BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-090517
Article Type:	Original research
Date Submitted by the Author:	01-Jul-2024
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Keywords:	ACCIDENT & EMERGENCY MEDICINE, TRAUMA MANAGEMENT, Triage

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Derivation and validation of the Simplified Bleeding Audit Triage Tool (sBATT): a simplified trauma score for major trauma patients injured in Motor Vehicle Collisions

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Keywords:
Trauma
Emergency Medical Systems
Motor Vehicle Collisions
Post-collision care

Word count: 2736

Abstract:

Objectives: To develop and validate a simplified Bleeding Audit and Triage Trauma Score (sBATT) for use by lay persons, or in areas and environments where physiological monitoring equipment may be unavailable or inappropriate.

Design
The sBATT score was derived from the original BATT, which included prehospital systolic blood pressure (SBP), heart rate (HR), respiratory rate (RR), Glasgow Coma Score (GCS), age, and trauma mechanism; variables suitable for lay interpretation without monitoring equipment were included. The sBATT was validated using data from the UK Trauma Audit Research Network (TARN) registry.

Setting
Data sourced from prehospital observations from multiple trauma systems in the United Kingdom.

Participants
70,027 MVC patients from the TARN registry (2012-2019). Participants included were those involved in motor vehicle collisions MVCs, with exclusion criteria being incomplete data or non-trauma-related admissions.

Interventions
Not applicable.

Primary and Secondary Outcome Measures
Death within 24 hours of MVC. Secondary: need for trauma intervention.

Results
In a cohort of 70,027 MVC patients, 1,976 (3%) died within 24 hours. The sBATT score showed an AUROC of 0.90 (95% CI: 0.90-0.91) for predicting 24-hour mortality, surpassing other trauma scores such as the Shock Index and ABC score. Sensitivity was 96%, specificity 72%, with a negative likelihood ratio below 0.1, indicating strong rule-out capability. Sensitivity analyses confirmed consistent performance across varying SBP and GCS thresholds. The sBATT score was equally effective across sexes with no significant predictive discrepancies.

Conclusions
The sBATT score is a reliable, simplified tool for early risk stratification by lay persons in low-resource settings or without physiological monitoring equipment. It demonstrates high predictive accuracy for 24-hour mortality and NFTI. Further research should validate sBATT in diverse populations and real-world scenarios to confirm its utility and applicability.

Strengths and limitations of this study:

Strengths:

- Clearly understood and patient centred outcome measure (24 hr mortality) and a large validation cohort (70k + patients)
- Sensitivity analyses across different physiological thresholds (e.g., SBP, GCS) and demographic groups (sexes)

Limitations:

- Validation cohort consisted of patients from the UK, limiting generalisability to other geographic regions, particularly LMICs where EMS availability and patient demographics may differ significantly.
- Data Source Bias**:** TARN only includes cases that were severe enough to warrant inclusion in the registry. We do not know how sBATT performs in those with minor or no injuries.
- Although designed for low-resource settings, the actual implementation and feasibility of using sBATT by lay persons in such environments were not directly assessed and would require further investigation.

Introduction:

Road traffic injury is the leading cause of death in children and young adults aged 5-29 years [1]. In addition to the 1.3 million deaths per year associated with road trauma, an additional 20-50 million people incur significant injury and often long-term disability [1]. Ninety-three percent of fatalities occur in lower- and middle-income countries (LMIC) where Emergency Medical Services (EMS) are often not available [2,3]. In many such countries motor vehicle collisions (MVC) are attended by lay bystanders, non-clinical professionals (such as firefighters) and frequent road users such as taxi drivers[4–6]. These non-clinical responders will not have access to physiological monitoring equipment which is ubiquitously available to clinical responders in higher income countries (HIC).

Following a MVC, up to 40% of patients may remain trapped in their vehicle [7–9]. These patients have more severe injuries and an excess mortality [9]. Such patients may remain trapped in their vehicle for an extended period of time [10]. The application of physiological monitoring equipment to a patient, and the clinical responders' interaction with this system is associated with prolonged entrapment times [11]. New UK national guidance recognises that frequent clinical monitoring may prolong entrapment time and and as such should be kept to the minimum[12].

In established emergency care systems, initial risk stratification occurs with a patient or bystander call to Emergency Medical Services (EMS), with key data points extracted through conversation inputting into algorithmic decision trees. Systems such as Advanced Priority Medical Dispatch System (AMPDS) tend towards being sensitive4 but not specific [13]. Such systems have low specificity which may result in unnecessary resource utilisation. This in turn may prolong response times to subsequent incidents, and limit availability of EMS, especially in LMICs where resource is already most limited. Decision making at initial emergency call may activate varying levels of ambulance service response from first responders through to critical care teams. Depending upon patient condition, instructions to bystanders may be given; for example to start cardiopulmonary resuscitation or arrest haemorrhage. Bystander instructions for the approach to trauma patients vary significantly between regions and often specific instructions are not available x[14]. Accurate early risk stratification is fundamental to the chain of survival for patients with trauma as it ensures optimum use of clinical and operational resources [15].

Non-compressible haemorrhage is common in those injured following a MVC [7–9]. Bleeding is the most frequently identified cause of preventable death from trauma [16–19]. Early identification of clinically significant bleeding at the scene of injury is key for appropriate allocation of resources, to enable early life-saving treatment such as the administration of tranexamic acid and blood product resuscitation, to minimise on-scene time and expedite transfer to definitive treatment [18–20].

The Bleeding Audit and Triage Trauma Score (BATT) is a simple triage tool that has been derived from an international cohort of trauma patients across 274 trauma centres and validated in a variety of European settings [21]. This score includes systolic blood pressure (SBP), heart rate (HR), respiratory rate (RR), Glasgow Comas Score (GCS), age and simple mechanism of trauma (high energy and penetrating injury). BATT has been identified as a tool that is useful in ensuring equitable and appropriate utilisation of tranexamic acid (TXA) and is both sensitive and specific at predicting death from bleeding at 24 hours [21]. The BATT outperforms other recognised scoring systems such as the Shock Index (SI) [21].

In this pre-specified analysis, we develop a simplified BATT (sBATT) score derived from the initial prognostic model equation of BATT using clinical variables that may be measured in environments where physiological monitoring equipment is unavailable, impractical, or may prolong entrapment times.

Methods:

This study consists of a development and validation stage.

Stage 1: Development of the sBATT score

The original BATT was developed in an international cohort of 23,202 injured patients treated in 274 trauma centres in 40 countries and subsequently validated in European settings [21,22]. In the development of the BATT a number of predictors of death from bleeding were identified; in this study, covariables were selected for sBATT that could be reported without the use of physiological monitoring equipment (Table 1). The sBATT weighting was derived using the integer from the coefficient of the regression equation. Points were assigned based on their significance (Table 1) giving a sBATT score range from 0 to 14.

Table 1: Variables suitable for use by bystanders from original BATT and their suggested lay application

Variable from BATT	Suggested interpretation	Interpretation considerations	Points assigned in the sBATT
Age	Older age	>65 years of age	+2
		<65 years of age	+0
Consciousness	Eyes open, converses, follows simple commands	GCS 15*	+4
		GCS <15	+0
Hypotension	Is the radial pulse present or absent?	Present: Systolic blood pressure >85mmHg **	+0
		Absent: Systolic blood pressure <85	+4
Tachycardia	Is the radial pulse rate low, normal or fast?6	Heart rate ≥100	+1
		Heart rate 50-99	+0
		Heart rate <50	+1
Trapped		Trapped	+1

	Is the patient unable to leave their vehicle	Not trapped	+0

* Range assessed in validation model

** Minimum values extracted from literature review [23–26].

Stage 2: Validation of the sBATT with Trauma Audit Research Network data

Primary outcome: Death within 24 hours. This is the most relevant primary outcome as bystander and prehospital care is most likely to impact on early deaths [27].

Secondary outcome: Need for trauma intervention (NFTI). We utilised a previous definition of NFTI which includes transfusion, damage control surgery or ICU admission [28].

Comparison: The performance of the sBATT is compared to other frequently utilised trauma scores including the original BATT, the ABC score, Shock Index (SI), Kampala Trauma Score (KTS), Mechanism/Glasgow Coma Scale/Age/Pressure (MGAP) and Revised Trauma Score (RTS) [29–33].

We considered the UK Trauma Audit Research Network (TARN) registry in patients injured in a MVC between January 2012 to December 2019 to validate the sBATT. See Box 1 for inclusion and exclusion criteria for TARN.

Box 1: Inclusion and exclusion criteria for the UK Trauma Audit Research Network (TARN)

The TARN database includes data on patients with an Injury Severity Score (ISS) of nine or more who are admitted to hospital in England and Wales for at least three nights, died in hospital or were transferred to another hospital for specialist care. TARN exclude patients with isolated mild traumatic brain injury with loss of consciousness, superficial scalp injury, patients 65 years or older with femoral neck or single pubic rami fracture, fracture or dislocation of the foot or hand, closed fracture or dislocation of an isolated limb, or simple skin laceration with blood loss < 20%.7

Continuous variables were described by the mean and standard deviation (sd) or the median and interquartile range (IQR) according to the parametric or non-parametric distribution.

