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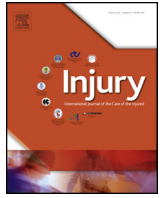
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Choice of injury scoring system in low- and middle-income countries: Lessons from Mumbai

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A B S T R A C T

Introduction: Injury is a major cause of morbidity and mortality in low- and middle-income countries. Effective trauma surveillance is imperative to guide research and quality improvement interventions, so an accurate metric for quantifying injury severity is crucial. The objectives of this study are (1) to assess the feasibility of calculating five injury scoring systems – ISS (injury severity score), RTS (revised trauma score), KTS (Kampala trauma score), MGAP (mechanism, GCS (Glasgow coma score), age, pressure) and GAP (GCS, age, pressure) – with data from a trauma registry in a lower middle-income country and (2) to determine which of these scoring systems most accurately predicts in-hospital mortality in this setting.
Patients and methods: This is a retrospective analysis of data from an institutional trauma registry in Mumbai, India. Values for each score were calculated when sufficient data were available. Logistic regression was used to compare the correlation between each score and in-hospital mortality.
Results: There were sufficient data recorded to calculate ISS in 73% of patients, RTS in 35%, KTS in 35%, MGAP in 88% and GAP in 92%. ISS was the weakest predictor of in-hospital mortality, while RTS, KTS, MGAP and GAP scores all correlated well with in-hospital mortality (area under ROC (receiver operating characteristic) curve 0.69 for ISS, 0.85 for RTS, 0.86 for KTS, 0.84 for MGAP, 0.85 for GAP). Respiratory rate measurements, missing in 63% of patients, were a major barrier to calculating RTS and KTS.
Conclusions: Given the realities of medical practice in low- and middle-income countries, it is reasonable to modify the approach to characterising injury severity to favour simplified injury scoring systems that accurately predict in-hospital mortality despite limitations in trauma registry datasets.

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Introduction

Injury accounts for at least 10% of the global burden of disease, with 5.8 million deaths due to injury annually [1]. In India, it is estimated that 10% of deaths and 13% of disability-adjusted life years lost are due to injury, which is likely lower than the true burden of injury [2]. As in other low- and middle-income countries, major challenges to trauma care include inadequate manpower, limited physical and financial resources and uncoordinated healthcare systems [3,4]. Effective trauma surveillance is imperative to guide further research and quality improvement interventions, and trauma registries are critical research tools to describe the true burden of injury [5–7]. The World Health Organization and the International Association for Trauma Surgery

and Intensive Care recognize trauma registries as an essential aspect of trauma care [8].

One key component of a trauma registry is a metric for quantifying the severity of injuries and predicting the probability of in-hospital mortality. This is essential for assessing the burden of trauma and the quality of care that is being provided, which can inform quality improvement and advocacy strategies [9]. Multiple injury scoring systems are used in low- and middle-income countries [10]. The most common is the Injury Severity Score (ISS), an anatomic score that incorporates multiple Abbreviated Injury Scores (AIS), which reflect the severity of injuries to different body regions [11]. A popular alternative is the Revised Trauma Score (RTS), a physiologic score that reflects a patient's systemic response to injury measured through Glasgow Coma Score (GCS), systolic blood pressure and respiratory rate [12]. It is the current standard physiologic scoring system used in trauma research and quality improvement in both high-income countries and low- and middle-income countries [13]. The Kampala Trauma Score (KTS) is a simplified injury scoring system that reflects patient age, systolic blood pressure, respiratory rate, neurologic status and number of serious injuries, which was developed in Uganda specifically for use in resource-limited settings [14].

The MGAP score and the GAP score are two novel, simplified scoring systems that are not yet widely used in low- and middle-income countries. The acronym MGAP stands for "mechanism (of injury), GCS, age, (systolic blood) pressure," and the MGAP score differs from RTS by including patient age and injury mechanism but excluding respiratory rate. The MGAP score was initially developed and validated in France as a pre-hospital triage score to 30-day mortality [15]. It has also been shown to be effective in predicting prolonged ICU stay and massive haemorrhage in a European cohort [16]. The GAP score modifies the MGAP score to exclude injury mechanism – the acronym GAP represents "GCS, age, (systolic blood) pressure." The GAP score was validated in a sample from the Japan Trauma Data Bank [17].

