Early identification of bleeding in trauma patients: external validation of traumatic bleeding scores in the Swiss Trauma Registry

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Swiss Trauma Registry

Research Article

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Abstract

Background: Early identification of bleeding at the scene of an injury is important for triage and timely treatment of injured patients and transport to an appropriate facility. The aim of the study is to compare the performance of different bleeding scores.

Methods: We examined data from the Swiss Trauma Registry for the years 2015 to 2019. The Swiss Trauma Registry includes patients with major trauma (injury severity score (ISS) ≥ 16 and/or abbreviated injury scale (AIS) head ≥ 3) admitted to any level one trauma center in Switzerland. We evaluated ABC, TASH, and Shock index (SI), used to predict massive transfusion (MT) and the BATT score, used to predict death from bleeding. We evaluated the scores when used prehospital and in-hospital in terms of discrimination (C-Statistic) and calibration (calibration slope). The outcomes were massive transfusion and death from bleeding.

Results: We examined data from 13,222 major trauma patients. There were 1,533 (12%) deaths from any cause, 344 (3%) deaths from bleeding and 128 (1%) patients who received a MT. The BATT score had the highest discrimination for MT (C-statistic: 0.87, 95%CI 0.84-0.90) followed by SI (0.84, 95%CI 0.80-0.88) and ABC (0.82, 95%CI 0.77-0.86). At hospital admission, the BATT score had the highest discrimination for death from bleeding (0.89, 95%CI 0.87-0.90) but the TASH score had the highest discrimination for MT (C-statistic: 0.94, 95%CI 0.92-0.95).

Conclusions: The BATT score can be used to estimate the risk of death from bleeding for prehospital treatment decision-making. Others scores predicting MT are not suitable to identify life-threatening bleeding.


Introduction

Trauma is a leading cause of death world-wide (1) and bleeding is one of the most preventable causes of traumatic death (2)(3)(4). Early identification of bleeding at the scene of injury is important for triage and timely treatment of injured patients, for ensuring that patients are taken to the most appropriate facility and for trauma team activation (5).

Accurate prehospital prediction of the risk of life-threatening bleeding and the need for blood transfusion could improve patient outcome. Many trauma scores predict death from any cause after injury but far fewer predict bleeding related outcomes. Most of those that do predict surrogates of bleeding such as massive transfusion (MT) or the use of specific interventions for hemorrhage (6).

Massive Transfusion (MT) is defined as administration of ≥ 10 units of red cells in the first 24 hours after injury or ≥ 3 units in the first hour after injury (5)(7)(8)(9)(10). The most popular trauma scores used to assess traumatic bleeding are the TASH (11)(12) and ABC score (13)(14). Both predict MT as a surrogate of risk of death from bleeding and include clinical parameters as well as imaging and laboratory values. Because they involve imaging and laboratory testing these scores cannot be readily assessed at the scene. Shock index (SI) (15) has recently attracted attention because it can be used at the scene of the injury (16).

The BATT score is a new prognostic model that can be used in the pre-hospital environment to predict death from bleeding. The score was developed in a large international cohort (17) of trauma patients and externally validated using data from England and Wales (18).

We used data from the Swiss Trauma Registry to externally validate existing prognostic scores for traumatic bleeding when used prehospital and after hospital admission. We compare score performances in term of overall performance, discrimination and calibration (19).
Methodology

We compared the performance of different bleeding scores using data from the Swiss Trauma Registry (STR) from January 1st 2015 to December 31st 2019. The STR includes patients with major trauma (injury severity score (ISS) ≥ 16 and/or abbreviated injury scale (AIS) head ≥ 3) admitted to any of twelve level one trauma centers in Switzerland. We excluded patients with isolated burns (including electric shock) or if the burn was the first injury, patients arriving in hospital without sign of life where no diagnostic or therapeutic measures had been initiated, patients with choking or hanging without any other injury and victims of drowning.

Calculation of bleeding scores.