We estimated the discrimination of each trauma score. Sensitivity (Se) is the true-positive rate from which the false-negative rate (commonly named under-triage) is derived. Specificity (Sp) is the true-negative rate from which the false-positive rate (commonly named over-triage rate) is derived. We plotted the Receiver Operating Characteristic (ROC) curves for each score. We calculated the area under the ROC curve (AUROC) as an overall indicator of discrimination. An AUROC of 1 corresponds to an ideal score. We calculated the likelihood ratio (LR). A positive likelihood ratio of 10 or above results in a large increase in the probability of the outcome and a negative likelihood ratio of 0.1 or less results in a large decrease in the probability of the outcome. In trauma risk stratification, a negative LR is the most useful indicator to safely rule-out injured patients who do not have major trauma.

Because AUROC is a composite of sensitivity and specificity and as such has little practical application for clinical decision-making we plotted separately the sensitivity and the specificity for each value of the score with a grey-zone approach [34]. The grey-zone approach identifies two boundaries of a score threshold corresponding to different objectives in clinical decision-making. The lower boundary represents the 'rule-out' limit in which major trauma could be safely excluded. The American College of Surgeons recommends an under-triage rate less than 5%, i.e. a sensitivity higher than 95% [35]. To avoid overloading of the trauma system, over-triage should not exceed 50% at this boundary. The upper boundary represents the 'rule-in' limit in which major trauma is highly certain. A specificity of 90% or higher is usually acceptable for recommending an expensive intervention, a treatment with serious side-effects or the use of scarce resources. For trauma risk stratification, the 'rule-in' boundary is often not useful.

It is important that trauma scores perform equitably for women and men, we report a sex-disaggreated analysis of the sBATT to evaluate this.

Missing data

Multiple imputation by chained equations was used in replacement of missing data. We drew 20 imputed datasets to impute values for systolic blood pressure, heart rate, respiratory rate and glasgow coma scale. We did not report any missing value for the outcomes.

Sensitivity analysis

There will be a range of accuracy of interpretation of the parameters included in the sBATT. This is particularly the case for the 'GCS' where we could find no supporting literature on lay-application and interpretation, and 'the absence of a radial pulse' where a range of collected minimum systolic blood pressure values (55-85mmHg) were reported [23–26]. To allow for this we performed sensitivity analysis with a GCS of 13 for level of consciousness and an alternative threshold of 60 mmHg of systolic blood pressure for the loss of radial pulse.

All analyses were performed using STATA software (v.16.1; Stata Corp, Station, TX, USA).

Ethics approval and consent to participate

The TARN Registry has ethical approval from the UK Health Research Authority (section 251 PIAG) for analysis of anonymised data.

Patients or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Results:

Patient characteristics

Overall, 70,027 patients were included in the TARN registry and injured in a MVC between 2017 and 2021. The mean age was 46 (sd 20) years (Table 2). There were 13,851 (20%) older injured patients over 65 years and 18,175 (26%) women. Entrapment was recorded for 18,175 (11%) patients. The mean injury severity score (ISS) was 17 (sd 12). There were 1,976 (3%) patients who died at 24 hours and 3,868 (6%) died at 30 days. Considering each score threshold to identify injured patients with significant risk of early death, 20,082 (29%) injured patients were considered at risk with a sBATT≥3, 7,407 patients (11%) with a shock index ≥0.9, 9,393 (13%) with a MGAP <23; 27,650 (40%) patients with a KTS ≤13, 12,627 (18%) with a T-RTS ≤11.

Trauma score performance

The AUROC for the sBATT score was 0.90, 95%CI (0.90-0.91) (table 3 and supp.figure 1). BATT, MGAP, T-RTS and KTS scores presented an AUROC between 0.91 and 0.94. The Shock index and the ABC score presented a low discrimination with an AUROC less than 0.70. The sensitivity of all scores were above 0.90 except for the Shock index and the ABC score. The negative likelihood ratio of the sBATT, BATT and KTS scores were below 0.1. The grey zone approach showed appropriate sensitivity for the rule-out limit with specificity exceeding 50% for sBATT, BATT, MGAP, T-RTS and KTS (figure 1). The sensitivity analysis of different thresholds of SBP and GCS of the sBATT did not show a difference on AUROC, sensitivity and negative likelihood ratio (table 4). The performances of all scores to predict NFTI were between 0.70 and 0.75 and were summarised in the supplement file 1. The sex-disaggregated analysis did not find any heterogeneity of the AUROC and NLR by sex (supplement file 2). The performance of the sBATT score to predict secondary outcomes (NFTI and NFTI or death) was summarised in the supplement file 3.

Discussion:

We present the sBATT, a novel trauma score which utilises clinical variables that may be measured in environments where physiological monitoring equipment is unavailable or impractical. The sBATT performs well at predicting death at 24 hours with an AUROC of 0.90, 95%CI (0.90-0.91). This performs well compared to the original BATT and other established trauma scores.

Our study has important strengths. sBATT was derived and validated within TARN, a well established UK dataset with high standards of data collection and validation. We have assessed the performance of the score across values to allow for the range of systolic blood pressures at which a radial pulse might be lost and at which GCS could be incorrectly allocated - the consistently high AUROC across these ranges adds strength to the utility of the score. This score is unique in that we have demonstrated its performance for injured females and males. The precision of our results is enhanced by the substantial number of patients included in this study. Predictor variables had minimal missing values, and there was no absence of outcome data. The outcome was clearly defined and documented at a specific time point, contributing to the robustness of the results.

Our research also comes with constraints. The accuracy of predictor variable measurements may impact discrimination and calibration. Random errors could potentially emerge in all predictors (blood pressure, heart rate, Glasgow Coma scale), resulting in diminished discrimination and calibration. The use of monitoring devices to collect the original TARN data may be prone to systematic errors, which are likely to influence calibration [36]. Deriving and validating such a scoring system from the same dataset can lead to overfitting, where the model performs well on the training data but may fail to generalise to new data [37]. This approach may inadvertently capture noise or specific characteristics of the dataset rather than true physiological relationships. Our validation on the TARN dataset threatens the external validity of the sBATT and risks an over optimistic performance estimate. Validation from a non TARN dataset, from settings other than high-income countries, and / or a dataset for each intended population group is an important next step.

Frequently utilised trauma scores rely on physiological data and/ or specific details of the injuries sustained. We could not identify a comparable trauma score that had been rigorously derived and did not rely on variables that were captured by a monitoring device. This limits the utility of other scores to contexts where clinical professionals are able to undertake such monitoring or where the necessary equipment is available. Nordberg and team developed a simplified bystander score and demonstrated its utility in the hands of untrained lay rescuers; the efficacy of the sBATT when utilised by untrained lay rescuers, trained lay rescuers and professional bystanders (such as police and fire services) would similarly need to be ascertained [38]. Such validation would be necessary in each target population and region to ensure utility, accuracy, and acceptability across a range of socio-cultural contexts.

Ninety-three percent of road trauma deaths occur in LMICs [1]. LMICs are a large range of countries and regions: often with disparate approaches to road trauma, a wide-range of nascent and evolved EMS and socio-cultural differences that may affect the utility and adoption of such a score by lay and professional bystanders. As such significant validation and context-specific adaptation will be required in relation to sBATT.

Subject to appropriate validation sBATT has significant potential for utilisation in environments where physiological monitoring systems are not available or impractical. The use of the sBATT by those first on scene may add utility through enabling more accurate risk stratification and as such dispatch of specialist resources to the scene, trigger particular care pathways such as the administration of intramuscular TXA and improve multi-disciplinary on-scene communication through the use of a common language which delineates casualty severity. Members of this team have previously demonstrated the inequitable administration of TXA to women, and the adoption of a score such as this and its incorporation into documents that guide practice such as Patient Group Directives (PGDs) could help overcome these inequalities [39]. Patients that are trapped following a MVC have significant injuries and are more likely to die [9]. Previous work has demonstrated that pauses in extrication for physiological monitoring contribute to extended entrapment times [11]. The use of sBATT may offer an opportunity to decrease entrapment times as it has the potential to be performed quickly and with minimal disruption to the process of extrication. The 'extrication buddy' who joins the patient in the vehicle to explain the extrication process will be well placed to utilise the sBATT [12]. Further exploration of these areas in relation to the utility of sBATT from a clinical, operational and systems perspective is justified.

Key questions as to how the sBATT performs in different population groups and when delivered by a range of clinicians, non-clinical professionals and bystanders are essential next steps. Prospective clinical, operational and communication effectiveness studies of the performance of sBATT in the hands of clinicians caring for trapped patients following a MVC are warranted.

Conclusion

We present sBATT a simple trauma score for use in patients injured in MVC. This score has potential to be used where monitoring equipment is unavailable or impractical and could enable the optimum use of resources, serve as a communication aid and have utility as a conduit to enable bystander delivered clinical interventions.

Declarations

Ethics approval and consent to participate

TARN data analyses are conducted using anonymised data which is governed by a code of practice approved by the Confidentiality Advisory Group who are appointed by the Health Research Authority. Additional individual ethical approval was not required for this analysis.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding statement

This work was supported by Vision Zero South West (UK) grant number DA01.

Author contributions

TN, FXA, EF and WS contributed to the conception and study design, analysis and interpretation of data, drafting and revising the manuscript. All authors read and approved the final manuscript.

Competing interests:

None declared.

