2015, China   AIS derived injury score

Table 1 highlights that a number of empirically developed anatomic, physiological and

composite measures such as AIS, or Glasgow Coma scale (GCS), later became the basis of more complex

measures such as Revised Trauma Score (RTS), Injury severity score (ISS), and Revised Injury Severity

Classification (RISC) score, and some of them (RTS, ISS, NISS) in turn became components of a more

complex scoring system such TRISS, Sequential trauma score, etc. The use of injury measures in studies

published by different LMICs is depicted in figure 2. A total of 597 studies from 54 LMICs were listed as

eligible studies between 2006 and 2016, which were a combination of empirical, epidemiological, review,

and validation studies. China, Turkey, Iran, South Africa, Colombia, and Brazil are some of the upper-

middle-income countries that contributed to the majority of injury literature published in the last ten

years (figure 3), whereas India, Pakistan, Nigeria and Tanzania are some of the lower-middle-income and

low-income countries that extensively used injury measures in a number of injury and trauma related

publications. 31 publications described multi-country studies, which may also include a high-income

country. Approximately 31% (n=186) of all studies were related to head or traumatic brain injuries.

-    Insert Figure 2 here –

-    Insert Figure 3 here –

Table 2 outlines different injury measures used in publications from 54 LMICs in injury-related research.

GCS, ISS, TRISS and RTS are the most commonly used injury measures, however, some attempts have

been made to develop new injury measures. Examples include Exponential Injury Severity score (EISS),

Ganga hospital score for lower limb fractures, Tangent Injury severity score (TISS), and some novel

biomarkers such as Lactate and serum acetylcholinesterase. Other scores that were not traditionally

used in injury or trauma research such as McLaughlin, Modified Rankin, South African Triage score,

Modified Early Warning System (MEWS), and Rwanda mortality prediction model have also been utilized

for prediction of mortality in trauma populations. Glasgow outcome scale is widely used in documenting

the outcomes of traumatic brain injuries (TBI), and Functional Independence measure (FIM) was used in

some studies focusing on functional outcomes of injured patients. Some attempts have been made to

modify existing injury measures; for example, in Simplified RTS, Glasgow coma score was replaced by

five different levels of consciousness, or NISS was used instead of traditional ISS in TRISS method, etc.

Table 2: Injury measures used in last ten years' published literature from LMICs

Country	Injury measures
Algeria	GCS, ISS
Argentina	GCS, GOS-E, Modified Rankin scale
Bangladesh	GCS, GOS
Benin	GCS
Bosnia	ISS
Brazil	AIS, RTS, ISS, NISS, APACHE II, SAPS II, RAPS, REMS, GCS, MAIS, TRISS, FIM, Abdominal trauma index, OIS, MESS
Cambodia	GCS, GOS
Cameroon	ISS, TRISS, KTS, RTS, GCS, KTS II
China	AIS, ISS, TRISS, GCS, APACHE II, NISS, trauma index, Pre-hospital index, GOS, serum Acetylcholinesterase, Exponential injury severity score (EISS), Tangent ISS, FOUR score, SAPS II
Colombia	RTS, GCS, ISS, NISS, ABCD, ABC, McLaughlin, GOS, AIS
Croatia	GCS, GOS
Cuba	GCS, GOS
Egypt	GCS, APACHE II, GOS
Ethiopia	TRISS, GCS
Ghana	KTS II
Guinea	GCS
India	AIS, ISS, TRISS, KTS, RTS, GAP, MGAP, GCS, OIS, Pediatric Trauma Score (PTS), SOFA, NISS, ICISS, Ganga hospital score
Indonesia	ISS, AIS, TRISS, GCS, REMS,
Iran	AIS, ISS, TRISS, RTS, GCS, APACHE II, NISS, ASCOT, Modified ISS, APACHE III, GOS-E, Abdominal trauma index, Simplified RTS, MESS
Iraq	TRISS, PATI, ISS, Simplified RTS
Jamaica	ISS, GCS
Jordan	GCS, FIM, GOS
Kenya	GCS, GOS, ISS, TRISS
Lebanon	ISS, NISS
Malawi	KTS, RTS, MGAP, GCS

Malaysia	AIS, GOS, GCS, RTS, ISS
Mali	GCS
Mexico	OIS, APACHE II, ISS, PATI, AIS
Montenegro	ISS
Morocco	APACHE II, SAPS II
Mozambique	RTS, ISS,
Nepal	AIS, ISS, GCS, GOS
Niger	GCS
Nigeria	RTS, GCS, ISS, Facial injury severity, AIS, PTS, GOS, MESS
Pakistan	ISS, RTS, TRISS, GCS, OIS, GOS, Trauma Index
Papua N. Guinea	GCS, GOS
Paraguay	ISS
Rwanda	GCS, ISS, TRISS, Rwanda Mortality Probability Model
Senegal	GCS
Serbia	GCS, ISS, APACHE II, SOFAS, SAPS II
South Africa	AIS, ISS, RTS, GCS, NISS, MEWS, South African Triage Score, GOS, Lactate, s-APACHE, RAPS, REMS, APACHE II, OIS
Sri Lanka	ISS, GCS, GOS
Suriname	ISS
Tanzania	ISS, GCS, KTS, PTS, RTS, KTS II, OIS
Thailand	GCS, ISS, TRISS, APACHE II, ABCD, modified TRISS, GOS
Trinidad	TRISS
Tunisia	GCS, ISS, PTS, PRISM, GOS, FIM
Turkey	ISS, AIS, RTS, TRISS, GCS, Pediatric Trauma score, Organ specific scores, Lactate, GOS, PATI, NISS, Turkish penal code
Uganda	KTS, GCS, Lactate, KTS II
Ukraine	GCS
Uruguay	ISS, APACHE II, SAPS II, SOFA, GCS
Uzbekistan	GCS
Vietnam	SOFA score
Zambia	KTS, KTS II

Full text review of eligible articles was conducted to understand of validity of these new or

existing injury measures and revealed that 37 studies examined the performance of injury severity

measures for the prediction of hospital length of stay, in-hospital mortality, and functional outcome of

injured patients. Supplemental file 2 details 25 of 37 validations studies, as the remaining 12 use

different outcomes (e.g. respiratory failure, ICU admission etc.) or use a different algorithm. These twenty-five articles from thirteen LMICs assessed the validity of at least one injury severity measure in hospital settings. ISS was the most commonly validated measure in LMICs in the past ten years, assessed in eleven studies. TRISS was the second most commonly validated injury severity measure in LMICS, followed by GCS, APACHE II, and NISS. GCS was more commonly assessed among head/traumatic brain injuries, while also validated among patients with general injuries. The majority of validation studies included all injury mechanisms, some studies included critically ill populations such as ICU patients, while others included patients admitted to the emergency room. The proportion of mortality also varied widely among different settings, ranging from 0.6% to 40%.

Among injury severity measures that were validated in multiple contexts, many presented a wide range of AUROC estimates. Out of the eleven validation studies on ISS, five estimated AUROC above 0.90, and two of the studies had AUROC below 0.70 with 95% CI overlapping 0.65. Similarly, as majority of the validation studies on TRISS reported AUROC between 0.80 and 0.98, three studies reported 95% CI of AUROC overlapping 0.70. More than a third of the validation studies did not present 95% CI estimates of AUROC, and more than half of the validation studies did not provide estimates on calibration (fifteen studies).

A majority of the validation studies included only adults, and sometimes adolescents. A third of the validation studies included both adults and children, and one study included only pediatric injury population. Many of the validation studies also did not report proportion of missing data. Of those articles mentioned about missing data, all excluded records with missed information from analyses.

Besides using in-hospital death as outcome, other studies included morbidity outcomes such as length of hospitalization, damage control resuscitation, severe trauma, life-threatening injury, respiratory failure, and sepsis. These morbidity outcomes are less standardized and therefore limited the ability for comparison.

DISCUSSION

Our review points to an ongoing search for a comprehensive yet simple scoring system applicable to LMICs research and trauma care needs. While Glasgow coma scale, AIS and its derivatives, and TRISS methodology have established themselves as gold standards in injury research, there seems to be a need for injury severity measures that are reliable even in the light of the realities facing patient care systems in LMICs. Looking closely at the components of injury measures, it is evident that many complex measures require a host of information starting from pre-hospital phase until the discharge from the hospital. Henceforth, resources required to record the anatomical and biochemical evidence of injury

severity are more readily available in high-income settings but may be difficult to obtain in resource constrained environments.

Injuries and their physiological response are complex mechanisms, and the outcome of injuries is frequently affected by a number of factors ranging from age and pre-existing conditions of the patient to biochemical response of the body. It is difficult to account for all factors in a single model or severity measure; therefore, use of non-injury-specific-measures such as APACHE II, SOFAS, and SAPS has gained traction in trauma research. Simple yet composite measures such as MGAP and KTS have become more popular, which have been widely used and validated across the globe.[9, 25, 26, 80] Our review demonstrated that, although a number of injury severity measures were developed during the 1990s and early 2000s, there have been limited applications in LMICs. Furthermore, very few validation studies were conducted in low-income settings (Supplemental file 2). Over 70% of publications on injury research in LMICs have been published from only 11 countries (Figure 3), which is obviously incomparable with their burden of injuries; moreover, the body of research comprises mostly of descriptive or epidemiological studies. Comparison of the most commonly applied injury measures aligns with the most commonly validated injury severity measures, including GCS, ISS, TRISS, APACHE and KTS scores. It is important to note that the majority validation studies have been conducted in upper-middle-income countries such as China, Turkey, Brazil, and Thailand; involved single centers; or included specific study population such as head or abdominal injuries. New methods and models such as EISS, TISS and new TRISS have not been validated in other LMICs, outside of their origin.