While ISS and RTS have been widely studied in high-income countries, none of these injury scoring systems have been rigorously validated in low- and middle-income countries [18,19]. There are substantial logistical demands associated with implementing the ISS, including detailed medical records, extensive radiographic studies and autopsy results, which are often unavailable in resource-poor settings [20]. We hypothesise that anatomic scoring systems do not perform well in trauma registries in low- and middle-income countries, and physiologic scoring systems more effective in predicting in-hospital mortality in this context. The objectives of this study are (1) to assess the feasibility of calculating five injury scoring systems – ISS, RTS, KTS, MGAP and GAP – with data from a trauma registry in a lower middle-income countries (Table 1) and (2) to determine which of these scoring systems most accurately predicts in-hospital mortality in this setting.

This study was approved by the Lokmanya Tilak Municipal General Hospital institutional ethics committee, the World Health Organization Ethics Review Committee, and the University of California San Francisco Committee on Human Research.

Patients and methods

Five injury scoring systems – ISS, RTS, KTS, MGAP and GAP – were compared using data collected in the institutional trauma registry of Lokmanya Tilak Municipal General Hospital, an urban Level I trauma center in Mumbai, India, between October 2010 and February 2012. All severely injured patients presenting to the hospital with life- or limb-threatening injuries according to the criteria of the World Health Organization Trauma Care Checklist study were evaluated and received standardized care from surgical registrars in the Trauma Ward (see electronic supplement). At the time of triage, the surgical registrars completed an intake form, which included the patient's age, vital signs, neurologic status and injury mechanism. For three 8-h shifts per month, an independent senior observer accompanied the primary observer to check for consistency of the GCS scoring. Other data including disposition and in-hospital mortality were recorded during the hospital stay. Gunshot wounds, stab wounds and lacerations were classified as penetrating, while all other injury mechanisms were classified as blunt. Patients with minor or isolated limb injuries, such as superficial soft tissue injuries or uncomplicated, closed fractures, were not included in this analysis.

Trauma registry data were entered into the EpiInfo 6 software (CDC Statistical package), transferred to Excel (Microsoft, Redmond, Washington: 2007) for editing, and then imported to Stata 13 statistical software (StataCorp, College Station, TX: 2013) for analysis. Anonymous, de-identified data were shared with authors at the Center for Global Surgical Studies, University of California San Francisco Department of Surgery for analysis. AIS values were coded at the World Health Organization Headquarters in Geneva, Switzerland by a single coder who was trained in AIS coding by the World Health Organization Injury and Violence Prevention division. RTS, KTS, MGAP and GAP score values were calculated retrospectively based on available data. All values were calculated according to published formulas [11,12,14, 15,17].

Minor modifications were made to the KTS score so that it could be calculated retrospectively. The number of serious injuries for each patient was determined based on a list of final diagnoses by a member of the research team with expertise in trauma care. Because no standardised conversion from GCS to AVPU ("alert, voice, pain, unresponsive") score exists, an estimated AVPU score was assigned based on GCS using data from the original validation study of the KTS (GCS 14–15 = "alert", GCS 10–13 = "responds to voice", GCS 5–9 = "responds to pain", GCS 3–4 = "unresponsive") [14]. A note was made when insufficient data prevented calculation of any of the scores.

Pearson's chi-squared test was used to compare mortality rates among patients who did and did not have sufficient data to calculate each score recorded. Association between injury scoring systems and in-hospital mortality was evaluated with bivariate logistic regression. The goodness-of-fit of the injury scoring systems was quantified using the Akaike information criterion, a parametric likelihood-based model that assumes a linear relationship on the logistic scale. The discrimination of the scoring systems

Table 1
Comparison of injury scoring systems.

Injury Scoring System	Acronym	Type	Variables Included
Injury Severity Score	ISS	Anatomic	AIS values
Revised Trauma Score	RTS	Physiologic	GCS, SBP, RR
Kampala trauma score	KTS	Combined	Age, SBP, RR, AVPU score, number of serious injuries
Mechanism, GCS, age, pressure	MGAP	Physiologic	Penetrating mechanism of injury, GCS, age, SBP
GCS, age, pressure	GAP	Physiologic	GCS, age, SBP

AIS, abbreviated injury score; SBP, systolic blood pressure; RR, respiratory rate; GCS, Glasgow coma score; AVPU, "alert, voice, pain, unresponsive".

was characterized using nonparametric receiver operating characteristic (ROC) analysis.