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Table 2. Characteristic of the study population presenting vehicle incident or collision

	N (%)	Missing %
Age, mean (sd)	46 (20)	0
16-44	34,871 (50)	
45-64	21,305 (30)	
65-84	11,605 (17)	
≥ 85	2,246 (3)	
Women	18,175 (26)	0
Trapped at scene	7,754 (11)	0
Systolic blood pressure at scene, mean (sd)	133 (28)	22
SBP <85 mmHg	1,752 (3)	
SBP <60 mmHg	423 (1)	
Heart rate at scene, mean (sd)	87 (22)	19
Slow, HR < 50 bpm	1,149 (2)	
Fast, HR > 100 bpm	14,431 (25)	
Glasgow Coma Scale at scene, mean (sd)	14 (3)	3
15 (Alert)	58,803 (77)	
12-14 (verbal)	8,524 (12)	
7-11 (Pain)	3,081 (5)	
3-6 (Unconsciousness)	4,003 (6)	
ISS, mean (sd)	17 (12)	0
ISS <9	12,178 (17)	

ISS 9-15	26,542 (38)	
ISS ≥ 15	31,306 (45)	
AIS Head ≥ 3	15,634 (22)	0
Prehospital intubation	3,846 (6)	0
Prehospital tranexamic acid	9,567 (14)	0
Admission to MTC	44,984 (64)	0
Need for trauma intervention	21,473 (31)	0
Admission in ICU	19,947 (28)	0
Urgent surgery or embolization	5,086 (7)	0
Urgent blood transfusion	3,299 (5)	0
Early death at 24 hrs	1,976 (3)	0
Death at 30 days	3,868 (6)	0

SBP: Systolic Blood Pressure, HR: Heart rate; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; MTC: Major Trauma Centre; ICU: Intensive Care Unit

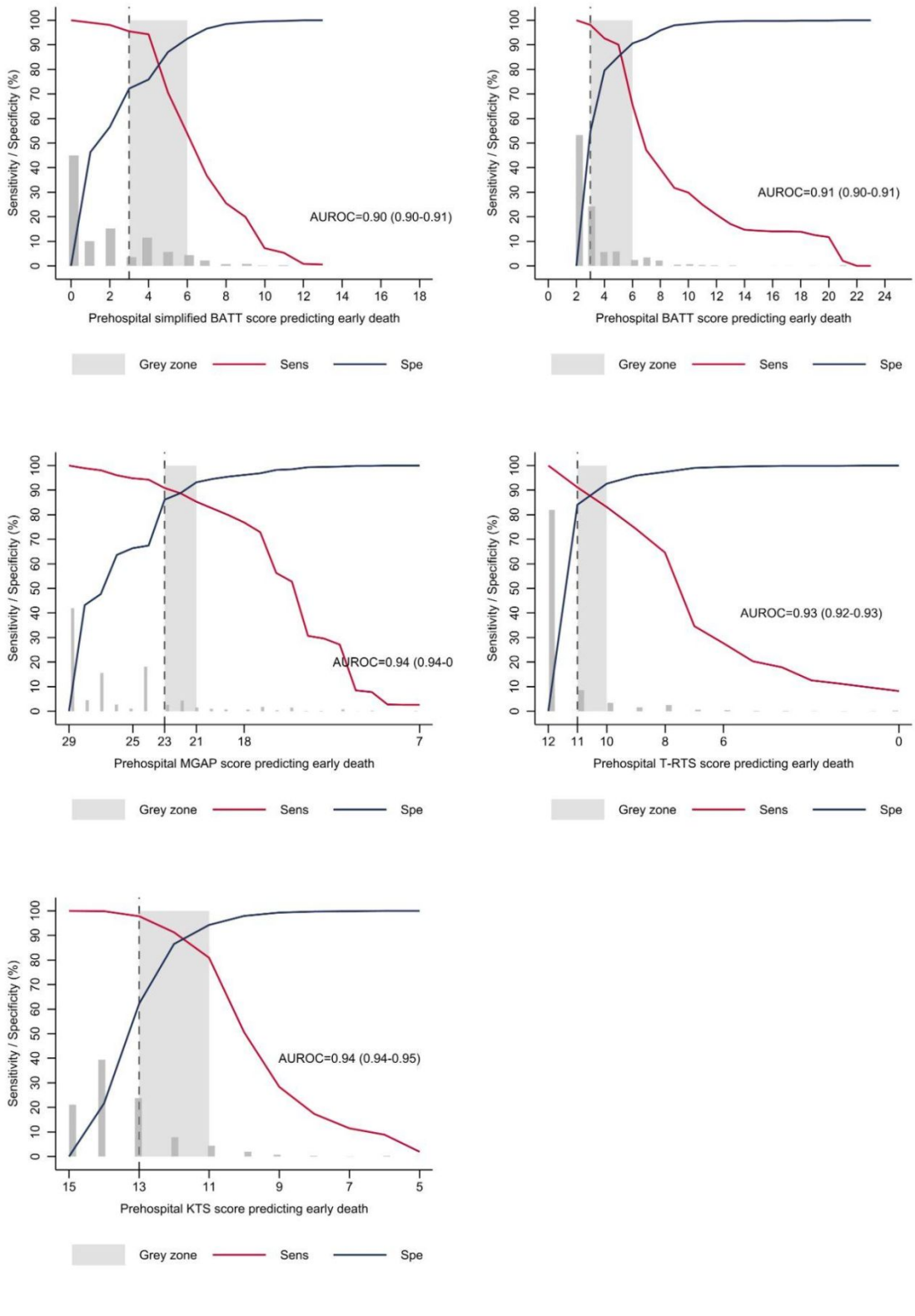
Table 3. Discrimination of the different trauma scores

	AUROC (95% CI)	Sensitivity	Specificity	Negative Likelihood ratio
sBATT score (≥3)	0.90 (0.90-0.91)	96 %	72 %	0.06
BATT score (≥3)	0.91 (0.90-0.92)	98 %	55 %	0.04
Shock Index (≥0.9)	0.61 (059-0.63)	33 %	90 %	0.75
ABC score (≥2)	0.66 (0.65-0.67)	5 %	99 %	0.96
MGAP (< 23)	0.94 (0.94-0.95)	91 %	86 %	0.11
T-RTS (≤ 11)	0.93 (0.92-0.93)	91 %	84 %	0.11
KTS (≤ 13)	0.94 (0.94-0.95)	98 %	62 %	0.04

Table 4. Sensitivity analysis according to systolic blood pressure and Glasgow coma scale threshold.

sBATT predicting early death	GCS 15	GCS 14	GCS 13
SBP 85 mmHg			
AUROC	0.91 (0.90-0.91)	0.92 (0.92-0.93)	0.93 (0.92-0.93)
Sensitivity	96%	93%	91%
Specificity	72%	82%	85%
Negative likelihood ratio	0.06	0.09	0.10
SBP 60 mmHg			
AUROC	0.90 (0.89-0.90)	0.92 (0.92-0.93)	0.93 (0.92-0.93)
Sensitivity	95%	92%	90%
Specificity	73%	83%	86%
Negative likelihood ratio	0.07	0.10	0.11

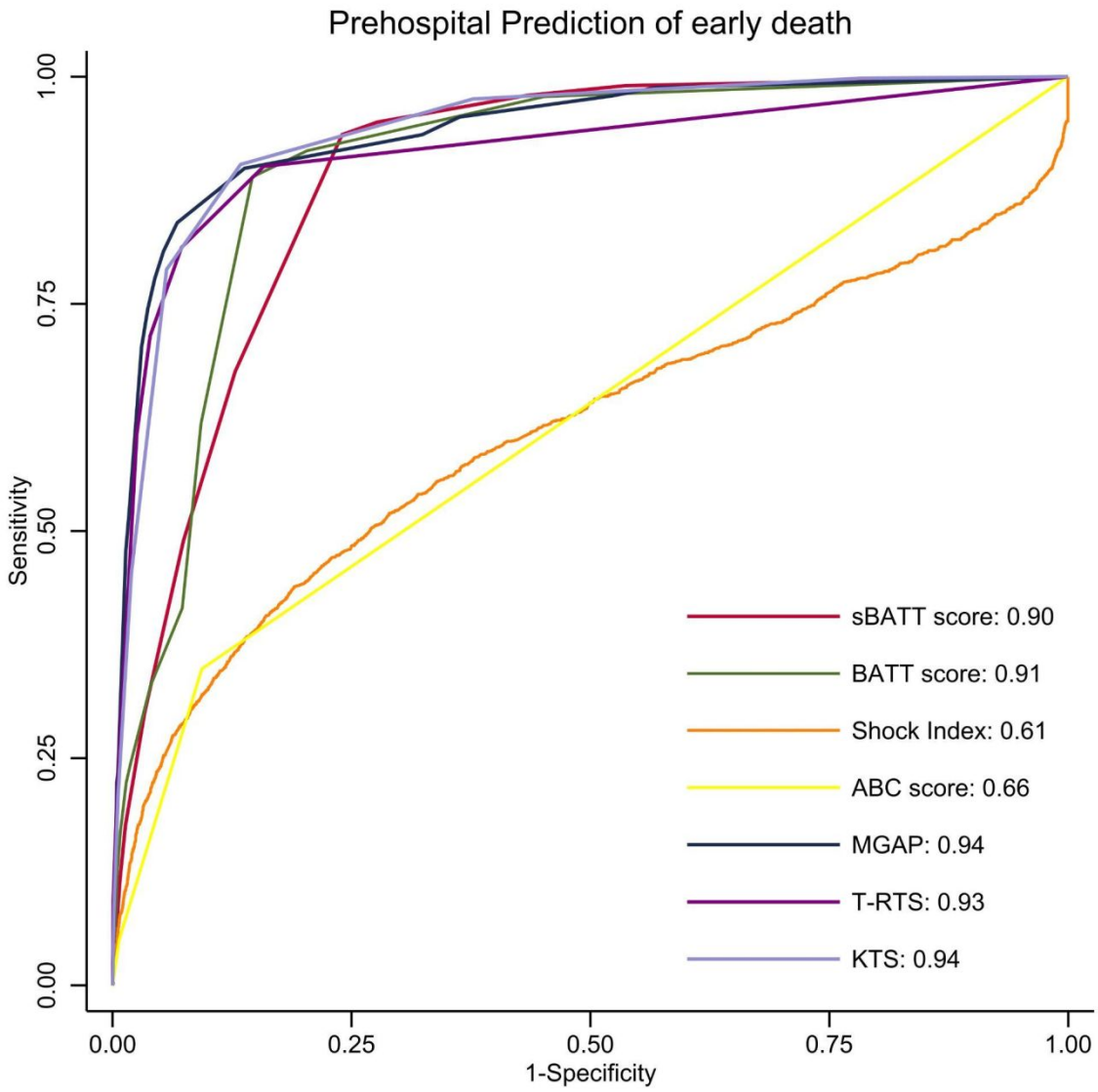
Figure 1. Sensitivity and specificity with grey-zone approach