A subset of studies found relatively low performance of injury severity measures, which demonstrates large deviation from studies conducted in predominantly high-income settings (e.g. TRISS, ISS). These differences may be due to a wide range of factors, such as delays in recording time sensitive injury data (such as blood pressure or GCS), training of personnel administering AIS codes, limited resources and equipment available for diagnosis, missed injuries, etc. Some recent studies confirm that

commonly used injury severity measures that depend on in-depth information may not perform well in mortality prediction, especially with limited or incomplete data.[25, 26] Such differences underline the importance of assessing the performance and calibration of measures in specific contexts prior to their use in trauma registries or for outcome prediction. A review of publications on validation studies demonstrated that limited statistical analysis was performed in validation studies and the issue of missing data was not addressed. This may introduce bias in the estimates of performance of the injury severity measures. As mentioned before, many of the validation studies were limited with small sample size and single institutions, restricting to the specific setting and a lack of comparison among similar institutions within the country. Very often, the validation studies did not include statistical inference of the estimation, further restricting the ability to compare performance among injury severity measures inspected. Calibration is another feature of the measure that should be more commonly assessed.

Overall, our study has been able to highlight several important issues. First, the "10-90" funding and research gap is also quite evident for injury and trauma, and we have observed that the amount of injury research from LMICs is still far less than the burden of injuries faced by these countries.[81] The quality and depth of research is also not sufficient, being mostly limited to small empirical studies. The findings of validation studies focusing on mortality prediction highlight large variability in performance of commonly applied injury measures including GCS, ISS, RTS, TRISS and KTS. However, lack of large multicenter databases restricts the generalizability of results in large populations, even within a country.

The results nevertheless corroborate the assumption that no single injury measure has shown a consistent result in all settings and thus underscores the importance of context specific validation studies. This has also been reported previously from systematic reviews for injury severity measures such as ISS, NISS, ICISS and TMPM, mainly featuring studies from high-income settings.[82, 83] Furthermore, application of injury measures in field triage or emergency room disposition is also heavily influenced by the system of trauma care delivery, and hence, their performance in terms of prediction

of survival, hospital length of stay or complications has to be tested and validated in specific settings where they are being used.

Our study has a few limitations. First, we conducted this literature review between 2006 and 2016, covering a ten-year period, and studies that were published outside of this timeframe are not included. Second, we have limited our literature search to three databases; nonetheless, inclusion of the Global Health database enabled us to review several Latin American publications that would have been otherwise missed. Third, we limited our detailed analysis of validation studies to those that focused on mortality prediction; this was due to a very limited number of studies focusing on a specific non-fatal outcome. We also did not focus on studies that used alternative coefficients for some of the established measures, as they were not consistently tested across settings.

CONCLUSION:

The science of injury severity measurement has been growing to predict injury outcomes, help in decision making and support epidemiological research. Empirical studies from upper- and lower-middle-income countries frequently utilize injury severity measures. However, there is still a lack of large multicenter validation studies. The evidence base from low-income countries is even less established, where most of the burden of injury and trauma lies. No single injury severity measure has shown a consistent result in all settings and thus underscores the importance of context specific validation studies.

List of Abbreviations:

AIS: Abbreviated Injury Scale

ABC: Assessment of Blood Consumption

ABCD: Acidosis, Blood loss, Cold, Damage

APACHE: Acute Physiology And Chronic Health Evaluation

ASCOT: A Severity Categorization Of Trauma

AUROC: Area Under Receiver Operating Characteristic

CRAMS: Circulation, Respiration, Abdomen, Motor and Speech

EISS: Exponential Injury Severity Score

FIM: Functional Independence measure

GAP: GCS, Age, Pressure

GCS: Glasgow Coma Scale

GCS-E: Glasgow Coma Scale- Extended

GOS: Glasgow Outcome Scale

H-L: Hosmer-Lemeshow

ICISS: ICD-9-Injury Severity Score

ISS: Injury Severity Score

KTS: Kampala Trauma Score

LISS: Logarithmic Injury Severity Score

MeSH: Medical Subject Heading

MEWS: Modified Early Warning System

MGAP: Mechanism, GCS, Age, Pressure

MTOS: Major Trauma Outcome Study

NISS: New Injury Severity Scores

REMS: Rapid Emergency Medicine score

RISC: Revised Injury Severity Classification

RTS: Revised Trauma Score

SAPS: Simplified Acute Physiology Score

SOFAS: Sequential Organ Failure Assessment Score

TBI: Traumatic Brain Injury

TISS: Tangent Injury severity score

TMPM: Trauma Mortality Prediction Model

TRISS: Trauma and Injury Severity Score

Figure 1: Flow diagram of search strategy and study selection according to Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) guidelines

Figure 2: LMIC publications using Trauma/ Injury severity measures

Figure 3: Top Ten countries with trauma/ injury publications

Supplemental file 1: Literature review search terms

Supplemental file 2: Validations studies describing performance of Injury severity measures to predict mortality

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Consent for publication: Not applicable.

Data Sharing and availability of other material: We have included additional information as supplemental files. There is no other unpublished data to share.

Authors Contribution:
A.M., H.H., and Y.W.H. conceptualized the study. S.H., A.M., Y.W.H., and H.H. and participated in data extraction and analysis. A.M., and Y.W.H. produced the first draft of the manuscript, while A.B. provided overall guidance and final review of all manuscript drafts.

Competing Interest: The authors have no competing interests to declare

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I am one author signing on behalf of all co-owners of the Contribution.

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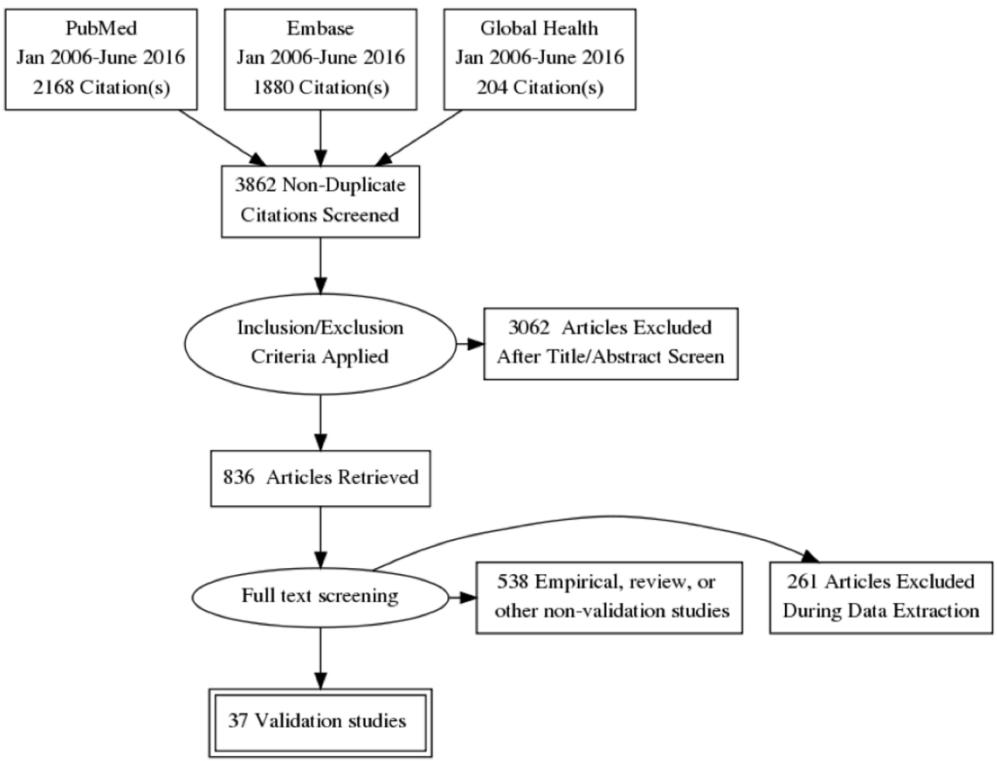
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Flow diagram of search strategy and study selection according to Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) guidelines
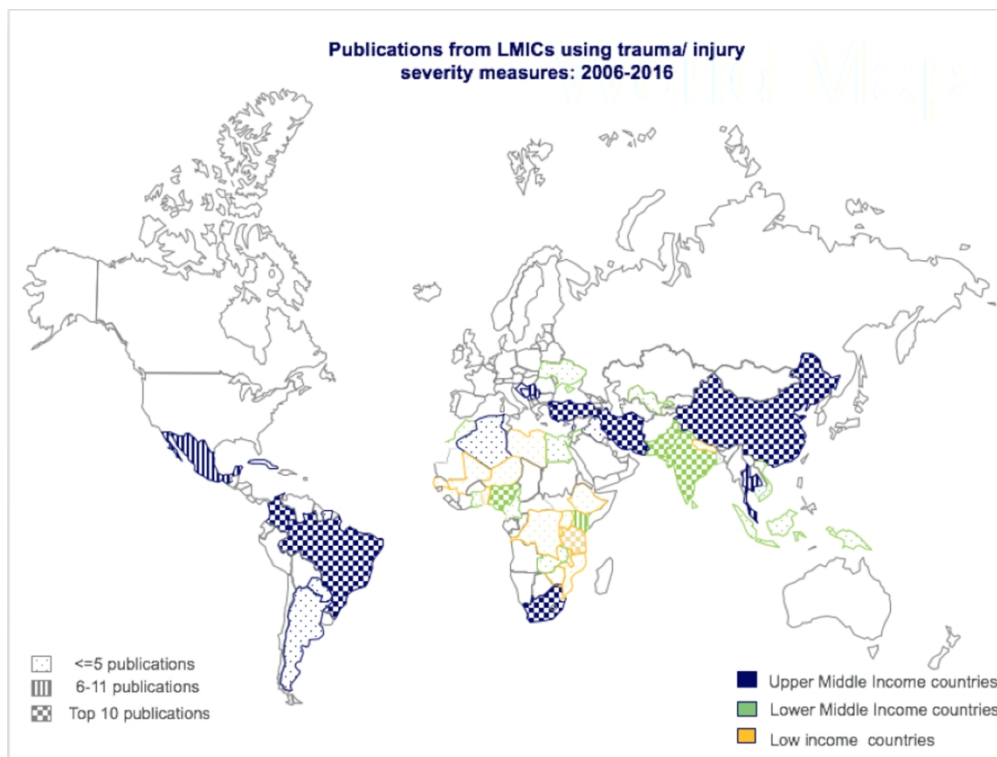
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Map showing research publications from Low-Middle Income Countries using trauma/ injury severity measures 2006-2016