All five scores were compared on the subset of patients with all five scores available, and additional pairwise comparisons were performed to compare each score to the four other scores in the analysis on the subset of patients who had both scores available. Subgroup comparisons of the scores among transferred and non-transferred patients were also performed. Logistic regression was also used to compare the odds of mortality between patients with penetrating and blunt mechanisms of injury when controlling for GAP score to address the question of whether a penetrating mechanism of injury is associated with higher mortality, as the MGAP model suggests. A p-value of less than 0.05 was determined to be statistically significant.

Results

A total of 1117 severely injured patients with life- or limb-threatening injuries were treated by the Lokmanya Tilak Municipal General Hospital Trauma Ward between October 16, 2010 and February 14, 2012. The mean age of injured patients was 30.9 years (SD 17.1), and 981 were male (88%). The most common mechanisms of injury were road traffic injuries ($n = 357$, 32%) and falls ($n = 270$, 24%), and 677 patients were transferred from other medical centers (61%). Only one patient was discharged from the emergency department (<1%), 88 were taken directly from the emergency department to surgery (8%), and 899 were admitted to the intensive or intermediate care units (81%). Three hundred fifty eight patients died, for an in-hospital mortality rate among patients treated by the Trauma Ward of 32%.

A value for ISS was recorded for 811 patients (73%). Sufficient data was collected to calculate RTS or KTS in 386 patients (35%), and 416 patients (37%) had a respiratory rate documented. Of the 701 patients without a documented respiratory rate, 31 were intubated at the time of initial evaluation (5%), and those patients were all transferred from other medical centers. Sufficient data was available to calculate MGAP in 988 patients (88%) and GAP in 1027 patients (92%). ISS values ranged from 0 to 45, with a median value of 10 (IQR 5–18), including three patients with an assigned ISS value of 0 despite meeting the World Health Organization Trauma Care Checklist study's criteria for life- or limb-threatening injuries. RTS values ranged from 1.76–7.84, with a median value of 6.90 (IQR 5.97–7.84). KTS values ranged from 9 to 16 with a median value of 14 (IQR 13–15). MGAP values ranged from 10 to 29, with a median

value of 23 (IQR 19–27). GAP values ranged from 6 to 24, with a median value of 19 (IQR 14–22).

The mortality rate was higher among patients with a documented ISS (272 out of 811) than those without a documented ISS (86 out of 306) at 34% vs. 28% ($p = 0.08$). The mortality rate was the same among patients with sufficient data to calculate RTS or KTS values (122 of the 386) as it was among patients without sufficient data (236 out of 731) at 32% for both groups ($p = 0.82$). The mortality rate was lower among patients with sufficient data to calculate MGAP values (291 out of 988) than among patients without sufficient data (67 out of 129) at 29% vs. 52% ($p < 0.01$). Similarly, the mortality rate was lower among patients with sufficient data to calculate GAP values (311 out of 1027) than among patients without sufficient data (47 out of 90) at 30% vs. 52% ($p < 0.01$).

In bivariate logistic regression models, increasing value of ISS was very modestly associated with increasing odds of death (OR: 1.05, 95% CI: 1.03–1.07, $p < 0.01$). Decreasing RTS was associated with increasing odds of death (OR: 0.31, 95% CI: 0.25–0.40, $p < 0.01$), as was decreasing KTS (OR: 0.31, 95% CI: 0.24–0.39, $p < 0.01$). Similarly, decreasing MGAP was associated with increasing odds of death (OR: 0.71, 95% CI: 0.68–0.74, $p < 0.01$), as was decreasing GAP (OR: 0.71, 95% CI: 0.68–0.74, $p < 0.01$). When stratifying each score as mild, moderate, and severe, RTS, KTS, MGAP and GAP each demonstrated a stepwise increase in mortality that was statistically significant in a bivariate logistic regression model ($p < 0.01$), but ISS did not demonstrate a similar stepwise increase in mortality ($p = 0.19$) (Fig. 1).