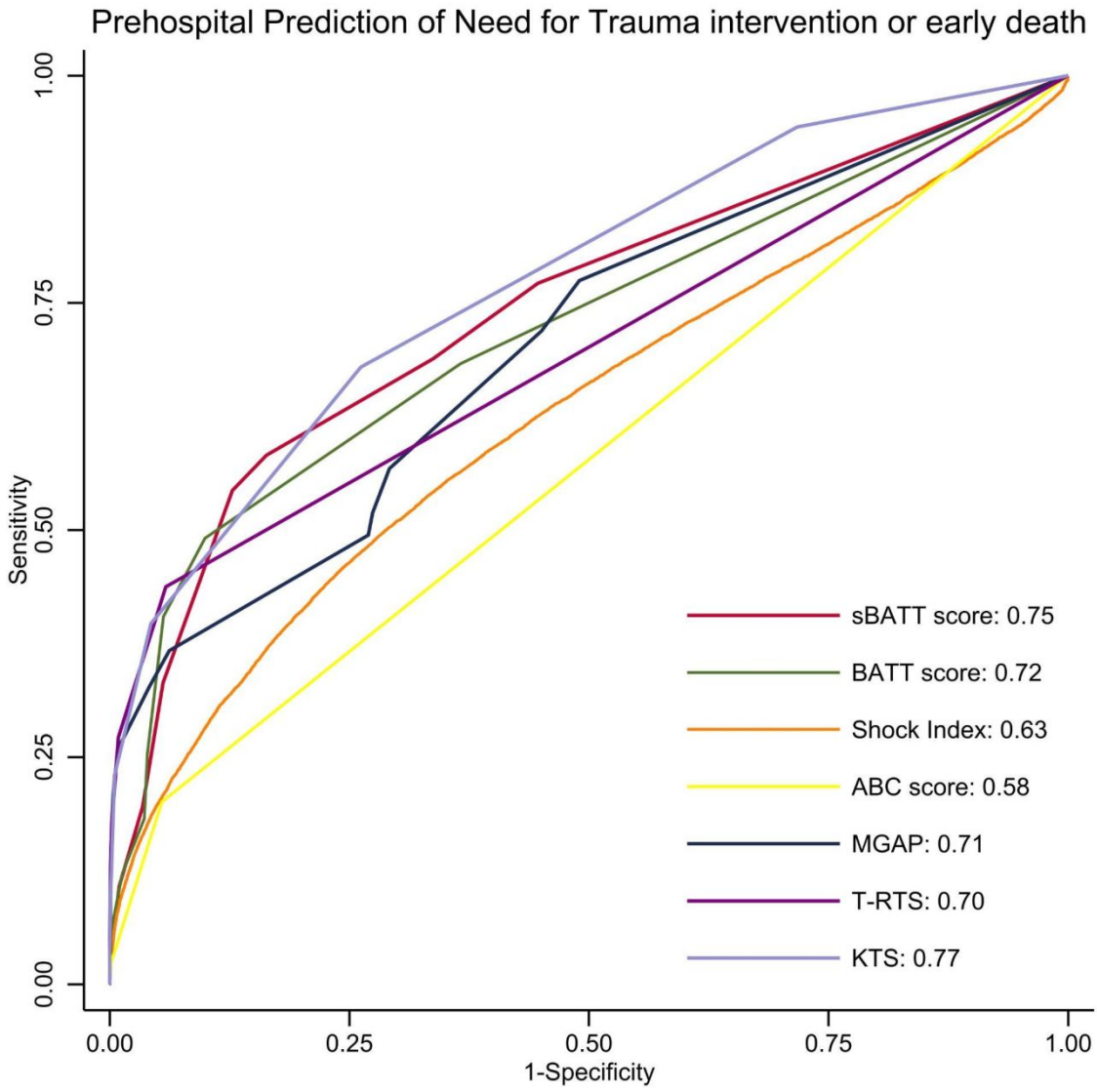
Derivation and validation of the Simplified Bleeding Audit Triage Tool (sBATT): a simplified trauma score for major trauma patients injured in Motor Vehicle Collisions

Supplementary material:

Suppl Figure 1. Receiver Operating Characteristic curves for trauma scores predicting early death



Suppl Figure 2. Receiver Operating Characteristic curves for trauma scores predicting early death or need for trauma intervention



Supplement file 2. Discrimination of the different trauma scores by sex

	Women N=18,175		Men N=51,852	
	AUROC (95% CI)	Negative LR	AUROC (95% CI)	Negative LR
sBATT score (≥3)	0.89 (0.88-0.90)	0.09	0.90 (0.90-0.91)	0.05
BATT score (≥3)	0.90 (0.90-0.91)	0.04	0.91 (0.91-0.92)	0.03
Shock Index (≥0.9)	0.62 (059-0.65)	0.74	0.61 (059-0.63)	0.75
ABC score (≥2)	0.64 (0.62-0.66)	0.96	0.67 (0.65-0.68)	0.96
MGAP (< 23)	0.95 (0.94-0.95)	0.11	0.95 (0.94-0.95)	0.11
T-RTS (≤ 11)	0.91 (0.90-0.93)	0.13	0.93 (0.92-0.94)	0.11
KTS (≤ 13)	0.94 (0.93-0.95)	0.03	0.95 (0.94-0.95)	0.04

Supplement file 3. Discrimination of the sBATT score to predict primary and secondary outcomes.

	Early death	NFTI-Death	NFTI
sBATT (85 mmHg)			
AUROC	0.90 (0.90-0.91)	0.75 (0.74-0.75)	0.73 (0.73-0.74)
Sensitivity	96%	59%	58%
Specificity	72%	84%	83%
Negative likelihood ratio	0.06	0.49	0.51
sBATT (60 mmHg)			
AUROC	0.90 (0.89-0.90)	0.74 (0.74-0.75)	0.73 (0.72-0.73)
Sensitivity	95%	57%	56%
Specificity	73%	84%	83%
Negative likelihood ratio	0.07	0.51	0.53

BMJ Open

Derivation and validation of the Simplified Bleeding Audit Triage Tool (sBATT): a simplified trauma score for major trauma patients injured in Motor Vehicle Collisions

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-090517.R1
Article Type:	Original research
Date Submitted by the Author:	10-Nov-2024
Complete List of Authors:	Nutbeam, Tim; IMPACT: Centre for Post-Collision Research, Innovation and Translation; Plymouth Hospitals NHS Foundation Trust, Emergency Medicine Stassen, Willem; University of Cape Town Foote, Emily; University Hospitals Plymouth NHS Trust, Emergency Department AGERON, Francois-Xavier; Lausanne University Hospital, Emergency Department
Primary Subject Heading:	Emergency medicine
Secondary Subject Heading:	Global health, Diagnostics
Keywords:	ACCIDENT & EMERGENCY MEDICINE, TRAUMA MANAGEMENT, Triage

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Derivation and validation of the Simplified Bleeding Audit Triage Tool (sBATT): a simplified trauma score for major trauma patients injured in Motor Vehicle Collisions

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Abstract:

Abstract:

Objectives: To develop and validate a simplified Bleeding Audit and Triage Trauma Score (sBATT) for use by lay persons, or in areas and environments where physiological monitoring equipment may be unavailable or inappropriate.

Design
The sBATT score was derived from the original BATT, which included prehospital systolic blood pressure (SBP), heart rate (HR), respiratory rate (RR), Glasgow Coma Score (GCS), age, and trauma mechanism; variables suitable for lay interpretation without monitoring equipment were included (age, level of consciousness, absence of radial pulse, tachycardia and trapped status). The sBATT was validated using data from the UK Trauma Audit Research Network (TARN) registry.

Setting
Data sourced from prehospital observations from multiple trauma systems in the United Kingdom.