We collected a set of demographic data, first prehospital and in-hospital physiological variables (Heart Rate [HR], systolic blood pressure [SBP], respiratory rate [RR], peripheral capillary oxygen saturation [SpO2], Glasgow coma scale [GCS]), first measures of in-hospital biochemical values (hemoglobin [Hb], base excess [BE]), first-read imaging (Focused Assessment with Sonography for Trauma [FAST]) and blood transfusion records (Type of Blood product, volume and time). We evaluated the most widely used scores for predicting bleeding (ABC, TASH, and SI) and a score that predicts death from bleeding (BATT). Trauma Associated Severe Haemorrhage (TASH) includes sex, HR, SBP, Hb, intra-abdominal fluid and complex fracture of the pelvis and/or long bone. Assessment of Blood Consumption (ABC) includes penetrating trauma, SBP, HR and FAST. Bleeding Audit for Trauma & Triage (BATT) includes age, mechanism of trauma (penetrating/high energy), SBP, HR, GCS, RR or SpO2. Shock Index (SI) is defined by the ratio of HR to SBP. Details about development and validation of each score is summarized in supplement 1. Others variables collected followed the Utstein for major trauma template (20) and regularly cross-checked for external validity and completeness by the register.

Calculation of outcome measures.

We assessed the accuracy of the scores to predict death from bleeding and MT (defined as receipt of ≥ 10 RBC units in the first 24 hours). We defined death from bleeding as death from any cause within 12 hours of injury, excluding asphyxia and massive destruction of skull or brain, or deaths of < 24 hours of injury with evidence of hemorrhage (with AIS diagnosis associated with bleeding listed in supplement 2). This definition was used in a previous study based on the Trauma Audit Research Network (TARN) (18). Two studies, one in North America and one including two large European registries (UK and Germany), showed that deaths due to exsanguination occurred within 24 hours with a peak at 6 hours after admission, and deaths due to head injuries occurred within 72 hours with a peak at 24 hours after admission (21) (22). We also performed sensitivity analysis with early death (less than 24 hours).

Statistical Analysis

The statistical analysis plan for the pre-specified analysis is registered at www.clinicaltrials.gov: NCT04561050. The STR has authorized us to access and process the registry data (ID-project: STR-ID 8) and granted us with the permission to publish the manuscript in accordance with the STR publication guidelines. Descriptive statistics included frequencies, 95% confidence interval (CI) for categorical variables, and either the mean (SD) or median (Interquartile range [IQR]) for continuous variables, according to data distribution. We compared the overall performance with the Brier score, discrimination, and calibration of the different scores for the prediction of MT and death from bleeding at scene and at hospital admission. The Brier Scores for the ABC score and SI were not calculated as they are not able to predict the probability of an outcome. For discrimination, we estimated the sensitivity, specificity, positive and negative likelihood ratio for the cut-off point of each score. We plotted the Receiving Operating Characteristic (ROC) curve and estimated the area under the ROC curve (AUROC) that corresponds to the concordance statistic (C-Statistic). Definitions of the statistical terms and indicators are shown in supplement 3. We plotted graphs of sensitivity (1-under-triage) and specificity (1-over-triage) separately by score's cut-off and defined two strategies of cut-off choice. The under-triage
preference zone minimized the false negative with a sensitivity of at least 95% and a specificity of about 50%. The overtriage preference zone minimized the false positive with a specificity of at least 90% and a sensitivity about 50%.

For the calibration, we estimated calibration in the large, the ratio of the predicted and observed number of events (P/O). We plotted the observed and predicted probabilities of MT for the TASH score and hemorrhagic death for the BATT by decile of the score and with local regression based on LOESS algorithm (19). The calibration of the ABC score and SI could not be assessed as they are not able to predict a probability of MT.

**Missing data**

Because there were missing values for some predictors, we used multiple imputation by chained equations, with 20 imputed datasets, to impute missing values for sex, age, SBP, RR, HR, GCS, Hb, BE, and type of injury (penetrating/blunt).

**Results**

We examined data from 13,222 trauma patients. Their characteristics are shown in Table 1. There were 1,533 (11.6%) deaths from any cause, 344 (2.6%) bleeding deaths and 128 (1.0%) patients received a MT. The median ISS of patients who received a MT was 35 [IQR 27–45] compared with 19 [IQR 14–25] for those who did not. Of patients who received a MT, 40% died compared with 12% (95%CI 11–13) of those who did not.
### Table 1
Characteristics of the Swiss Trauma Registry