In the subset of patients with all five scores available ($n = 244$), RTS, KTS, MGAP and GAP had similar discrimination—characterised by the area under the ROC curve—and goodness-of-fit—characterised by the Akaike information criterion. All four physiologic scores had better discrimination and goodness-of-fit than ISS (Fig. 2). Given only 244 patients had all five scores available and the concern for introducing selection bias (22%), these findings were confirmed in pairwise comparisons of the five scores on the subset of patients with both scores available (Table 2). Each score had similar discrimination among the subgroups of transferred and non-transferred patients.

When stratifying MGAP scores as low (23–29), intermediate (18–22) and high (3–17) risk for death, the in-hospital mortality rates were uniformly higher than in the original validation cohort of the MGAP score in France (Table 3). The area under the ROC curve for the MGAP score in the French validation cohort was 0.90, compared with 0.85 in the subset of patients with sufficient data to
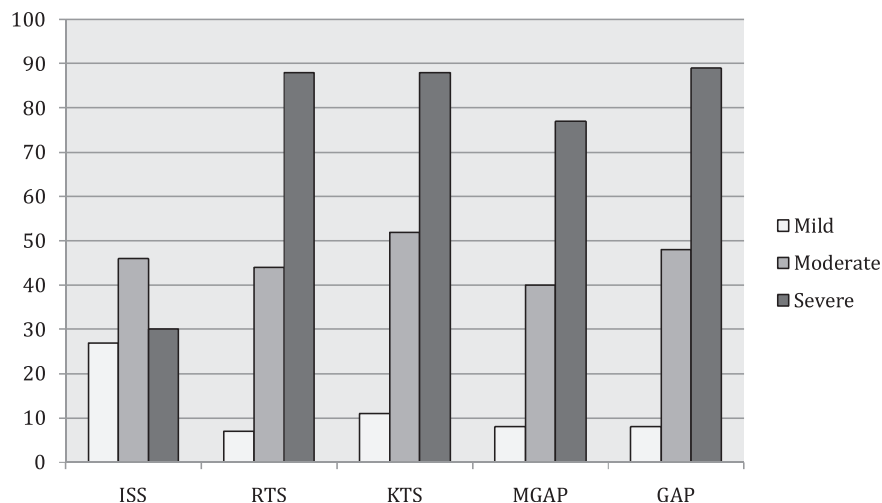

Fig. 1. Comparison of mortality rates associated with scores predicting mild, moderate and severe injuries.
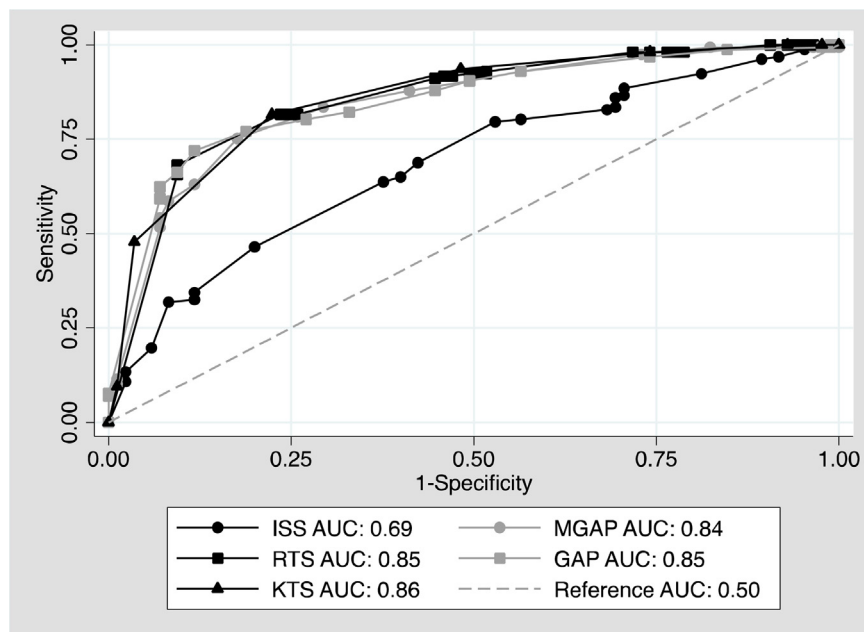
Fig. 2. Receiver operating characteristic curves and area under the curve (AUC) values for ISS, RTS, KTS, MGAP and GAP among patients with all five scores available.

calculate an MGAP value in this population [15]. Similarly, when stratifying GAP scores as low (19–24), intermediate (11–18) and high (3–10) risk for death, the in-hospital mortality rates were uniformly higher than in the original validation cohort of the GAP score in Japan. The area under the ROC curve for the GAP score in the Japanese validation cohort was 0.93, compared with 0.85 the subset of patients with sufficient data to calculate a GAP value in this population [17].