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TOP TEN COUNTRIES

- Tanzania — 16
- Colombia — 16
- Pakistan — 24
- Nigeria — 27
- South Africa — 33
- Turkey — 55
- Iran — 56
- India — 66
- Brazil — 68
- China — 70

Top ten countries with trauma/ injury publications between 2006-2016

150x90mm (300 x 300 DPI)

Supplemental file 1: Literature review search terms

PUBMED LMIC Filter

"Trauma Severity Indices"[Mesh] OR "Trauma Severity Indices/utilization"[Mesh] OR
"Injury severity measures" OR "Trauma Scores"[all fields] OR "Trauma Score"[all fields] OR "Injury
Scales"[all fields] OR "severity scores"[all fields] OR "Anatomic Profile"[all fields] OR "severity
classifications"[all fields] OR "severity classification"[all fields] OR "ISS"[all fields] OR "NISS" [all fields]
OR "ASCOT" [all fields] OR "RISC" [all fields] OR "MGAP" [all fields] OR "Probability of Death score"[all
fields] OR "TRISS"[all fields] OR "Trauma index" OR "Trauma indices"[all fields] OR "CRAMS" OR
"Circulation, Respiration, Abdomen, Motor, and Speech"[all fields] OR "Anatomic Index" OR "Anatomic
Indices" [all fields] OR "Injury severity score" [all fields]

"Trauma Severity Indices"[Mesh] OR "Trauma Severity Indices/utilization"[Mesh] OR
"Injury severity measures" OR"Trauma Scores"[tiab] OR "Trauma Score"[tiab] OR "Injury Scales"[tiab]
OR "severity scores"[tiab] OR "Anatomic Profile"[tiab] OR "severity classifications"[tiab] OR "severity
classification"[tiab] OR "ISS"[tiab] OR "NISS" [tiab] OR "ASCOT" [tiab] OR "RISC" [tiab] OR "MGAP" [tiab]
OR "Probability of Death score"[tiab] OR "TRISS"[tiab] OR "Trauma index" OR "Trauma indices"[tiab] OR
"CRAMS" OR "Circulation, Respiration, Abdomen, Motor, and Speech"[tiab] OR "Anatomic Index" OR
"Anatomic Indices" [tiab] OR "Injury severity score" [tiab] OR" Rapid Emergency Medicine score"[tiab]
OR "Acute Physiology and Chronic Health Evaluation" OR "APACHE"[tiab]

AND ("emerging country"[all fields] OR "emerging countries"[all fields] OR "emerging nation"[all fields]
OR "emerging nations"[all fields] OR "emerging population"[all fields] OR "emerging populations"[all
fields] OR "developing country"[tiab] OR "developing countries"[tiab] OR "developing nation"[tiab] OR
"developing nations"[tiab] OR "developing population"[tiab] OR "developing populations"[tiab] OR
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"underdeveloped populations"[tiab] OR "underdeveloped world"[tiab] OR "middle income
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"underserved world"[tiab] OR "under served country"[tiab] OR "under served countries"[tiab] OR
"under served nation"[tiab] OR "under served nations"[tiab] OR "under served population"[tiab] OR
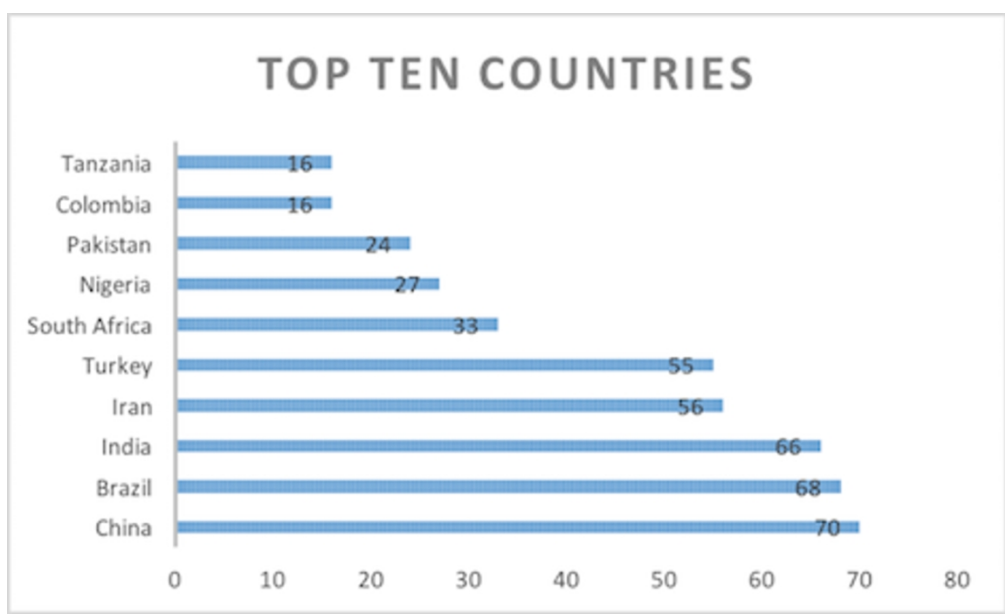
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"under served populations"[tiab] OR "under served world"[tiab] OR "deprived country"[tiab] OR "deprived countries"[tiab] OR "deprived nation"[tiab] OR "deprived nations"[tiab] OR "deprived population"[tiab] OR "deprived populations"[tiab] OR "deprived world"[tiab] OR "poor country"[tiab] OR "poor countries"[tiab] OR "poor nation"[tiab] OR "poor nations"[tiab] OR "poor population"[tiab] OR "poor populations"[tiab] OR "poor world"[tiab] OR "poorer country"[tiab] OR "poorer countries"[tiab] OR "poorer nation"[tiab] OR "poorer nations"[tiab] OR "poorer population"[tiab] OR "poorer populations"[tiab] OR "poorer world"[tiab] OR "developing economy"[tiab] OR "developing economies"[tiab] OR "less developed economy"[tiab] OR "less developed economies"[tiab] OR "lesser developed economy"[tiab] OR "lesser developed economies"[tiab] OR "under developed economy"[tiab] OR "under developed economies"[tiab] OR "underdeveloped economy"[tiab] OR "underdeveloped economies"[tiab] OR "middle income economy"[tiab] OR "middle income economies"[tiab] OR "low income economy"[tiab] OR "low income economies"[tiab] OR "lower income economy"[tiab] OR "lower income economies"[tiab] OR "low gdp"[tiab] OR "low gnp"[tiab] OR "low gross domestic"[tiab] OR "low gross national"[tiab] OR "lower gdp"[tiab] OR "lower gnp"[tiab] OR "lower gross domestic"[tiab] OR "lower gross national"[tiab] OR lmic[tiab] OR lmics[tiab] OR "third world"[tiab] OR "lami country"[tiab] OR "lami countries"[tiab] OR "transitional country"[tiab] OR "transitional countries"[tiab] OR Africa[tiab] OR Asia[tiab] OR Caribbean[tiab] OR West Indies[tiab] OR South America[tiab] OR Latin America[tiab] OR Central America[tiab] OR "Atlantic Islands"[tiab] OR "Commonwealth of Independent States"[tiab] OR "Pacific Islands"[tiab] OR "Indian Ocean Islands"[tiab] OR "Eastern Europe"[tiab] OR Afghanistan[tiab] OR Albania[tiab] OR Algeria[tiab] OR Angola[tiab] OR Antigua[tiab] OR Barbuda[tiab] OR Argentina[tiab] OR Armenia[tiab] OR Armenian[tiab] OR Aruba[tiab] OR Azerbaijan[tiab] OR Bahrain[tiab] OR Bangladesh[tiab] OR Barbados[tiab] OR Benin[tiab] OR Byelarus[tiab] OR Byelorussian[tiab] OR Belarus[tiab] OR Belorussian[tiab] OR Belorussia[tiab] OR Belize[tiab] OR Bhutan[tiab] OR Bolivia[tiab] OR Bosnia[tiab] OR Herzegovina[tiab] OR Hercegovina[tiab] OR Botswana[tiab] OR Brasil[tiab] OR Brazil[tiab] OR Bulgaria[tiab] OR Burkina Faso[tiab] OR Burkina Fasso[tiab] OR Upper Volta[tiab] OR Burundi[tiab] OR Urundi[tiab] OR Cambodia[tiab] OR Khmer Republic[tiab] OR Kampuchea[tiab] OR Cameroon[tiab] OR Cameroons[tiab] OR Cameron[tiab] OR Cape Verde[tiab] OR Central African Republic[tiab] OR Chad[tiab] OR Chile[tiab] OR China[tiab] OR Colombia[tiab] OR Comoros[tiab] OR Comoro Islands[tiab] OR Comores[tiab] OR Mayotte[tiab] OR Congo[tiab] OR Zaire[tiab] OR Costa Rica[tiab] OR Cote d'Ivoire[tiab] OR Ivory Coast[tiab] OR Croatia[tiab] OR Cuba[tiab] OR Cyprus[tiab] OR Czechoslovakia[tiab] OR "Czech Republic" [tiab] OR Slovakia[tiab] OR Slovak Republic[tiab] OR Djibouti[tiab] OR French Somaliland[tiab] OR Dominica[tiab] OR Dominican Republic[tiab] OR East Timor[tiab] OR East Timur[tiab] OR Timor Leste[tiab] OR Ecuador[tiab] OR Egypt[tiab] OR United Arab Republic[tiab] OR El Salvador[tiab] OR Eritrea[tiab] OR Estonia[tiab] OR Ethiopia[tiab] OR Fiji[tiab] OR Gabon[tiab] OR Gabonese Republic[tiab] OR Gambia[tiab] OR Gaza[tiab] OR Georgia Republic[tiab] OR Georgian Republic[tiab] OR Ghana[tiab] OR Gold Coast[tiab] OR Greece[tiab] OR Grenada[tiab] OR Guatemala[tiab] OR Guinea[tiab] OR Guam[tiab] OR Guiana[tiab] OR Guyana[tiab] OR Haiti[tiab] OR Honduras[tiab] OR Hungary[tiab] OR India[tiab] OR Maldives[tiab] OR Indonesia[tiab] OR Iran[tiab] OR Iraq[tiab] OR Jamaica[tiab] OR Jordan[tiab] OR Kazakhstan[tiab] OR Kazakh[tiab] OR Kenya[tiab] OR Kiribati[tiab] OR Korea[tiab] OR Kosovo[tiab] OR Kyrgyzstan[tiab] OR Kirghizia[tiab] OR Kyrgyz Republic[tiab] OR Kirghiz[tiab] OR Kirgizstan[tiab] OR "Lao PDR"[tiab] OR Laos[tiab] OR Latvia[tiab] OR Lebanon[tiab] OR Lesotho[tiab] OR Basutoland[tiab] OR Liberia[tiab] OR Libya[tiab] OR Lithuania[tiab]OR Macedonia[tiab] OR Madagascar[tiab] OR Malagasy Republic[tiab] OR Malaysia[tiab] OR Malaya[tiab] OR Malay[tiab] OR Sabah[tiab] OR Sarawak[tiab] OR Malawi[tiab] OR Nyasaland[tiab] OR Mali[tiab] OR Malta[tiab] OR Marshall Islands[tiab] OR Mauritania[tiab] OR Mauritius[tiab] OR Agalega Islands[tiab] OR "Melanesia"[tiab] OR Mexico[tiab] OR Micronesia[tiab] OR Middle East[tiab] OR Moldova[tiab] OR Moldovia[tiab] OR Moldovian[tiab] OR Mongolia[tiab] OR Montenegro[tiab] OR Morocco[tiab] OR Ifni[tiab] OR Mozambique[tiab] OR Myanmar[tiab] OR Myanma[tiab] OR Burma[tiab] OR Namibia[tiab]