Participants
70,027 MVC patients from the TARN registry (2012-2019). Participants included were those involved in motor vehicle collisions MVCs, with exclusion criteria being incomplete data or non-trauma-related admissions.

Interventions
Not applicable.

Primary and Secondary Outcome Measures
Death within 24 hours of MVC. Secondary: need for trauma intervention.

Results
In a cohort of 70,027 MVC patients, 1,976 (3%) died within 24 hours. The sBATT score showed an AUROC of 0.90 (95% CI: 0.90-0.91) for predicting 24-hour mortality, surpassing other trauma scores such as the Shock Index and ABC score. Sensitivity was 96%, specificity 72%, with a negative likelihood ratio below 0.1, indicating strong rule-out capability. Sensitivity analyses confirmed consistent performance across varying SBP and GCS thresholds. The sBATT score was equally effective across sexes with no significant predictive discrepancies.

Conclusions
The sBATT score is a novel, simplified tool that performs well at predicting early death in the TARN dataset. It demonstrates high predictive accuracy for 24-hour mortality and NFTI. Further research should validate sBATT in diverse populations and real-world scenarios to confirm its utility and applicability.

Strengths and limitations of this study:

Strengths:

- Clearly understood and patient centred outcome measure (24 hr mortality) and a large validation cohort (70k + patients)
- Sensitivity analyses across different physiological thresholds (e.g., SBP, GCS) and demographic groups (sexes)

Limitations:

- -Validation cohort consisted of patients from the UK, limiting generalisability to other geographic regions, particularly LMICs where EMS availability and patient demographics may differ significantly; the actual implementation and feasibility of using sBATT by lay persons in such environments were not directly assessed and would require further investigation.
- Deriving and validating such a scoring system from the same dataset can lead to overfitting, where the model performs well on the training data but may fail to generalise to new data
- Data Source Bias: TARN only includes cases that were severe enough to warrant inclusion in the registry with an injury severity score (ISS) >9; we do not know how sBATT performs in those with minor or no injuries.

Background:

Road traffic injury is the leading cause of death in children and young adults aged 5-29 years [1]. In addition to the 1.3 million deaths per year associated with road trauma, an additional 20-50 million people incur significant injury and often long-term disability [1]. Ninety-three percent of fatalities occur in lower- and middle-income countries (LMIC) where Emergency Medical Services (EMS) are often not available [2,3]. In many such countries MVCs are attended by lay bystanders, non-clinical professionals (such as firefighters) and frequent road users such as taxi drivers [4–6]. These non-clinical responders will not have access to physiological monitoring equipment which is ubiquitously available to clinical responders in higher income countries (HIC).

Following a MVC, up to 40% of patients may remain trapped in their vehicle which may be for an extended period of time [7–10]. These patients have more severe injuries and an excess mortality [9]. The application of physiological monitoring equipment to a patient, and the clinical responders' interaction with this system is associated with prolonged entrapment times [10]. New UK national guidance recognises that frequent clinical monitoring may prolong entrapment time and and as such should be kept to the minimum [11].

In established emergency care systems, initial risk stratification occurs with a patient or bystander call to EMS, with key data points extracted through conversation inputting into algorithmic decision trees. Systems such as Advanced Priority Medical Dispatch System (AMPDS) tend towards being sensitive but not specific [12]. Such systems have low specificity which may result in unnecessary resource utilisation. This in turn may prolong response times to subsequent incidents, and limit availability of EMS, especially in LMICs where resource is already most limited. In both LMIC and HIC decision making at initial emergency call may activate varying levels of ambulance service response from first responders through to critical care teams. Depending upon patient condition, instructions to bystanders may be given; for example to start cardiopulmonary resuscitation or arrest haemorrhage. Bystander instructions for the approach to trauma patients vary significantly between regions and often specific instructions are not available [13]. Accurate early risk stratification is challenging and fundamental to the chain of survival for patients with trauma as it ensures optimum use of clinical and operational resources [14,15].

The Bleeding Audit and Triage Trauma Score (BATT) is a simple triage tool that has been derived from an international cohort of trauma patients across 274 trauma centres and

validated in a variety of European settings [16]. This score includes systolic blood pressure (SBP), heart rate (HR), respiratory rate (RR), Glasgow Comas Score (GCS), age and simple mechanism of trauma (high energy and penetrating injury). BATT has been identified as a tool that is useful in ensuring equitable and appropriate utilisation of TXA and is both sensitive and specific at predicting death from bleeding at 24 hours [16]. The BATT outperforms other recognised scoring systems such as the Shock Index (SI) [16].

The purpose of this study is to validate ~~develop~~ a simplified BATT (sBATT) score derived from the initial prognostic model equation of BATT using clinical variables that may be measured in environments where physiological monitoring equipment is unavailable, impractical, or may prolong entrapment times.

Methods:

This study consists of a validation of a simplified version of the BATT score in the Trauma Audit Research Network data and compared to existing trauma score.

The original BATT was previously developed in an international cohort of 23,202 injured patients treated in 274 trauma centres in 40 countries and subsequently validated in different European studies to predict death due to bleeding and early death [16–18]. In this study, the sBATT was developed by simplification of the covariables used in the original BATT to be collected without monitoring equipment (Table 1). The sBATT weighting was derived using the integer from the coefficient of the regression equation of the prognostic model previously published [ref bmj open 17]. Points were assigned based on their significance (Table 1) giving a sBATT score range from 0 to 14.

Table 1: Variables suitable for use by bystanders from original BATT and their suggested lay application

Variable from BATT	Suggested interpretation	Interpretation considerations	Points assigned in the sBATT
Age	Older age	>65 years of age	+2
		<65 years of age	+0
Consciousness	Eyes open, converses, follows simple commands	GCS 15*	+4
		GCS <15	+0
Hypotension	Is the radial pulse present or absent?	Present: Systolic blood pressure >85mmHg **	+0
		Absent: Systolic blood pressure <85	+4
Tachycardia	Is the radial pulse rate low, normal or fast?	Heart rate ≥100	+1
		Heart rate 50-99	+0
		Heart rate <50	+1
Trapped		Trapped	+1

	Is the patient unable to leave their vehicle	Not trapped	+0

* Range assessed in validation model
** Minimum values extracted from literature review [19–22].

Primary outcome: Death within 24 hours. This is the most relevant primary outcome as bystander and prehospital care is most likely to impact on early deaths [23].

Secondary outcome: Need for trauma intervention (NFTI). We utilised a previous definition of NFTI which includes transfusion, damage control surgery or ICU admission [24].

Comparison: The performance of the sBATT is compared to other frequently utilised trauma scores including the original BATT, the ABC score, Shock Index (SI), Kampala Trauma Score (KTS), Mechanism/Glasgow Coma Scale/Age/Pressure (MGAP) and Revised Trauma Score (RTS) [25–29].

We considered the UK Trauma Audit Research Network (TARN) registry in patients injured in a MVC between January 2012 to December 2019 to validate the sBATT. See Box 1 for inclusion and exclusion criteria for TARN.

Box 1: Inclusion and exclusion criteria for the UK Trauma Audit Research Network (TARN)

The TARN database includes data on patients with an Injury Severity Score (ISS) of nine or more who are admitted to hospital in England and Wales for at least three nights, died in hospital or were transferred to another hospital for specialist care. TARN exclude patients with isolated mild traumatic brain injury with loss of consciousness, superficial scalp injury, patients 65 years or older with femoral neck or single pubic rami fracture, fracture or dislocation of the foot or hand, closed fracture or dislocation of an isolated limb, or simple skin laceration with blood loss < 20%.

Continuous variables were described by the mean and standard deviation (sd) or the median and interquartile range (IQR) according to the parametric or non-parametric distribution.

We estimated the discrimination of each trauma score. Sensitivity (Se) is the true-positive rate from which the false-negative rate (commonly named under-triage) is derived. Specificity (Sp) is the true-negative rate from which the false-positive rate (commonly named over-triage rate) is derived. We plotted the Receiver Operating Characteristic (ROC) curves for each score. We calculated the area under the ROC curve (AUROC) as an overall indicator of discrimination. An AUROC of 1 corresponds to an ideal score. We calculated the likelihood ratio (LR). A positive likelihood ratio of 10 or above results in a large increase in the probability of the outcome and a negative likelihood ratio of 0.1 or less results in a large decrease in the probability of the outcome. In trauma risk stratification, a negative LR is the most useful indicator to safely rule-out injured patients who do not have major trauma.

Because AUROC is a composite of sensitivity and specificity and as such has little practical application for clinical decision-making we plotted separately the sensitivity and the specificity

for each value of the score with a grey-zone approach [30]. The grey-zone approach identifies two boundaries of a score threshold corresponding to different objectives in clinical decision-making. The lower boundary represents the 'rule-out' limit in which major trauma could be safely excluded. The American College of Surgeons recommends an under-triage rate less than 5%, i.e. a sensitivity higher than 95% [31]. To avoid overloading of the trauma system, over-triage should not exceed 50% at this boundary. The upper boundary represents the 'rule-in' limit in which major trauma is highly certain. A specificity of 90% or higher is usually acceptable for recommending an expensive intervention, a treatment with serious side-effects or the use of scarce resources. For trauma risk stratification, the 'rule-in' boundary is often not useful.

It is important that trauma scores perform equitably for women and men, we report a sex-disaggreated analysis of the sBATT to evaluate this.