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Missing N (%)</th>
<th>All patients (N = 13,222)</th>
<th>&lt;10 RCB units/24H (N = 11,341)</th>
<th>≥ 10 RCB units/24H (MT) (N = 126)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD)</td>
<td>0</td>
<td>59 (21)</td>
<td>59 (22)</td>
<td>50 (20)</td>
</tr>
<tr>
<td>Male, % (95% CI)</td>
<td>0</td>
<td>68 (67–69)</td>
<td>68 (67–69)</td>
<td>66 (57–74)</td>
</tr>
<tr>
<td>Circumstances, % (95% CI)</td>
<td>156 (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic accident</td>
<td>31 (30–32)</td>
<td>31 (30–32)</td>
<td>51 (42–60)</td>
<td></td>
</tr>
<tr>
<td>Gunshots</td>
<td>0.9 (0.7–1)</td>
<td>0.9 (0.7–1)</td>
<td>2.4 (0.5–6.8)</td>
<td></td>
</tr>
<tr>
<td>Stabbings</td>
<td>0.9 (0.7–1)</td>
<td>0.9 (0.7–1)</td>
<td>8 (4–14)</td>
<td></td>
</tr>
<tr>
<td>Falls</td>
<td>59 (58–60)</td>
<td>59 (58–60)</td>
<td>32 (24–41)</td>
<td></td>
</tr>
<tr>
<td>Mechanism, % (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penetrating</td>
<td>16 (0.12)</td>
<td>6.6 (6.1–7)</td>
<td>7 (6.5–7.5)</td>
<td>37 (28–45)</td>
</tr>
<tr>
<td>High Energy</td>
<td>146 (1)</td>
<td>56.6 (55.7–57.4)</td>
<td>56 (55–57)</td>
<td>85 (77–90)</td>
</tr>
<tr>
<td>Injury Severity Scale (ISS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>6 (0.04)</td>
<td>20 (16–26)</td>
<td>19 (14–25)</td>
<td>35 (27–45)</td>
</tr>
<tr>
<td>Category, % (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–15</td>
<td></td>
<td>23.8 (23.1–24.5)</td>
<td>25.3 (24.5–26.1)</td>
<td>3.2 (0.9–7.9)</td>
</tr>
<tr>
<td>16–24</td>
<td></td>
<td>39.7 (38.9–40.6)</td>
<td>40 (39.1–40.9)</td>
<td>14.3 (8.7–21.6)</td>
</tr>
<tr>
<td>25–34</td>
<td></td>
<td>28.2 (27.4–28.9)</td>
<td>27 (26.2–27.9)</td>
<td>31.7 (23.7–40.6)</td>
</tr>
<tr>
<td>&gt;35</td>
<td></td>
<td>8.3 (7.8–8.8)</td>
<td>7.6 (7.2–8.1)</td>
<td>50.8 (41.7–59.8)</td>
</tr>
<tr>
<td>AIS head ≥ 3, % (95% CI)</td>
<td>0</td>
<td>68 (67–68.5)</td>
<td>68 (67–69)</td>
<td>38 (29–47)</td>
</tr>
<tr>
<td>SBP</td>
<td>4412 (33)</td>
<td>134 (117–155)</td>
<td>135 (118–155)</td>
<td>97 (80–117)</td>
</tr>
<tr>
<td>&lt; 90, % (95% CI)</td>
<td></td>
<td>5.6 (5.2–6.1)</td>
<td>5.2 (4.7–5.7)</td>
<td>36 (27–47)</td>
</tr>
<tr>
<td>HR</td>
<td>4172 (31)</td>
<td>84 (72–100)</td>
<td>84 (72–100)</td>
<td>105 (88–120)</td>
</tr>
<tr>
<td>RR</td>
<td>9090 (69)</td>
<td>16 (14–20)</td>
<td>16 (14–20)</td>
<td>16 (12–25)</td>
</tr>
<tr>
<td>SpO2</td>
<td>5486 (41)</td>
<td>96 (93–98)</td>
<td>96 (93–98)</td>
<td>94 (84–94)</td>
</tr>
<tr>
<td>&lt; 90, % (95% CI)</td>
<td></td>
<td>12.3 (11.6–13.1)</td>
<td>12 (11–13)</td>
<td>38 (27–50)</td>
</tr>
</tbody>
</table>
Table 2 shows the performance of bleeding scores calculated pre-hospital and in-hospital. The Brier score for BATT was 0.023 both pre-hospital and in-hospital. The Brier score for the TASH score at hospital admission was 0.039. In the prehospital setting, the BATT score had a higher discrimination for death from bleeding than ABC and SI, respectively C-statistic: 0.86, 95%CI (0.84–0.88); 0.64, 95%CI (0.61–0.67); 0.57, 95%CI (0.53–0.61); P < 0.001. The BATT score had the highest discrimination for MT (C-statistic: 0.87, 95%CI 0.84–0.90) followed by the Shock Index (C-statistic: 0.84, 95%CI 0.80–0.88) and the ABC score (C-statistic: 0.82, 95%CI 0.77–0.86), P = 0.02. At hospital admission, the BATT score had the highest discrimination for death from bleeding (C-statistic: 0.89, 95%CI 0.87–0.90). The TASH score had the highest discrimination for MT (C-statistic: 0.94, 95%CI 0.92–0.95). Figure 1 shows ROC curves for MT and death from bleeding. We presented in supplement 4 ROC curves for early death (within 24 hours) as sensitivity analysis for death from bleeding.
### Table 2
Performance of bleeding scores