OR Nepal[tiab] OR Netherlands Antilles[tiab] OR New Caledonia[tiab] OR Nicaragua[tiab] OR Niger[tiab] OR Nigeria[tiab] OR Northern Mariana Islands[tiab] OR Oman[tiab] OR Muscat[tiab] OR Pakistan[tiab] OR Palau[tiab] OR Palestine[tiab] OR Panama[tiab] OR Paraguay[tiab] OR Peru[tiab] OR Philippines[tiab] OR Philipines[tiab] OR Phillipines[tiab] OR Phillippines[tiab] OR Poland[tiab] OR Portugal[tiab] OR Puerto Rico[tiab] OR Romania[tiab] OR Rumania[tiab] OR Roumania[tiab] OR Russia[tiab] OR Russian[tiab] OR Rwanda[tiab] OR Ruanda[tiab] OR Saint Kitts[tiab] OR St Kitts[tiab] OR Nevis[tiab] OR Saint Lucia[tiab] OR St Lucia[tiab] OR Saint Vincent[tiab] OR St Vincent[tiab] OR Grenadines[tiab] OR Samoa[tiab] OR Samoan Islands[tiab] OR Navigator Island[tiab] OR Navigator Islands[tiab] OR Sao Tome[tiab] OR Saudi Arabia[tiab] OR Senegal[tiab] OR Serbia[tiab] OR Montenegro[tiab] OR Seychelles[tiab] OR Sierra Leone[tiab] OR Slovenia[tiab] OR Sri Lanka[tiab] OR Ceylon[tiab] OR Solomon Islands[tiab] OR Somalia[tiab] OR Sudan[tiab] OR Suriname[tiab] OR Surinam[tiab] OR Swaziland[tiab] OR Syria[tiab] OR Syrian[tiab] OR Tajikistan[tiab] OR Tadzhikistan[tiab] OR Tadjikistan[tiab] OR Tadzhik[tiab] OR Tanzania[tiab] OR Thailand[tiab] OR Togo[tiab] OR Togolese Republic[tiab] OR Tonga[tiab] OR Trinidad[tiab] OR Tobago[tiab] OR Tunisia[tiab] OR Turkey[tiab] OR Turkmenistan[tiab] OR Turkmen[tiab] OR Tuvalu[tiab] OR Uganda[tiab] OR Ukraine[tiab] OR Uruguay[tiab] OR USSR[tiab] OR Soviet Union[tiab] OR Union of Soviet Socialist Republics[tiab] OR Uzbekistan[tiab] OR Uzbek OR Vanuatu[tiab] OR New Hebrides[tiab] OR Venezuela[tiab] OR Vietnam[tiab] OR Viet Nam[tiab] OR West Bank[tiab] OR Yemen[tiab] OR Yugoslavia[tiab] OR Zambia[tiab] OR Zimbabwe[tiab] OR Rhodesia[tiab] OR Developing Countries[Mesh] OR Africa[Mesh:NoExp] OR Africa, Northern[Mesh:NoExp] OR Africa South of the Sahara[Mesh:NoExp] OR Africa, Central[Mesh:NoExp] OR Africa, Eastern[Mesh:NoExp] OR Africa, Southern[Mesh:NoExp] OR Africa, Western[Mesh:NoExp] OR Asia[Mesh:NoExp] OR Asia, Central[Mesh:NoExp] OR Asia, Southeastern[Mesh:NoExp] OR Asia, Western[Mesh:NoExp] OR Caribbean Region[Mesh:NoExp] OR West Indies[Mesh:NoExp] OR South America[Mesh:NoExp] OR Latin America[Mesh:NoExp] OR Central America[Mesh:NoExp] OR "Atlantic Islands"[Mesh:NoExp] OR "Commonwealth of Independent States"[Mesh:NoExp] OR "Pacific Islands"[Mesh:NoExp] OR "Indian Ocean Islands"[Mesh:NoExp] OR "Europe, Eastern"[Mesh:NoExp] OR Afghanistan[Mesh] OR Albania[Mesh] OR Algeria[Mesh] OR American Samoa[Mesh] OR Angola[Mesh] OR "Antigua and Barbuda"[Mesh] OR Argentina[Mesh] OR Armenia[Mesh] OR Azerbaijan[Mesh] OR Bahrain[Mesh] OR "Baltic States"[Mesh] OR Bangladesh[Mesh] OR Barbados[Mesh] OR Benin[Mesh] OR "Republic of Belarus"[Mesh] OR Belize[Mesh] OR Bhutan[Mesh] OR Bolivia[Mesh] OR Bosnia-Herzegovina[Mesh] OR Botswana[Mesh] OR Brazil[Mesh] OR Bulgaria[Mesh] OR Burkina Faso[Mesh] OR Burundi[Mesh] OR Cambodia[Mesh] OR Cameroon[Mesh] OR Cape Verde[Mesh] OR Central African Republic[Mesh] OR Chad[Mesh] OR Chile[Mesh] OR China[Mesh] OR Colombia[Mesh] OR Comoros[Mesh] OR Congo[Mesh] OR Costa Rica[Mesh] OR Cote d'Ivoire[Mesh] OR Croatia[Mesh] OR Cuba[Mesh] OR Cyprus[Mesh] OR Czechoslovakia[Mesh] OR Czech Republic[Mesh] OR Slovakia[Mesh] OR Djibouti[Mesh] OR "Democratic Republic of the Congo"[Mesh] OR "Democratic People's Republic of Korea"[Mesh] OR Dominica[Mesh] OR Dominican Republic[Mesh] OR East Timor[Mesh] OR Ecuador[Mesh] OR Egypt[Mesh] OR El Salvador[Mesh] OR Eritrea[Mesh] OR Estonia[Mesh] OR Ethiopia[Mesh] OR "Equatorial Guinea"[Mesh] OR Fiji[Mesh] OR "French Guiana"[Mesh] OR Gabon[Mesh] OR Gambia[Mesh] OR "Georgia (Republic)"[Mesh] OR Ghana[Mesh] OR Greece[Mesh] OR Grenada[Mesh] OR Guatemala[Mesh] OR Guinea[Mesh] OR Guinea-Bissau[Mesh] OR Guam[Mesh] OR Guyana[Mesh] OR Haiti[Mesh] OR Honduras[Mesh] OR Hungary[Mesh] OR "Independent State of Samoa"[Mesh] OR India[Mesh] OR Indonesia[Mesh] OR Iran[Mesh] OR Iraq[Mesh] OR Jamaica[Mesh] OR Jordan[Mesh] OR Kazakhstan[Mesh] OR Kenya[Mesh] OR Korea[Mesh] OR Kyrgyzstan[Mesh] OR Laos[Mesh] OR Latvia[Mesh] OR Lebanon[Mesh] OR Lesotho[Mesh] OR Liberia[Mesh] OR Libya[Mesh] OR Lithuania[Mesh] OR "Macedonia (Republic)"[Mesh] OR Madagascar[Mesh] OR Malawi[Mesh] OR Malaysia[Mesh] OR Mali[Mesh] OR Malta[Mesh] OR Mauritania[Mesh] OR Mauritius[Mesh] OR "Melanesia"[Mesh] OR Mexico[Mesh] OR Micronesia[Mesh] OR Middle East[Mesh:NoExp] OR