Missing data

Multiple imputation by chained equations was used in replacement of missing data. We drew 20 imputed datasets to impute values for systolic blood pressure, heart rate, respiratory rate and glasgow coma scale. We did not report any missing value for the outcomes.

Sensitivity analysis

There will be a range of accuracy of interpretation of the parameters included in the sBATT. This is particularly the case for the 'GCS' where we could find no supporting literature on lay-application and interpretation, and 'the absence of a radial pulse' where a range of collected minimum systolic blood pressure values (55-85mmHg) were reported [19–22]. To allow for this we performed sensitivity analysis with a GCS of 13 for level of consciousness and an alternative threshold of 60 mmHg of systolic blood pressure for the loss of radial pulse.

All analyses were performed using STATA software (v.16.1; Stata Corp, Station, TX, USA).

Ethics approval and consent to participate

TARN data analyses are conducted using anonymised data which is governed by a code of practice approved by the Confidentiality Advisory Group who are appointed by the Health Research Authority. Additional individual ethical approval was not required for this analysis.

Patient and Public Involvement

Patients or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Results:

Patient characteristics

Overall, 70,027 patients were included in the TARN registry and injured in a MVC between 2017 and 2021. The mean age was 46 (sd 20) years (Table 2). There were 13,851 (20%) older injured patients over 65 years and 18,175 (26%) women. Entrapment was recorded for 18,175 (11%) patients. The mean injury severity score (ISS) was 17 (sd 12). There were 1,976 (3%) patients who died at 24 hours and 3,868 (6%) died at 30 days. Considering each score threshold to identify injured patients with significant risk of early death, 20,082 (29%) injured patients were considered at risk with a sBATT≥3, 7,407 patients (11%) with a shock index ≥0.9, 9,393 (13%) with a MGAP <23; 27,650 (40%) patients with a KTS ≤13, 12,627 (18%) with a T-RTS ≤11.

Trauma score performance

The AUROC for the sBATT score was 0.90, 95%CI (0.90-0.91) (table 3 and figure 1). BATT, MGAP, T-RTS and KTS scores presented an AUROC between 0.91 and 0.94. The Shock index and the ABC score presented a low discrimination with an AUROC less than 0.70. The sensitivity of all scores were above 0.90 except for the Shock index and the ABC score. The negative likelihood ratio of the sBATT, BATT and KTS scores were below 0.1. The grey zone approach showed appropriate sensitivity for the rule-out limit with specificity exceeding 50% for sBATT, BATT, MGAP, T-RTS and KTS (figure 2). The sensitivity analysis of different thresholds of SBP and GCS of the sBATT did not show a difference on AUROC, sensitivity and negative likelihood ratio (table 4). The performances of all scores to predict NFTI were between 0.70 and 0.75 and were summarised in the supplemental figure 1. The sex-disaggregated analysis did not find any heterogeneity of the AUROC and negative LR by sex (supplemental table 1). The performance of the sBATT score to predict secondary outcomes (NFTI and NFTI or death) was summarised in the supplemental table 2.

Discussion:

We present the sBATT, a novel trauma score which utilises clinical variables that may be measured in environments where physiological monitoring equipment is unavailable or impractical. The sBATT performs well at predicting death at 24 hours with an AUROC of 0.90, 95%CI (0.90-0.91). This performs well compared to the original BATT and other established trauma scores. Neither established trauma scores or sBATT performed well at predicting NFTI-Death or NFTI alone.

Our study has important strengths. sBATT was derived and validated within TARN, a well established UK dataset with high standards of data collection and validation. We have assessed the performance of the score across values to allow for the range of SBPs at which a radial pulse might be lost and at which GCS could be incorrectly allocated - the consistently high AUROC across these ranges adds strength to the utility of the score. This score is unique in that we have demonstrated its performance for injured females and males. The precision of our results is enhanced by the substantial number of patients included in this study. Predictor variables had minimal missing values and there was no absence of outcome data (Table 2). The outcome was clearly defined and documented at a specific time point, contributing to the robustness of the results.

Our research also comes with constraints. The accuracy of predictor variable measurements may impact discrimination and calibration. Random errors could potentially emerge in all predictors (SBP, HR, GCS), resulting in diminished discrimination and calibration. The use of monitoring devices to collect the original TARN data may be prone to systematic errors, which are likely to influence calibration [32]. The rate of missing data is relatively high and may lead to biassed or misclassification. However, we performed multiple imputation to fulfil the missing value of physiological parameters. As missing values are more likely to be missing at random and dependent on the outcome, multiple imputation is more appropriate than complete case analysis that may lead to bias toward the null. Deriving and validating such a scoring system from the same dataset can lead to overfitting, where the model performs well on the training data but may fail to generalise to new data [33]. This approach may inadvertently capture noise or specific characteristics of the dataset rather than true physiological relationships. Our validation on the TARN dataset threatens the external validity of the sBATT and risks an over optimistic performance estimate. The TARN database includes a more severely injured population than typical MVC patients encountered by EMS in limiting generalisability; further, differences in measurement timing may affect transportability of the result to lay persons, requiring validation before use by EMS or laypersons in other settings. Validation from a non TARN dataset, from settings other than high-income countries, and / or a dataset for each intended population group is an important next step.

Frequently utilised trauma scores rely on physiological data and/or specific details of the injuries sustained. We could not identify a comparable trauma score that had been rigorously derived and did not rely on variables that were captured by a monitoring device. This limits the utility of other scores to contexts where clinical professionals are able to undertake such monitoring or where the necessary equipment is available. Nordberg and team developed a simplified bystander score and demonstrated its utility in the hands of untrained lay rescuers; the efficacy of the sBATT when utilised by untrained lay rescuers, trained lay rescuers and professional bystanders (such as police and fire services) would similarly need to be

ascertained [34]. Such validation would be necessary in each target population and region to ensure utility, accuracy, and acceptability across a range of socio-cultural contexts.

Ninety-three percent of road trauma deaths occur in LMICs [1]. LMICs are a large range of countries and regions: often with disparate approaches to road trauma, a wide-range of nascent and evolved EMS and socio-cultural differences that may affect the utility and adoption of such a score by lay and professional bystanders. As such significant validation and context-specific adaptation will be required in relation to sBATT.

Subject to appropriate validation sBATT has significant potential for utilisation in environments where physiological monitoring systems are not available or impractical. The use of the sBATT by those first on scene may add utility through enabling more accurate risk stratification and as such dispatch of specialist resources to the scene, trigger particular care pathways such as the administration of intramuscular TXA and improve multi-disciplinary on-scene communication through the use of a common language which delineates casualty severity. Members of this team have previously demonstrated the inequitable administration of TXA to women, and the adoption of a score such as this and its incorporation into documents that guide practice such as Patient Group Directives could help overcome these inequalities [35]. Patients that are trapped following a MVC have significant injuries and are more likely to die [9]. Previous work has demonstrated that pauses in extrication for physiological monitoring contribute to extended entrapment times [10]. The use of sBATT may offer an opportunity to decrease entrapment times as it has the potential to be performed quickly and with minimal disruption to the process of extrication. The 'extrication buddy' who joins the patient in the vehicle to explain the extrication process will be well placed to utilise the sBATT [11]. Further exploration of these areas in relation to the utility of sBATT from a clinical, operational and systems perspective is justified.

Key questions as to how the sBATT performs in different population groups and when delivered by a range of clinicians, non-clinical professionals and bystanders are essential next steps. In particular studies should address the question of lay persons ability to determine hypotension and tachycardia as defined in sBATT. Following validation studies, prospective clinical, operational and communication effectiveness studies of the performance of sBATT in the hands of clinicians caring for trapped patients following a MVC are warranted.

Conclusion

We present sBATT, a simple and reliable trauma score for use in patients injured in MVC to predict early death. This score has the potential to be used in various settings where monitoring equipment is unavailable or impractical. Future studies should validate the use of this tool by lay persons in a variety of health care environments.

Declarations

Ethics approval and consent to participate

TARN data analyses are conducted using anonymised data which is governed by a code of practice approved by the Confidentiality Advisory Group who are appointed by the Health Research Authority. Additional individual ethical approval was not required for this analysis.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding statement

This work was supported by Vision Zero South West (UK) grant number DA01.

Author contributions

TN, FXA, EF and WS contributed to the conception and study design, analysis and interpretation of data, drafting and revising the manuscript. All authors read and approved the final manuscript. FXA is the guarantor.

Competing interests:

None declared.