<table>
<thead>
<tr>
<th>Overall Performance</th>
<th>Discrimination</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brier score</td>
<td>C-statistic (95% CI) for massive transfusion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for massive transfusion</td>
</tr>
<tr>
<td>Prehospital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BATT score</td>
<td>0.023</td>
<td>0.87 (0.84–0.90)</td>
</tr>
<tr>
<td>Shock Index c</td>
<td>-</td>
<td>0.84 (0.80–0.88)</td>
</tr>
<tr>
<td>ABC score c,d</td>
<td>-</td>
<td>0.82 (0.77–0.86)</td>
</tr>
<tr>
<td>TASH score e</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>In-Hospital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BATT score</td>
<td>0.023</td>
<td>0.89 (0.86–0.91)</td>
</tr>
<tr>
<td>Shock Index c</td>
<td>-</td>
<td>0.89 (0.86–0.92)</td>
</tr>
<tr>
<td>ABC score c</td>
<td>-</td>
<td>0.84 (0.80–0.87)</td>
</tr>
<tr>
<td>TASH score</td>
<td>0.039</td>
<td>0.94 (0.92–0.95)</td>
</tr>
</tbody>
</table>

**a** BATT score predicted death from bleeding; TASH score predicted massive transfusion. **b** P < 0.001

**c** The Brier score, calibration in the large, calibration intercept and calibration slope cannot be estimated as SI and ABC score does not estimate a probability of massive transfusion or death from bleeding.

**d** ABC score was estimated without ultrasonography (FAST) as ultrasonography is not available in routine in the prehospital setting.

**e** TASH score in the prehospital setting is not feasible as biological assay and imaging are not available.

The prehospital BATT score ≥ 3 presented a sensitivity of 96% and a specificity of 50% for death from bleeding (Fig. 2, Supplement 5). The sensitivity for death from bleeding prediction were low for all thresholds of the ABC score, the TASH score, and the SI. ABC score ≥ 2 showed a sensitivity of 12% which means that 88% of injured patients died from...
bleeding had an ABC score < 2 (Fig. 3, supplement 5). In the prehospital setting, a BATT score ≥ 8, SI > 0.9 and ABC score ≥ 2 had a specificity of more than 90% for MT and death from bleeding (Fig. 2 and Supplement 5 and 6). At hospital admission, the TASH score ≥ 18 had the highest specificity for MT prediction (99.6%) but the lowest sensitivity (14.1%). A prehospital BATT score ≥ 3 showed an under-triage of 5% and an over-triage of 50% for both death from bleeding and MT (Supplement 5, 6 and 7). The ABC score and the SI were not able to provide a prediction allowing less than 5% of under-triage (Fig. 2).

For the BATT score, the calibration curve showed slight over-prediction in low-risk patients and under-prediction in intermediate and high-risk patients. For the TASH score at hospital admission, the calibration curve showed over-prediction of MT (Fig. 3).

Discussion

Main findings

Only the BATT score accurately predicts the risk of death from bleeding in the pre-hospital setting. The sensitivities of scores predicting MT (ABC, TASH, SI) are low and they are not suitable for the identification of life-threatening bleeding. All scores accurately predict MT.