Moldova[Mesh] OR Mongolia[Mesh] OR Montenegro[Mesh] OR Morocco[Mesh] OR Mozambique[Mesh] OR Myanmar[Mesh] OR Namibia[Mesh] OR Nepal[Mesh] OR Netherlands Antilles[Mesh] OR New Caledonia[Mesh] OR Nicaragua[Mesh] OR Niger[Mesh] OR Nigeria[Mesh] OR Oman[Mesh] OR Pakistan[Mesh] OR Palau[Mesh] OR Panama[Mesh] OR Papua New Guinea[Mesh] OR Paraguay[Mesh] OR Peru[Mesh] OR Philippines[Mesh] OR Poland[Mesh] OR Portugal[Mesh] OR Puerto Rico[Mesh] OR "Republic of Korea"[Mesh] OR Romania[Mesh] OR Russia[Mesh] OR "Russia (Pre-1917)"[Mesh] OR Rwanda[Mesh] OR "Saint Kitts and Nevis"[Mesh] OR Saint Lucia[Mesh] OR "Saint Vincent and the Grenadines"[Mesh] OR Samoa[Mesh] OR Saudi Arabia[Mesh] OR Senegal[Mesh] OR Serbia[Mesh] OR Montenegro[Mesh] OR Seychelles[Mesh] OR Sierra Leone[Mesh] OR Slovenia[Mesh] OR Sri Lanka[Mesh] OR Somalia[Mesh] OR South Africa[Mesh] OR Sudan[Mesh] OR Suriname[Mesh] OR Swaziland[Mesh] OR Syria[Mesh] OR Tajikistan[Mesh] OR Tanzania[Mesh] OR Thailand[Mesh] OR Togo[Mesh] OR Tonga[Mesh] OR "Trinidad and Tobago"[Mesh] OR Tunisia[Mesh] OR Turkey[Mesh] OR Turkmenistan[Mesh] OR Uganda[Mesh] OR Ukraine[Mesh] OR Uruguay[Mesh] OR USSR[Mesh] OR Uzbekistan[Mesh] OR Vanuatu[Mesh] OR Venezuela[Mesh] OR Vietnam[Mesh] OR Yemen[Mesh] OR Yugoslavia[Mesh] OR Zambia[Mesh] OR Zimbabwe[Mesh] OR "Southern African Development Community"[all fields] OR "East African Community"[all fields] OR "West African Health Organisation"[all fields] OR "Sub Saharan Africa "[all fields] OR "SubSaharan Africa "[all fields])

Global Health Search terms:

trauma severity indices OR trauma severity indices OR injury severity measures OR trauma scores OR trauma score OR injury scales OR injury severity scores OR anatomic profile OR injury severity classification OR ISS OR NISS OR ASCOT OR RISC OR MGAP OR probability of death score OR TRISS OR trauma index OR trauma indices OR CRAMS OR anatomic index OR injury severity score OR rapid emergency medicine score OR acute physiology and chronic health evaluation OR APACHE

(emerging country OR emerging countries OR emerging nation OR emerging nations OR emerging population OR emerging populations developing country OR developing countries OR developing nation OR developing nations OR developing population OR developing populations OR developing world OR less developed country OR less developed countries OR less developed nation OR less developed nations OR less developed population OR less developed populations OR less developed world OR lesser developed country OR lesser developed countries OR lesser developed nation OR lesser developed nations OR lesser developed population OR lesser developed populations OR lesser developed world OR under developed country OR under developed countries OR under developed nation OR under developed nations OR under developed population OR under developed populations OR under developed world OR underdeveloped country OR underdeveloped countries OR underdeveloped nation OR underdeveloped nations OR underdeveloped population OR underdeveloped populations OR underdeveloped world OR middle income country OR middle income countries OR middle income nation OR middle income nations OR middle income population OR middle income populations OR low income country OR low income countries OR low income nation OR low income nations OR low income population OR low income populations OR lower income country OR lower income countries OR lower income nation OR lower income nations OR lower income population OR lower income populations OR underserved country OR underserved countries OR underserved nation OR underserved nations OR (underserved population OR underserved populations OR underserved world OR under served country OR under served countries OR under served nation OR under served nations OR under served population OR under served populations OR under served world OR deprived country OR deprived countries OR deprived nation OR deprived nations OR deprived population OR deprived populations OR deprived world OR poor country OR poor countries OR poor nation OR poor nations OR poor population OR poor populations OR poor world OR poorer country OR poorer countries OR poorer nation OR poorer nations OR poorer population OR poorer populations OR poorer world OR developing economy OR developing economies OR less developed economy OR less developed economies OR lesser developed economy OR lesser developed economies OR under developed economy OR under developed economies OR underdeveloped economy OR underdeveloped economies OR middle income economy OR middle income economies OR low income economy OR low income economies OR lower income economy OR lower income economies OR low gdp OR low gnp OR low gross domestic OR low gross national OR lower gdp OR lower gnp OR lower gross domestic OR lower gross national OR lmic OR lmics OR third world OR lami country OR lami countries OR transitional country OR transitional countries OR Africa OR Asia OR Caribbean OR West Indies OR South America OR Latin America OR Central America OR Atlantic Islands OR Pacific Islands OR Indian Ocean Islands OR Eastern Europe OR Afghanistan OR Albania OR Algeria OR Angola OR Antigua OR Barbuda OR Argentina OR Armenia OR Armenian OR Aruba OR Azerbaijan OR Bahrain OR Bangladesh OR Barbados OR Benin OR Byelarus OR Byelorussian OR Belarus