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Table 2. Characteristic of the study population presenting vehicle incident or collision

	N (%) N=70,027	Missing %
Age, mean (sd)	46 (20)	0
16-44	34,871 (50)	
45-64	21,305 (30)	
65-84	11,605 (17)	
≥ 85	2,246 (3)	
Women	18,175 (26)	0
Trapped at scene	7,754 (11)	0
Systolic blood pressure at scene, mean (sd)	133 (28)	22
SBP <85 mmHg	1,752 (3)	
SBP <60 mmHg	423 (1)	
Heart rate at scene, mean (sd)	87 (22)	19
Slow, HR < 50 bpm	1,149 (2)	
Fast, HR > 100 bpm	14,431 (25)	
Glasgow Coma Scale at scene, mean (sd)	14 (3)	3
15 (Alert)	58,803 (77)	
12-14 (verbal)	8,524 (12)	
7-11 (Pain)	3,081 (5)	
3-6 (Unconsciousness)	4,003 (6)	
ISS, mean (sd)	17 (12)	0

ISS <9	12,178 (17)	
ISS 9-15	26,542 (38)	
ISS ≥ 15	31,306 (45)	
AIS Head ≥ 3	15,634 (22)	0
Prehospital intubation	3,846 (6)	0
Prehospital tranexamic acid	9,567 (14)	0
Admission to MTC	44,984 (64)	0
Need for trauma intervention	21,473 (31)	0
Admission in ICU	19,947 (28)	0
Urgent surgery or embolization	5,086 (7)	0
Urgent blood transfusion	3,299 (5)	0
Early death at 24 hrs	1,976 (3)	0
Death at 30 days	3,868 (6)	0

SBP: Systolic Blood Pressure, HR: Heart rate; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; MTC: Major Trauma Centre; ICU: Intensive Care Unit

Table 3. Discrimination of the different trauma scores

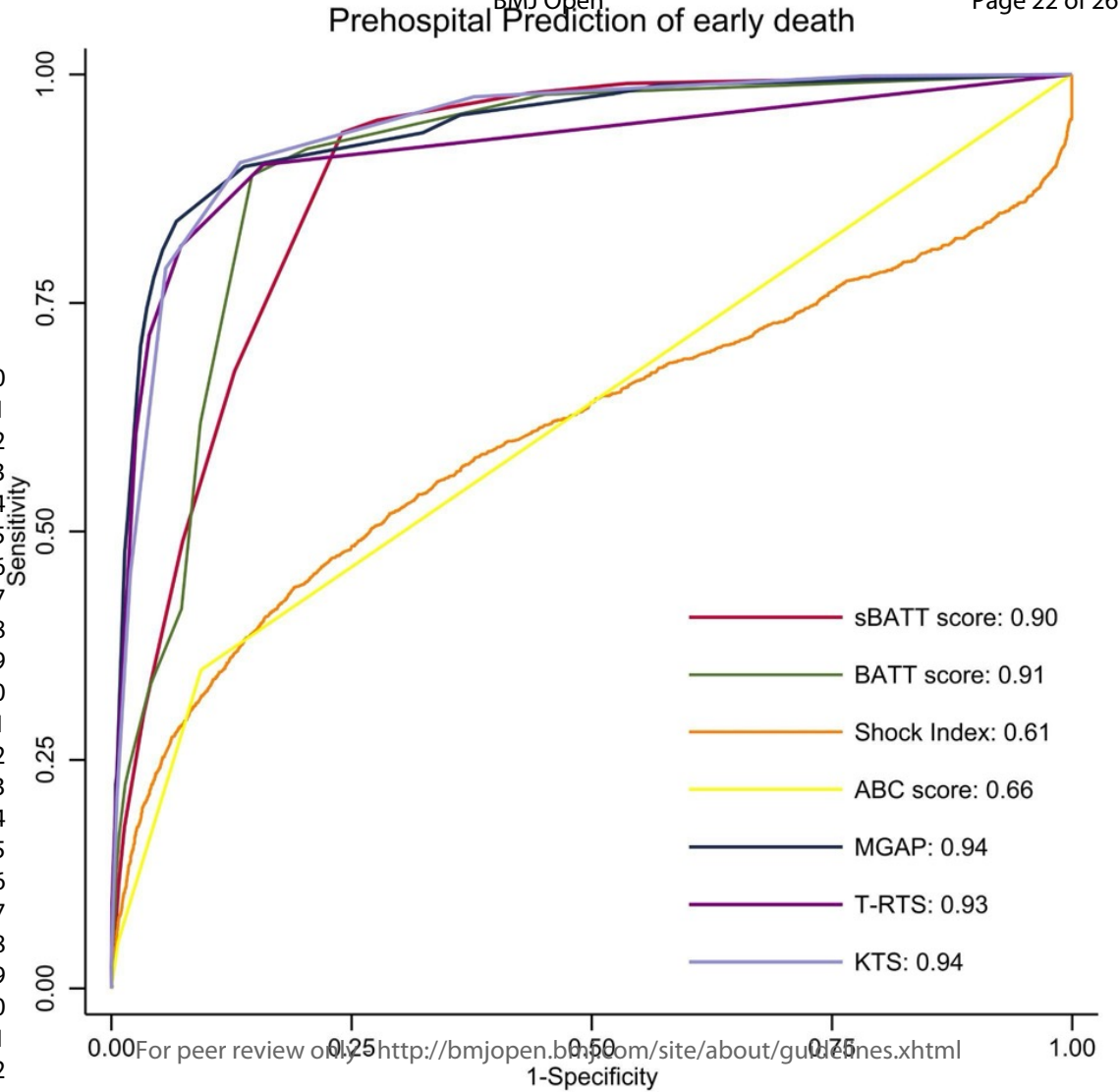
	AUROC (95% CI)	Sensitivity	Specificity	Negative Likelihood ratio
sBATT score (≥3)	0.90 (0.90-0.91)	96 %	72 %	0.06
BATT score (≥3)	0.91 (0.90-0.92)	98 %	55 %	0.04
Shock Index (≥0.9)	0.61 (0.59-0.63)	33 %	90 %	0.75
ABC score (≥2)	0.66 (0.65-0.67)	5 %	99 %	0.96
MGAP (< 23)	0.94 (0.94-0.95)	91 %	86 %	0.11
T-RTS (≤ 11)	0.93 (0.92-0.93)	91 %	84 %	0.11
KTS (≤ 13)	0.94 (0.94-0.95)	98 %	62 %	0.04

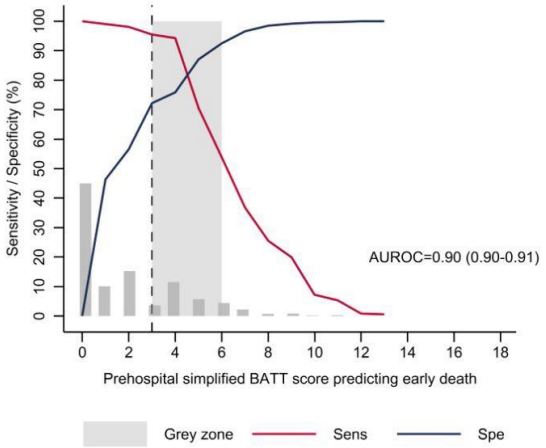
Table 4. Sensitivity analysis according to systolic blood pressure and Glasgow coma scale threshold.

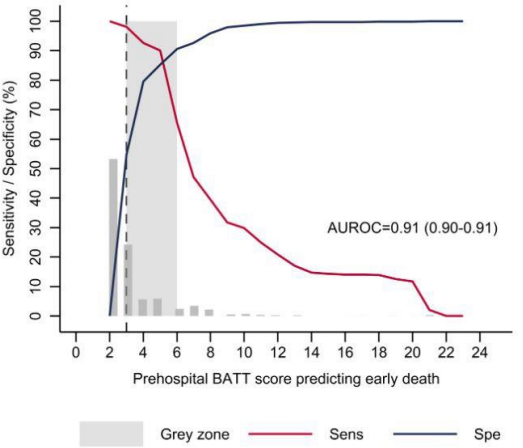
sBATT predicting early death	GCS 15	GCS 14	GCS 13
SBP 85 mmHg			
AUROC	0.91 (0.90-0.91)	0.92 (0.92-0.93)	0.93 (0.92-0.93)
Sensitivity	96%	93%	91%
Specificity	72%	82%	85%
Negative likelihood ratio	0.06	0.09	0.10
SBP 60 mmHg			
AUROC	0.90 (0.89-0.90)	0.92 (0.92-0.93)	0.93 (0.92-0.93)
Sensitivity	95%	92%	90%
Specificity	73%	83%	86%
Negative likelihood ratio	0.07	0.10	0.11

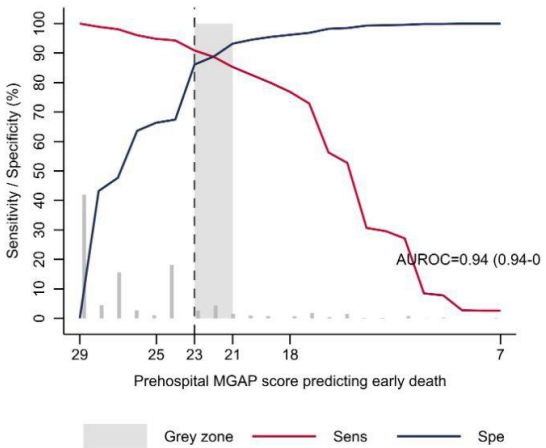
Figure 1. Receiver Operating Characteristic curves for trauma scores predicting early death

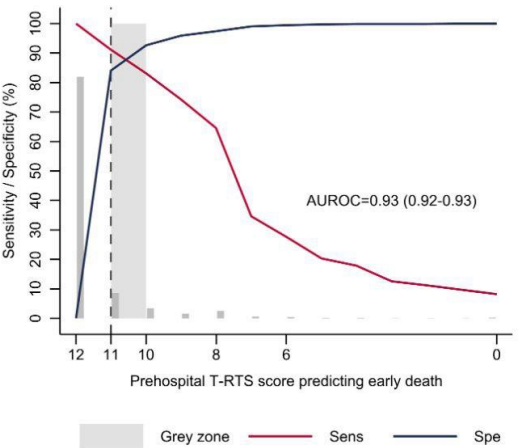
Figure 2. Sensitivity and specificity with grey-zone approach