Only 77 patients (7%) had a penetrating mechanism of injury. Of those, 74 (96%) were due to stab wounds and lacerations while only 3 (4%) were due to gunshot wounds. In a logistic regression model controlling for GAP score, a penetrating mechanism of injury was associated with a lower in-hospital mortality rate compared with a blunt mechanism that approached statistical significance (OR: 0.33, 95% CI: 0.06–1.02, $p = 0.05$).

Table 2
Pairwise comparisons of injury scoring systems' discrimination and goodness-of-fit in subsets of the population for which both scores are available, and in subset of patients with all four scores available.

	Score	Area under ROC curve[a]	95% Confidence interval	Akaike information criterion[b]
ISS vs. RTS ($n = 254$)	ISS	**0.69**	0.63–0.76	308
	RTS	**0.85**	0.81–0.90	228
ISS vs. KTS ($n = 254$)	ISS	**0.64**	0.60–0.67	308
	KTS	**0.86**	0.82–0.91	223
ISS vs. MGAP ($n = 709$)	ISS	**0.65**	0.60–0.69	847
	MGAP	**0.84**	0.80–0.87	640
ISS vs. GAP ($n = 745$)	ISS	**0.65**	0.61–0.69	901
	GAP	**0.84**	0.81–0.88	666
RTS vs. KTS ($n = 386$)	RTS	0.85	0.81–0.89	337
	KTS	0.85	0.81–0.89	330
RTS vs. MGAP ($n = 375$)	RTS	0.85	0.81–0.89	327
	MGAP	0.84	0.80–0.89	340
RTS vs. GAP ($n = 386$)	RTS	0.85	0.81–0.89	337
	GAP	0.85	0.81–0.89	345
KTS vs. MGAP ($n = 375$)	KTS	0.85	0.81–0.89	319
	MGAP	0.84	0.80–0.89	340
KTS vs. GAP ($n = 386$)	KTS	0.85	0.81–0.89	330
	GAP	0.85	0.81–0.89	345
MGAP vs. GAP ($n = 988$)	MGAP	0.85	0.82–0.87	852
	GAP	0.85	0.83–0.88	839
Patients with values for all five scores ($n = 244$)	ISS	**0.69**	0.62–0.76	297
	RTS	**0.85**	0.80–0.90	222
	KTS	**0.86**	0.81–0.91	215
	MGAP	**0.84**	0.79–0.89	232
	GAP	**0.85**	0.80–0.90	229

[a] When comparing models, a higher area under ROC curve indicates the model with better discrimination. Results are bolded when the differences between areas under the receiver operating characteristic curve (AUC) values are statistically significant.
[b] Akaike information criteria were obtained by fitting logistic regression models. When comparing models, the lower Akaike information criterion value indicates the model with better goodness-of-fit.

Table 3
Comparisons of Mortality Rate by MGAP and GAP score values between this sample and original validation cohorts [15,17].

MGAP Score				
MGAP value	India 2010–2011 (*n* = 1117)		France 2002 (*n* = 1360)	
	Patients (frequency, proportion)	Mortality (frequency, rate)	Proportion of sample	Mortality rate
Low (23–29)	545 (49%)	46 (8%)	45%	3%
Intermediate (18–22)	259 (23%)	103 (40%)	21%	15%
High (3–17)	184 (16%)	142 (77%)	33%	48%
Missing	129 (12%)	67 (52%)	–	–
Total	1117 (100%)	358 (32%)	100%	23%
GAP Score				
GAP value	India 2010–2011 (*n* = 1117)		Japan 2004–2009 (*n* = 13,463)	
	Patients (frequency, proportion)	Mortality (frequency, rate)	Proportion of sample	Mortality rate
Low (19–24)	536 (48%)	44 (8%)	75%	2%
Intermediate (11–18)	415 (37%)	199 (48%)	15%	21%
High (3–10)	76 (7%)	68 (89%)	10%	74%
Missing	90 (8%)	47 (52%)	–	–
Total	1117 (100%)	358 (32%)	100%	15%