OR Belorussian OR Belorussia OR Belize OR Bhutan OR Bolivia OR Bosnia OR Herzegovina OR Hercegovina OR Botswana OR Brasil OR Brazil OR Bulgaria OR Burkina Faso OR Burkina Fasso OR Upper Volta OR Burundi OR Urundi OR Cambodia OR Khmer Republic OR Kampuchea OR Cameroon OR Cameroons OR Cameron OR Camerons OR Cape Verde OR Central African Republic OR Chad OR Chile OR China OR Colombia OR Comoros OR Comoro Islands OR Comores OR Mayotte OR Congo OR Zaire OR Costa Rica OR Cote d'Ivoire OR Ivory Coast OR Croatia OR Cuba OR Cyprus OR Czechoslovakia OR Czech Republic OR Slovakia OR Slovak Republic OR Djibouti OR French Somaliland OR Dominica OR Dominican Republic OR East Timor OR East Timur OR Timor Leste OR Ecuador OR Egypt OR United Arab Republic OR El Salvador OR Eritrea OR Estonia OR Ethiopia OR Fiji OR Gabon OR Gabonese Republic OR Gambia OR Gaza OR Georgia Republic OR Georgian Republic OR Ghana OR Gold Coast OR Greece OR Grenada OR Guatemala OR Guinea OR Guam OR Guiana OR Guyana OR Haiti OR Honduras OR Hungary OR India OR Maldives OR Indonesia OR Iran OR Iraq OR Jamaica OR Jordan OR Kazakhstan OR Kazakh OR Kenya OR Kiribati OR Korea OR Kosovo OR Kyrgyzstan OR Kirghizia) OR (Kyrgyz Republic OR Kirghiz OR Kirgizstan OR Lao PDR OR Laos OR Latvia OR Lebanon OR Lesotho OR Basutoland OR Liberia OR Libya OR LithuaniaOR Macedonia OR Madagascar OR Malagasy Republic OR Malaysia OR Malaya OR Malay OR Sabah OR Sarawak OR Malawi OR Nyasaland OR Mali OR Malta OR Marshall Islands OR Mauritania OR Mauritius OR Agalega Islands OR Melanesia OR Mexico OR Micronesia OR Middle East OR Moldova OR Moldovia OR Moldovian OR Mongolia OR Montenegro OR Morocco OR Ifni OR Mozambique OR Myanmar OR Myanma OR Burma OR Namibia OR Nepal OR Netherlands Antilles OR New Caledonia OR Nicaragua OR Niger OR Nigeria OR Northern Mariana Islands OR Oman OR Muscat OR Pakistan OR Palau OR Palestine OR Panama OR Paraguay OR Peru OR Philippines OR Philipines OR Phillipines OR Phillippines OR Poland OR Portugal OR Puerto Rico OR Romania OR Rumania OR Roumania OR Russia OR Russian OR Rwanda OR Ruanda OR Saint Kitts OR St Kitts OR Nevis OR Saint Lucia OR St Lucia OR Saint Vincent OR St Vincent OR Grenadines OR Samoa OR Samoan Islands OR Navigator Island OR Navigator Islands OR Sao Tome OR Saudi Arabia OR Senegal OR Serbia OR Montenegro OR Seychelles OR Sierra Leone OR Slovenia OR Sri Lanka OR Ceylon OR Solomon Islands OR Somalia OR Sudan OR Suriname OR Surinam OR Swaziland OR Syria OR Syrian OR Tajikistan OR Tadzhikistan OR Tadjikistan OR Tadzhik OR Tanzania OR Thailand OR Togo OR Togolese Republic OR Tonga OR Trinidad OR Tobago OR Tunisia OR Turkey OR Turkmenistan OR Turkmen OR Tuvalu OR Uganda OR Ukraine OR Uruguay OR USSR OR Soviet Union OR Soviet Socialist Republics OR Uzbekistan OR Uzbek OR Vanuatu OR New Hebrides OR Venezuela OR Vietnam OR Viet Nam OR West Bank OR Yemen OR Yugoslavia OR Zambia OR Zimbabwe OR Rhodesia OR Developing Countries OR Africa OR Asia OR Caribbean Region OR West Indies OR South America OR Latin America OR Central America OR Atlantic Islands OR Pacific Islands OR Indian Ocean Islands OR Europe, Eastern OR Afghanistan OR Albania OR Algeria OR American Samoa OR Angola OR Antigua and Barbuda OR Argentina OR Armenia OR Azerbaijan OR Bahrain OR Baltic States OR Bangladesh OR Barbados OR Benin OR Belarus OR Belize OR Bhutan OR Bolivia OR Bosnia-Herzegovina OR Botswana OR Brazil OR Bulgaria OR Burkina Faso OR Burundi OR Cambodia OR Cameroon OR Cape Verde OR Central African Republic OR Chad OR Chile OR China OR Colombia OR Comoros OR Congo OR Costa Rica OR Cote d'Ivoire OR Croatia OR Cuba OR Cyprus OR Czechoslovakia OR Czech Republic OR Slovakia OR Djibouti OR Congo OR Korea OR Dominica OR Dominican Republic OR East Timor OR Ecuador OR Egypt OR El Salvador OR Eritrea OR Estonia OR Ethiopia OR Equatorial Guinea OR Fiji OR French Guiana OR Gabon OR Gambia OR Georgia OR Ghana OR Greece OR Grenada OR Guatemala OR Guinea OR Guinea-Bissau OR Guam OR Guyana OR Haiti OR Honduras OR Hungary OR Samoa OR India OR Indonesia OR Iran OR Iraq OR Jamaica OR Jordan OR Kazakhstan OR Kenya OR Korea OR Kyrgyzstan

OR Laos OR Latvia OR Lebanon OR Lesotho OR Liberia OR Libya OR Lithuania OR Macedonia OR Madagascar OR Malawi OR Malaysia OR Mali OR Malta OR Mauritania OR Mauritius OR Melanesia OR Mexico OR Micronesia OR Middle East OR Moldova OR Mongolia OR Montenegro OR Morocco OR Mozambique OR Myanmar OR Namibia OR Nepal OR Netherlands Antilles OR New Caledonia OR Nicaragua OR Niger OR Nigeria OR Oman OR Pakistan OR Palau OR Panama OR Papua New Guinea OR Paraguay OR Peru OR Philippines OR Poland OR Portugal OR Puerto Rico OR Romania OR Russia OR Russia OR Rwanda OR Saint Kitts and Nevis OR Saint Lucia OR Grenadines OR Samoa OR Saudi Arabia OR Senegal OR Serbia OR Montenegro OR Seychelles OR Sierra Leone OR Slovenia OR Sri Lanka OR Somalia OR South Africa OR Sudan OR Suriname OR Swaziland OR Syria OR Tajikistan OR Tanzania OR Thailand OR Togo OR Tonga OR Trinidad and Tobago OR Tunisia OR Turkey OR Turkmenistan OR Uganda OR Ukraine OR Uruguay OR USSR OR Uzbekistan OR Vanuatu OR Venezuela OR Vietnam OR Yemen OR Yugoslavia OR Zambia OR Zimbabwe OR Southern African Development Community OR East African Community OR West African Health Organisation)

EMBASE Search Terms

'Trauma Severity Indices':ab,ti OR 'Trauma Severity Indices/utilization':ab,ti OR
'Injury severity measures':ab,ti OR 'Trauma Scores':ab,ti OR 'Trauma Score':ab,ti OR 'Injury Scales':ab,ti OR
'injury severity scores':ab,ti OR 'Anatomic Profile':ab,ti OR 'injury severity classification':ab,ti OR 'ISS':ab,ti
OR 'NISS':ab,ti OR 'ASCOT':ab,ti OR 'RISC':ab,ti OR 'MGAP':ab,ti OR 'Probability of Death score':ab,ti OR
'TRISS':ab,ti OR 'Trauma index':ab,ti OR 'Trauma indices':ab,ti OR 'CRAMS':ab,ti OR 'Circulation,
Respiration, Abdomen, Motor, and Speech':ab,ti OR 'Anatomic Index':ab,ti OR 'Anatomic Indices':ab,ti OR
'Injury severity score':ab,ti OR 'Rapid Emergency Medicine score':ab,ti OR 'Acute Physiology and Chronic
Health Evaluation':ab,ti OR 'APACHE':ab,ti

Low and Middle Income Terms – Adapted from Norwegian Cochran Centers Developing Country filter
and Johns Hopkins filters. (Both filters based on World Bank LMIC country classification).

'developing country':ab,ti OR 'developing countries':ab,ti OR 'developing nation':ab,ti OR 'developing nations':ab,ti

OR 'developing population':ab,ti OR 'developing populations':ab,ti OR 'developing world':ab,ti OR 'less developed

country':ab,ti OR 'less developed countries':ab,ti OR 'less developed nation':ab,ti OR 'less developed nations':ab,ti

OR 'less developed population':ab,ti OR 'less developed populations':ab,ti OR 'less developed world':ab,ti OR

'lesser developed country':ab,ti OR 'lesser developed countries':ab,ti OR 'lesser developed nation':ab,ti OR 'lesser

developed nations':ab,ti OR 'lesser developed population':ab,ti OR 'lesser developed populations':ab,ti OR 'lesser

developed world':ab,ti OR 'under developed country':ab,ti OR 'under developed countries':ab,ti OR 'under

developed nation':ab,ti OR 'under developed nations':ab,ti OR 'under developed population':ab,ti OR 'under

developed populations':ab,ti OR 'under developed world':ab,ti OR 'underdeveloped country':ab,ti OR

'underdeveloped countries':ab,ti OR 'underdeveloped nation':ab,ti OR 'underdeveloped nations':ab,ti OR

'underdeveloped population':ab,ti OR 'underdeveloped populations':ab,ti OR 'underdeveloped world':ab,ti OR

'middle income country':ab,ti OR 'middle income countries':ab,ti OR 'middle income nation':ab,ti OR 'middle

income nations':ab,ti OR 'middle income population':ab,ti OR 'middle income populations':ab,ti OR 'low income

country':ab,ti OR 'low income countries':ab,ti OR 'low income nation':ab,ti OR 'low income nations':ab,ti OR 'low

income population':ab,ti OR 'low income populations':ab,ti OR 'lower income country':ab,ti OR 'lower income