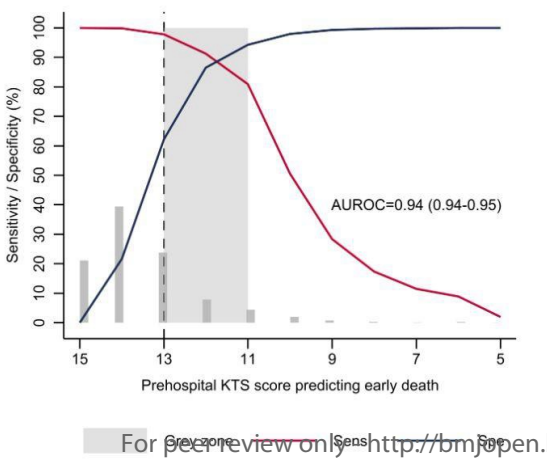


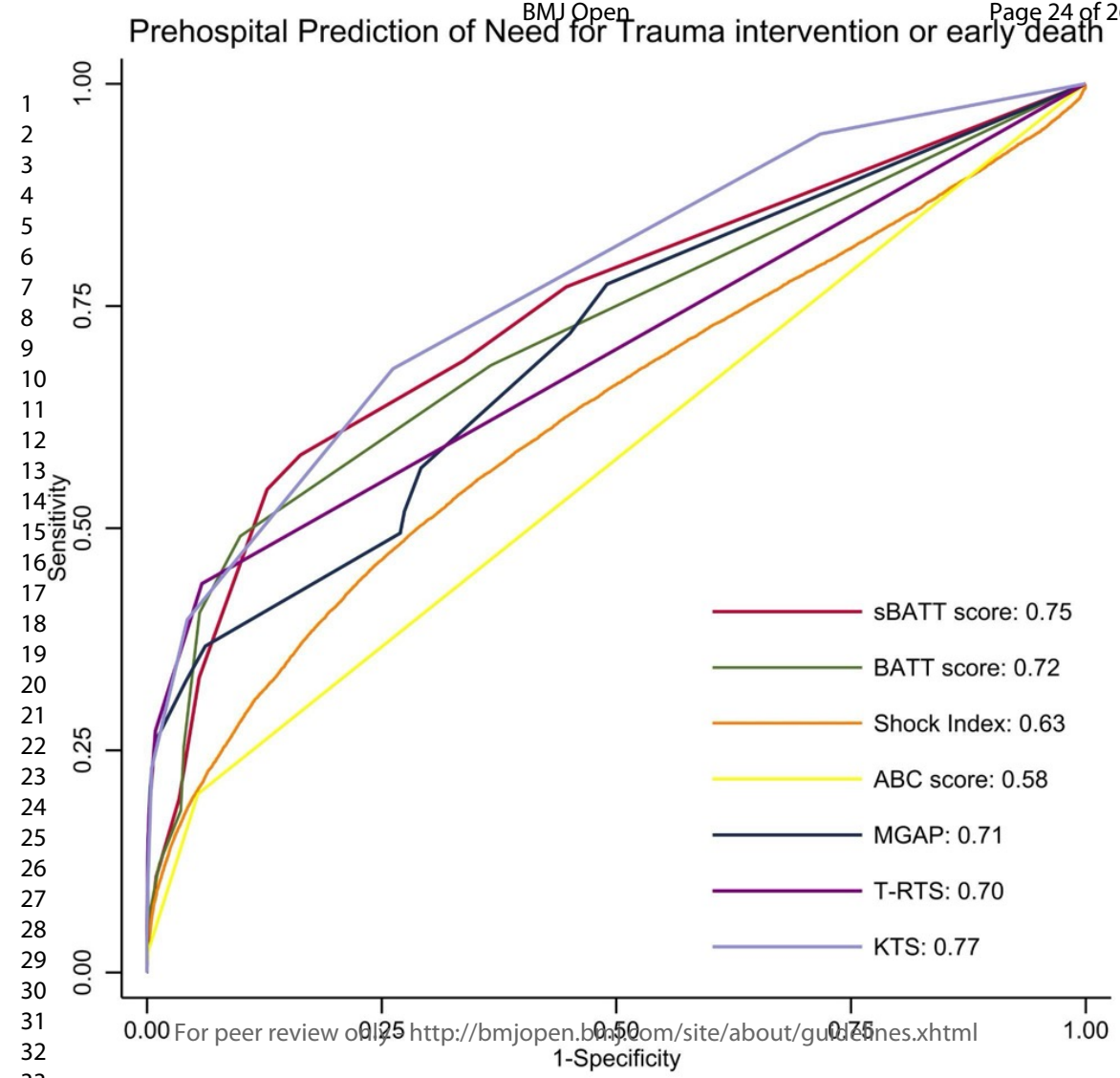




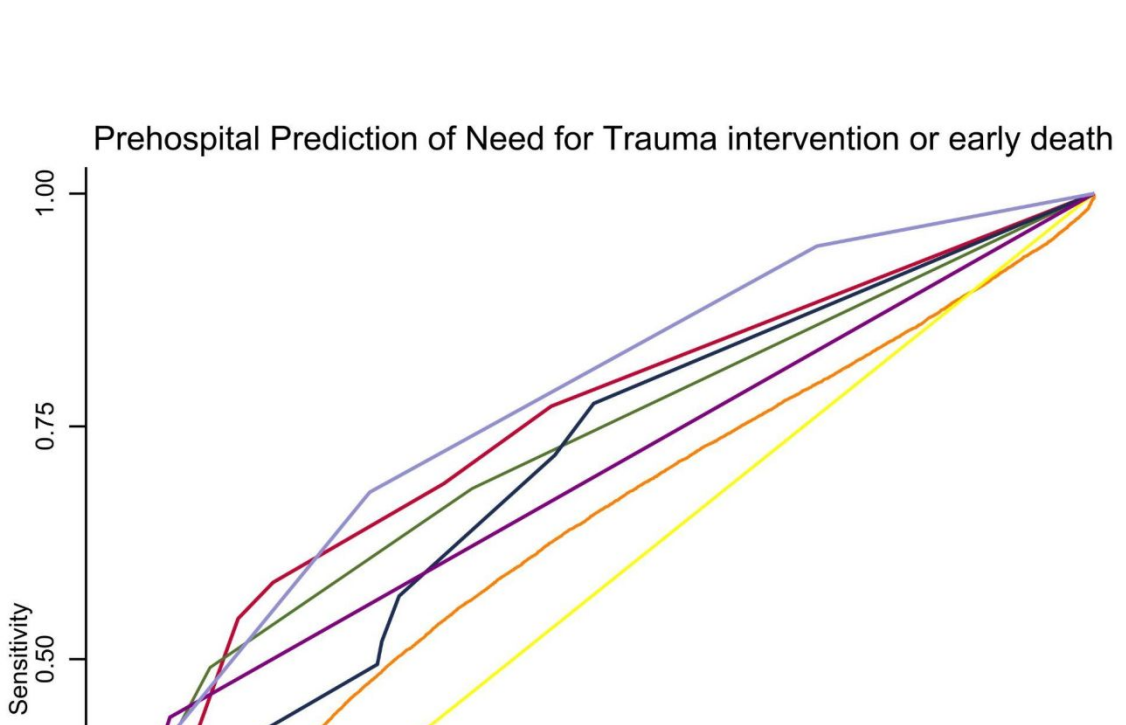








Supplemental Figure 1. Receiver Operating Characteristic curves for trauma scores predicting early death or need for trauma intervention



Supplemental Table 1. Discrimination of the different trauma scores by sex

	Women N=18,175		Men N=51,852	
	AUROC (95% CI)	Negative LR	AUROC (95% CI)	Negative LR
sBATT score (≥3)	0.89 (0.88-0.90)	0.09	0.90 (0.90-0.91)	0.05
BATT score (≥3)	0.90 (0.90-0.91)	0.04	0.91 (0.91-0.92)	0.03
Shock Index (≥0.9)	0.62 (0.59-0.65)	0.74	0.61 (0.59-0.63)	0.75
ABC score (≥2)	0.64 (0.62-0.66)	0.96	0.67 (0.65-0.68)	0.96
MGAP (< 23)	0.95 (0.94-0.95)	0.11	0.95 (0.94-0.95)	0.11
T-RTS (≤ 11)	0.91 (0.90-0.93)	0.13	0.93 (0.92-0.94)	0.11
KTS (≤ 13)	0.94 (0.93-0.95)	0.03	0.95 (0.94-0.95)	0.04

Supplemental Table 2. Discrimination of the sBATT score to predict primary and secondary outcomes.

	Early death	NFTI-Death	NFTI
sBATT (85 mmHg)			
AUROC	0.90 (0.90-0.91)	0.75 (0.74-0.75)	0.73 (0.73-0.74)
Sensitivity	96%	59%	58%
Specificity	72%	84%	83%
Negative likelihood ratio	0.06	0.49	0.51
sBATT (60 mmHg)			
AUROC	0.90 (0.89-0.90)	0.74 (0.74-0.75)	0.73 (0.72-0.73)
Sensitivity	95%	57%	56%
Specificity	73%	84%	83%
Negative likelihood ratio	0.07	0.51	0.53