Discussion

There is ongoing debate about the ideal choice of injury scoring system in low- and middle-income countries [21]. This study demonstrates that ISS correlates poorly with in-hospital mortality in an institutional trauma registry in Mumbai, India. Because ISS is a composite of AIS values, incomplete patient evaluation can result in underestimation of injury severity, which is a common threat in low- and middle-income countries due to lack of radiographic, intra-operative or autopsy data [22]. Several studies have used modified approaches to calculate ISS in low- and middle-income countries, such as retrospective analyses of billing codes or estimations based on initial clinical presentation [23,24]. However, even when full diagnostic information is available, ISS calculation is a labour-intensive process that requires specially trained staff, which is often unsustainable in low- and middle-income countries [7].

Some have argued that purely physiologic injury scoring systems like RTS are inferior to those that also include anatomic or injury mechanism information [25]. One concern is that vital sign measurements occurred at the time of hospital triage, not at a fixed interval after the injury event, which may introduce bias as vital signs fluctuate over time and with resuscitative measures. However, vital signs collected at the time of hospital arrival are routinely used for injury scoring in low- and middle-income countries without adjusting for time since injury [19,22,26–28]. In fact, because physiologic scoring systems do not rely on comprehensive anatomic evaluation, they potentially provide a more feasible means of estimating injury severity in low- and middle-income countries using readily available clinic or administrative data [29]. In fact in this study, RTS did correlate well with in-hospital mortality when values were available.

In high-income countries, the use of RTS is also limited because many severely injured patients are intubated or sedated prior to hospital arrival, resulting in inaccurate measurements of GCS and respiratory rate [30]. These concerns are less relevant in low- and middle-income countries where pre-hospital care is minimal [31]. In this sample, only 5% of patients without a documented respiratory rate were intubated at the time of evaluation. Still, shortcomings in data recording, particularly missing respiratory rate measurements, limited the utility of RTS in this setting.

The performance of KTS was slightly superior to RTS but its use was similarly limited by missing respiratory rate measurements, as well as the need to retrospectively determine the number of serious injuries and to estimate an AVPU score for each patient.

While this study reaffirms the utility of KTS in predicting mortality in low- and middle-income countries, it also highlights the idiosyncrasies of that injury scoring system, which requires the collection of data elements that are not routinely included in many trauma registries.

The Lokmanya Tilak Municipal General Hospital trauma registry provided sufficient data to calculate both MGAP and GAP scores for a large majority of patients. RTS, KTS, MGAP and GAP scores all predicted in-hospital mortality accurately when sufficient data were available to calculate them. In fact, the accuracy of the MGAP and GAP scores at Lokmanya Tilak Municipal General Hospital approached their performances in high-income countries. As in the original validation cohort for the GAP score, penetrating mechanisms account for less than 10% of injuries at Lokmanya Tilak Municipal General Hospital [17]. In this study, when adjusting for GAP score, penetrating mechanism was associated with a 76% decrease in in-hospital mortality rate compared with blunt injuries, suggesting that GAP score may reflect the clinical reality of trauma at Lokmanya Tilak Municipal General Hospital better than MGAP score (which predicts a worse prognosis in patients with penetrating injuries).

As a single-center analysis of a cohort of severely injured patients, this study has several limitations. It contains evidence to raise the question of what is the optimal injury scoring system to use in low- and middle-income countries where resources and accurate hospital records are a challenge, but cannot provide a single ideal solution. Only 22% of patients had sufficient data to calculate all five scores available which may introduce sampling bias, although the findings of the pairwise comparisons were similar to those of the comparison of all five scores. This limitation also highlights the common challenge of exhaustive data collection for trauma registries in low- and middle-income countries and emphasizes the importance of simplified, context-appropriate metrics. Although difficulty documenting respiratory rate has been noted in other trauma registries in low- and middle-income countries, this study cannot address the scope of such documentation problems [32]. This study also does not assess the feasibility of improving data collection for ISS, RTS or KTS at Lokmanya Tilak Municipal General Hospital.