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Gabon/exp OR Gambia/exp OR 'Georgia (Republic) '/exp OR Ghana/exp OR Greece/exp OR Grenada/exp OR Guatemala/exp OR Guinea/exp OR Guinea-Bissau/exp OR Guam/exp OR Guyana/exp OR Haiti/exp OR Honduras/exp OR Hungary/exp OR India/exp OR Indonesia/exp OR Iran/exp OR Iraq/exp OR Jamaica/exp OR Jordan/exp OR Kazakhstan/exp OR Kenya/exp OR Korea/exp OR Kyrgyzstan/exp OR Laos/exp OR Latvia/exp OR Lebanon/exp OR Lesotho/exp OR Liberia/exp OR 'Libyan Arab Jamahiriya'/exp OR Lithuania/exp OR 'Macedonia (republic)'/exp OR Madagascar/exp OR Malaysia/exp OR Malawi/exp OR Mali/exp OR Malta/exp OR Mauritania/exp OR Mauritius/exp OR "Melanesia"/exp OR Mexico/exp OR 'Federated States of Micronesia'/exp OR 'Middle East'/de OR Moldova/exp OR Mongolia/exp OR Montenegro/exp OR Morocco/exp OR Mozambique/exp OR Myanmar/exp OR Namibia/exp OR Nepal/exp OR 'Netherlands Antilles'/exp OR 'New Caledonia'/exp OR Nicaragua/exp OR Niger/exp OR Nigeria/exp OR 'North Korea'/exp OR Oman/exp OR Pakistan/exp OR Palau/exp OR Panama/exp OR 'Papua New Guinea'/exp OR Paraguay/exp OR Peru/exp OR Philippines/exp OR Poland/exp OR Portugal/exp OR 'Puerto Rico'/exp OR Romania/exp OR 'Russian Federation'/exp OR Rwanda/exp OR 'Saint Kitts and Nevis'/exp OR 'Saint Lucia'/exp OR 'Saint Vincent and the Grenadines'/exp OR 'Samoan Islands'/exp OR Samoa/exp OR 'Saudi Arabia'/exp OR Senegal/exp OR Serbia/exp OR 'Montenegro (republic)'/exp OR Seychelles/exp OR 'Sierra Leone'/exp OR Slovenia/exp OR 'Sri Lanka'/exp OR Somalia/exp OR 'South Korea'/exp OR 'South Africa'/exp OR Sudan/exp OR Suriname/exp OR Swaziland/exp OR 'Syrian Arab Republic'/exp OR Tajikistan/exp OR Tanzania/exp OR Thailand/exp OR Togo/exp OR Tonga/exp OR 'Trinidad and Tobago'/exp OR Tunisia/exp OR 'Turkey (republic)'/exp OR Turkmenistan/exp OR Uganda/exp OR Ukraine/exp OR Uruguay/exp OR USSR/exp OR Uzbekistan/exp OR Vanuatu/exp OR Venezuela/exp OR 'Viet Nam'/exp OR Yemen/exp OR Yugoslavia/exp OR 'Yugoslavia (pre-1992)'/exp OR Zambia/exp OR Zimbabwe/exp

Supplemental file 2: Validations studies describing performance of Injury severity measures to predict mortality

Injury severity measure	Country	Year	Number of hospital	Specific injury mechanism	Study population	Age included	Sample size	% mortality	Missing data %	Performance		Calibration	
										AUROC	95% CI	H-L	p-value
APACHE II	Turkey[1]	2011	1	All injuries	Injury patients admitted to ICU in a tertiary referral hospital	>=15	100	14%	NR*	0.92	NA‡	NA	NA
	Thailand[2]	2012	1	All injuries	Injury patients admitted to surgical ICU, neurosurgical ICU or burn unit in a tertiary referral hospital	Adult (not specified)	132	20%	NR	0.89	NA	NA	NA
	Iran[3]	2012	1	Head injuries	Head injury associated with systemic trauma admitted to neurosurgical ICU	>=14	93	19.5%	NR	0.892	NA	NA	NA
	Morocco[4]	2014	1	Moderate and severe traumatic brain injuries	Injury patients admitted to medical and surgical ICU due to TBI	>=16	225	40.0%	7.6%	0.92	(0.837-0.982)	NA	NA

	Country	Year		Injury type	Population	ISS	N	%	%	AUC	CI		
	Brazil[5]	2014	1	All injuries	Injury patients admitted for more than 24 hours in ER or ICU at a regional reference hospital	>12	163	10.4%	15.5%	0.777	(0.705-0.838)	NA	NA
	China[6]	2014	1	All injuries	Emergency ICU patients arrived within 24 h of injury, with ISS >16 in a university hospital	>18	81	30.9%	NR	Day 1: 0.926; day 3: 0.967; day 7: 0.936	NA	NA	NA
APACHE III	Iran[7]	2016	2	Multiple injuries from road traffic injuries	Injury patients admitted to ICU and survived for at least 4 hours upon arrival in ICU in two hospitals	>14	152	31.6%	NR	0.797	(0.652-0.901)	NA	NA
EISS	China[8]	2014	2	Moderate and severe injuries	Injury patients admitted to two tertiary hospitals	>=15	8040	6.2%	Excluded from analysis	Zhejiang: 0.949; Liaoning: 0.942	Zhejiang: (0.937-0.961); Liaoning: (0.930-0.955)	Zhejiang: 13.52; Liaoning: 15.55	Zhejiang: 0.0604; Liaoning: 0.0164

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GAP	India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.85	(0.80-0.90)	NA	NA
	Turkey[10]	2006	1	Falls	Injury pediatric patients due to specified mechanism admitted to ER in a university hospital	<14	749	3.6%	1.74%	0.975	(0.961-0.985)	NA	NA
GCS	Indonesia[11]	2009	1	Traumatic brain injury with severe or multi-trauma	Injury patients of specified mechanism with severe or multi-trauma to the university hospital (level 2 trauma center)	>=12	48	37.0%	Excluded from analysis	0.756	NA	NA	NA

Brazil[12]	2011	1	Blunt traumatic brain injury	Injury patients of specified mechanism hospitalized at a trauma referral center	>14	277	19.1%	NR	First care: 0.747; best score: 0.791; worst score: 0.782	First care: (0.675-0.819); best score: (0.735-0.848); worst score: (0.724-0.839)	NA	NA
Iran[3]	2012	1	Head injuries	Head injury associated with systemic trauma admitted to neurosurgical ICU	>=14	93	19.5%	NR	0.621	NA	NA	NA
Morocco[4]	2014	1	Moderate and severe traumatic brain injuries	Injury patients admitted to medical and surgical ICU due to TBI	>=16	225	40.0%	7.6%	0.862	(0.823-0.893)	NA	NA
Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7525; severe injuries: 0.9658	All injuries: (0.6184-0.8866); severe injuries: (0.9301-1.000)	NA	NA

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	Country	Year		Mechanism	Description	Age	N						
	Turkey[10]	2006	1	Falls	Injury pediatric patients due to specified mechanism admitted to ER in a university hospital	<14	749	3.6%	1.74%	0.962	(0.945-0.974)	NA	0.37
	Iran[14]	2007	3	All injuries	Injury patients admitted to the hospitals	All	4096	6%	NR	>0.93	NA	NA	NA
ISS	Lebanon[15]	2008	1	All injuries	Injury patients admitted in a major tertiary care referral hospital	All	891	3.6%	NR	0.881	(0.816-0.945)	2.97	0.70
	China[16]	2008	1	All injuries	Patients with multiple injuries admitted to Emergency ICU in a university hospital	>=16	2110	NR	NR	0.943	(0.922-0.949)	6.25	Compared with NISS: 0.052
	Turkey[17]	2009	1	Firearm injury	Firearm Injury patients admitted to ER in a level-1 trauma center	All	135	12.6%	NR	0.964	NA	1.908	0.965

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Country	Year				Age	N	%					
Brazil[18]	2009	1	All injuries	Injury patients hospitalized at ICU for >24 hours and within 48 hours in a university hospital	>=18	185	21.1%	NR	0.63	(0.52-0.72)	NA	0.636
Turkey[1]	2011	1	All injuries	Injury patients admitted to ICU in a tertiary referral hospital	>=15	100	14%	NR	0.878	NA	NA	NA
China[6]	2014	1	All injuries	Emergency ICU patients arrived within 24 h of injury, with ISS >16 in a university hospital	>18	81	30.9%	NR	0.804	NA	NA	NA
Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7183; severe injuries: 0.7521	All injuries: (0.5491-0.8885); Severe injuries: (0.4925-1.000)	NA	NA

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Country	Year		Mechanism	Inclusion criteria	Age	N	%	%	AUC	CI		
Pakistan[19]	2015	1	Abdominal gunshot injury	Injury patients admitted to a university hospital with the specified mechanism	>=16	70	15.7%	Excluded from analysis	0.952	(0.902-1.000)	NA	NA
India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.69	(0.62-0.76)	NA	NA
Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7784; severe injuries: 0.9820	All injuries: (0.6285-0.9212), severe injuries: (0.9585-1.000)	NA	NA
India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.86	(0.81-0.91)	NA	NA
Malawi[20]	2015	1	All injuries	Injury patients treated in a tertiary care referral hospital	Adults (not specified)	All: 15617; admitted:2811	5%	Excluded from analysis	All patients: 0.6904; admitted patients: 0.5929;	NA	NA	NA

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MGAP	India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.84	(0.79-0.89)	NA	NA
LISS	China[21]	2012	3	Major injuries	Patients with major injury (AIS>3 in a single body region) admitted in tertiary hospitals	>=15	12238 (3,784, 4,436, and 4,018 patients)	5.9%	NR	Hangzhou: 0.949; Zhejiang: 0.935; Shenyang: 0.936	Hangzhou: (0.938-0.959); Zhejiang: (0.921-0.953); Shenyang: (0.921-0.953)	Hangzhou: 13.79; Zhejiang: 18.43; Shenyang: 17.45	Hangzhou: 0.055; Zhejiang: 0.005; Shenyang: 0.008
LODS	Brazil[18]	2009	1	All injuries	Injury patients hospitalized at ICU for >24 hours and within 48 hours in a university hospital	>=18	185	21.1%	NR	0.83	(0.72-0.89)	NA	0.0596
NISS	China[16]	2008	1	All injuries	Patients with multiple injuries admitted to Emergency ICU in a university hospital	>=16	2110	NR	NR	0.938	(0.922-0.949)	7.36	Compared with ISS: 0.052

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Turkey[17]	2009	1	Firearm injury	Firearm Injury patients admitted to ER in a level-1 trauma center university hospital	All	135	12.6%	NR	0.98	NA	1.4	0.994
Brazil[18]	2009	1	All injuries	Injury patients hospitalized at ICU for >24 hours and within 48 hours in a university hospital	>=18	185	21.1%	NR	0.58	(0.47-0.67)	NA	0.1683
China[21]	2012	3	Major injuries	Patients with major injury (AIS>3 in a single body region) admitted in tertiary hospitals	>=15	12238 (3,784, 4,436, and 4,018 patients)	5.9%	NR	Hangzhou: 0.931; Zhejiang: 0.911; Shenyang: 0.918	Hangzhou: (0.918-0.944); Zhejiang: (0.890-0.931); Shenyang: (0.904-0.932)	Hangzhou: 15.76; Zhejiang: 22.70; Shenyang: 28.97	Hangzhou: 0.027; Zhejiang: 0.001; Shenyang: <0.001
China[22]	2015	2	Serious injury (exclude isolated minor or moderate injuries to a single body region)	Injury patients except those with minor injury, admitted to two level-3 first-class hospitals	>18	8079	6%	NR	Hangzhou: 0.929; Shenyang: 0.924	Hangzhou: (0.916-0.943); Shenyang: (0.910-0.938)	Hangzhou: 29.71; Shenyang: 33.49	Hangzhou: <0.001; Shenyang: <0.001

RAPS	Brazil[5]	2014	1	All injuries	Injury patients admitted for > 24 hours in ER or ICU at regional reference hospital	>12	163	10.4%	15.5%	0.806	(0.737-0.864)	NA	NA
REMS	Brazil[5]	2014	1	All injuries	Injury patients admitted for more than 24 hours in ER or ICU at a regional reference hospital	>12	163	10.4%	15.5%	0.761	(0.688-0.824)	NA	NA
RTS	Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7341; severe injuries: 0.9674	All injuries: (0.5896-0.8786); severe injuries: (0.9330-1.000)	NA	NA
	India[9]	2015	1	life- or limb-threatening injuries	Severely injured presented at the urban Level I trauma center	All	1117	32%	27%	0.85	(0.80-0.90)	NA	NA

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	Country	Year		Injury type	Setting	Age	Sample	Mortality %	Excluded	AUC	CI		
	Malawi[20]	2015	1	All injuries	Injury patients treated in a tertiary care referral hospital	Adults (age not specified)	All: 15617; admitted:2811	5%	Excluded from analysis	All patients: 0.6703; admitted patients: 0.6371	NA	NA	NA
SAPS II	Brazil[18]	2009	1	All injuries	Injury patients hospitalized at ICU >24 hours and <48 hours in a university hospital	>=18	185	21.1%	NR	0.85	(0.76-0.91)	NA	0.887
	Morocco[4]	2014	1	Moderate and severe traumatic brain injuries	Injury patients admitted to medical and surgical ICU due to TBI	>=16	225	40.0%	7.6%	0.843	(0.795-0.898)	NA	NA
s-APACHE II	Brazil[5]	2014	1	All injuries	Injury patients admitted for more than 24 hours in ER or ICU at a regional reference hospital	>12	163	10.4%	15.5%	0.788	(0.717-0.848)	NA	NA

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TISS	China[22]	2015	2	Serious injury (exclude isolated minor or moderate injuries to a single body region)	Injury patients except those with minor injury, admitted to two level-3 first-class hospitals	>18	8079	6%	NR	Hangzhou: 0.949; Shenyang: 0.942	Hangzhou: (0.939-0.959); Shenyang: (0.931-0.954)	Hangzhou: 19.59; Shenyang: 21.19	Hangzhou: 0.003; Shenyang: 0.002
	Indonesia[11]	2009	1	Traumatic brain injury with severe or multi-trauma	Injury patients of specified mechanism with severe or multi-trauma to the university hospital (level 2 trauma center)	>=12	48	37.0%	Excluded from analysis	0.796	NA	NA	NA
TRISS	Trinidad[23]	2009	3	All injuries	Injury patients admitted in the three tertiary care teaching hospitals	All	326	4.30%	NR	0.82	(0.69-0.96)	NA	NA
	Turkey[1]	2011	1	All injuries	Injury patients admitted to ICU in a tertiary referral hospital	>=15	100	14%	NR	0.926	NA	NA	NA

Country	Year		Injury type	Population	Age	N						
Brazil[24]	2011	1	All injuries	Injury patients admitted to ER at the level I trauma center	>=18	533	24.1%	2.8%	TRISS: 0.9; NTRISS: 0.92	NA	0.0000 for the TRISS; 0.0002 for NTRISS.	0.0012
Thailand[25]	2012	1	Blunt injuries	Injury patients registered in the Regional Hospital	All	6411	4.1%	Excluded from analysis	Modified version 1: 0.9619, version 2: 0.9601, version 3: 0.9115	NA	NA	NA
Thailand[2]	2012	1	All injuries	Injury patients admitted to surgical ICU, neurosurgical ICU or burn unit in tertiary referral hospital	Adult (not specified)	132	20%	NR	0.83	NA	NA	NA
China[6]	2014	1	All injuries	Emergency ICU patients arrived within 24 h of injury, with ISS >16 in a university hospital	>18	81	30.9%	NR	0.974	NA	NA	NA

Country	Year		Injury type	Setting	Age	Sample size						
Cameroon[13]	2014	1	All injuries (separate analysis for severe injuries)	Injury patients admitted to ER at the teaching and referral hospital	All	All injuries: 2855; severe injuries: 244	0.6%	13.4%	All injuries: 0.7117; severe injuries: 0.9386	All injuries: (0.5346-0.8888); severe injuries: (0.8566-1.000)	6.17	0.62
Iran[7]	2016	2	Multiple injuries from road traffic injuries	Injury patients admitted to ICU and survived for at least 4 hours upon arrival in ICU in two hospitals	>14	152	31.6%	NR	0.806	(0.663-0.908)	NA	NA

*Not reported; ‡Not applicable

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References

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Reporting Checklist for Meta-analyses of Observational Studies (MOOSE)

Performance of injury severity measures in trauma research:
a literature review and validation analysis of studies from Low- and Middle-Income Countries

	Reported	MS page	Art. page
Reporting of background should include:			
Problem definition	Yes	6	
Hypothesis statement	NA		
Description of study outcome(s)	Yes	6	
Type of exposure or intervention used	Yes	7	
Type of study designs used	Yes	7	
Study population	Yes	6, 7	
Reporting of search strategy should include:			
Qualifications of searchers (eg, librarians and investigators)	Yes	8	
Search strategy, including time period included in the synthesis and keywords	Yes	7	
Effort to include all available studies, including contact with authors	No		
Databases and registries searched	No		
Search software used, name and version, including special features used (eg, explosion)	No		
Use of hand searching (eg, reference lists of obtained articles)	Yes	6, 7	
List of citations located and those excluded, including justification	Yes	6, 7	
Method of addressing articles published in languages other than English	Yes	6	
Method of handling abstracts and unpublished studies	Yes	7, 8	
Description of any contact with authors	No		
Reporting of methods should include:			
Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	Yes	8	
Rationale for the selection and coding of data (eg, sound clinical principles or convenience)	Yes	8	
Documentation of how data were classified and coded (eg, multiple raters, blinding, and interrater reliability)	Yes	7, 8	
Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)	No		
Assessment of study quality, including blinding of quality assessors; stratification or regression on possible predictors of study results	NA		
Assessment of heterogeneity	NA		
Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	Yes	8,9	
Provision of appropriate tables and graphics	Yes	9, 13, Suppl F 2	
Reporting of results should include:			
Graphic summarizing individual study estimates and overall estimate	No		
Table giving descriptive information for each study included	Yes	Suppl F 2	
Results of sensitivity testing (eg, subgroup analysis)	Yes	15, 16	
Indication of statistical uncertainty of findings	Yes	15, 16	
Reporting of discussion should include:			
Quantitative assessment of bias (eg, publication bias)	No		
Justification of exclusion (eg, exclusion of non-English-language citations)	Yes	19	
Assessment of quality of included studies	Yes	18	
Reporting of conclusions should include:			
Consideration of alternative explanations for observed results	Yes	19	
Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	Yes	19	

Guidelines for future research	Yes	19	
Disclosure of funding source	NA		

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