If researchers continue to retrospectively calculate KTS based on trauma registry data, it will be important to formalize a methodology for calculating each patient's number of serious injuries and to establish a conversion from GCS to AVPU score. In the future, it will also be useful to investigate outcomes other than in-hospital mortality such as need for operation, length of stay, and

long-term disability. In addition, to use the Akaike information criterion to compare the goodness-of-fit of models, we had to assume a linear relationship between score values and the probability of in-hospital mortality on the logistic scale. Finally, when comparing prognostic models it is important to consider calibration as well as discrimination, which was beyond the scope of this analysis [33]. In particular, we are unable to comment on the performance of these scores in a less severely injured patient population.

Reliable surveillance data remains crucial in understanding the true burden of injury in low- and middle-income countries, which is necessary for quality improvement and to guide allocation of appropriate resources for injury prevention and care of the injured. Currently there is no single ideal injury scoring system, and the results of this study raise significant concerns about the reliance on ISS or RTS to predict in-hospital mortality at Lokmanya Tilak Municipal General Hospital. Ongoing reinforcement for registrars and training nurses or other medical professionals as skilled data collectors may improve trauma registry data accuracy and completeness.

In addition, when studying the burden of injury in low- and middle-income countries, it is important to choose an injury scoring strategy that correlates well with mortality risk in spite of imperfect and incomplete data instead of attempting to implement a complicated data collection protocol that is not locally feasible or sustainable, especially when the failure of these protocols can dramatically distort estimations of injury burden.

Conclusions

In this study, ISS had the poorest discrimination and goodness-of-fit of the evaluated injury scoring systems, despite significant efforts to ensure its accuracy. While missing data limited the utility of RTS and KTS, both of those injury scoring systems predicted in-hospital mortality well when values were available. The MGAP and GAP scores were easily implemented using the incomplete trauma registry data at Lokmanya Tilak Municipal General Hospital, and accurately predicted in-hospital mortality there.

Given the realities of medical practice in low- and middle-income countries, it is reasonable to modify the approach to characterizing injury severity in there to favour simplified injury scoring systems that accurately predict in-hospital mortality despite limitations in trauma registry datasets.

Conflict of interest statement

Acknowledgements

Appendix A

Definition of life or limb threatening injury – If patient has any of the following, they should be included in the WHO Trauma Care Checklist study:

Mechanism:

- MBA/cyclist impact > 30 kph
- Pedestrian impact > 30 kph
- Extrication > 30 min
- Vehicle rollover
- Fatality in same vehicle
- Ejection from vehicle
- Fall > 3 M
- Explosion
- Assault with obvious long bone fracture
- GSW/STW/ICEPICK; to head, neck, trunk, groins. To isolated extremity IF there is ongoing bleeding with obvious fracture.
- ALL shotgun/buckshot injuries

Injuries:

- All significant blunt injuries assessed by ambulance
- All penetrating head, neck and truncal injuries including groin and axilla
- All injuries involving:
    Suspected spinal cord injury
    Traumatic amputation proximal to carpus/tarsus or major degloving injury
    Pelvis/pulseless limb/dislocations with vascular compromise + ANY displaced pelvic fracture
- Evisceration
- Blast injuries
- Severe crush injury
- Serious burns > 20%TBSA (all face) > 15% TBSA OR obvious airway compromise. Electrical burns: high voltage OR sustained arrhythmias
- ANY traumatic pneumothorax
- Open fractures

Signs:

- SBP < 100 mmHg (<75 mmHg, child) or $p > 150$ or >50/min)
- GCS < 13 OR obvious peripheral deficit.
- SpO < 90%
- RR < 10 or >30

Treatment:

- Any airway manoeuvre including intubation
- Assisted ventilation
- Pleural decompression
- Haemostatic dressings/tourniquet application
- >1000 ml IV fluid or blood transfusion
- Neuromuscular blockade

Other:

- Mass casualty incident/>1 patient reception simultaneously
- All inter-hospital trauma transfers
- Pregnancy
- Significant co-morbidity
- Anticoagulant therapy including warfarin

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.injury.2015.06.029.

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