Strengths and limitations

Our study has important strengths. We validated the scores in data from a large national trauma registry which includes trauma patients with a wide range of bleeding severity. This provided a heterogenous case-mix that allowed for accurate assessment of discrimination (23). The large number of patients in this study increased the precision of the results. Finally, we used first parameters recorded by paramedics at trauma scene and at hospital admission when the decision of MT had to be made. We used rigorous methods, assessing not only discrimination but all performance criteria, including global performance, discrimination, and calibration. We determined sensitivity and specificity for each threshold and considered the risks of under-triage or over-triage.

Our study also has limitations. Measurement error in predictor variables could affect discrimination and calibration. Random error arises for all predictors (BP, HR, GCS, RR) and leads to reduced discrimination and calibration. Systematic errors arising from the use of monitoring devices is more likely to affect calibration (24). Because the outcome “death from bleeding” was not available in the STR database, we used early death with evidence of haemorrhage as a proxy (25) and subject to misclassification bias. Any outcome misclassification would be expected to decrease the C-statistic and reduce the model performance (26) and since the C-statistic was high and model performance was excellent, misclassification is unlikely to be an important weakness. We are also reassured by the sensitivity analysis with early death that found similar results. Because MT and some predictors were missing, we imputed theses data. We assumed that data were missing at random. If not, complete case should perform better. We noticed a survival bias on the primary outcome. As some patients may not survive long enough to receive 10 RBC in the first 24 hours, MT is subject to misclassification.

Comparison to other studies

Our patient's characteristics were similar to other European studies (12)(18). To the best of our knowledge, the BATT score is the only score that predicts traumatic death from bleeding and could be easily applied at the trauma scene (18). In our study, we found similar good discrimination to identify MT for TASH, ABC score and SI (11)(12)(13)(14)(15)(27) (28). The MT rate was low and comparable to the lower limit reported in the literature (11)(12)(13)(18)(28). For the TASH score, we observed a clear over-prediction of MT for all risk patients with 6.1% of predicted probability. In the literature, we observed a decrease of MT use over the last years. The German registry reported 14.1% of MT between 1993 to 2003
The decline in MT might be explained by changes in blood management practice in severe trauma. Moreover, early identification of acute trauma coagulopathy by thromboelastography might have decreased the use of blood products by using more coagulation factors than fresh-frozen plasma (30). As MT is practice-dependent, we presumed that MT is not a reliable outcome to assess the risk of bleeding.

**Clinical implication**

Early identification of patients at risk of life-threatening bleeding is critical for the administration of life-saving interventions and for transport to the appropriate hospital. Scores using laboratory assays and imaging such as TASH are not useful because they cannot be used pre-hospital. Scores using MT may not be able to identify life-threatening bleeding. More than three quarters of patients who died from bleeding or died within 24 hours were not identified by the SI and ABC scores. Moreover, predicting the receipt of particular types of medical care runs the risk of circularity with a high-risk of false prediction.

The BATT score accurately predicts death from bleeding and facilitates the identification of patients with a low, intermediate, and high-risk of life-threatening bleeding. Because it can be used in the prehospital setting it is ideal for early decision-making.

A BATT score $\geq 3$ includes patients with an intermediate and high risk and has an undertriage of 5% and an overtriage of 50%. This overtriage rate considered acceptable by the American College of Surgeon (31) and so a BATT score $\geq 3$ seems an appropriate cut off for triage. The high-risk BATT score ($\geq 8$) with less than 10% of overtriage may be useful for prehospital activation of MT protocol. There is recent evidence that many patients that could benefit from tranexamic acid treatment are not being treated, in particular older women (32). The use of the BATT score by paramedics could rationalize the use of tranexamic acid and help tackle inequalities (age and gender).

**Conclusion**

The BATT score accurately estimates the risk of death due to bleeding and can be used for prehospital treatment decision-making.

**Declarations**

**Ethics approval and consent to participate**

As mandatory by the Swiss law, trauma registry is authorized by the Human Research Act (HRA). Our study was approved by The Regional Institutional Ethics Committee of the Swiss Trauma Registry (review board 331/13). Due to the observational non-interventional aspect of the study based on a multicentric anonymized register, informed consent was waived.

**Competing interests**

The authors declare that they have no competing interests.

**Availability of data and material**

The datasets used during the current study belongs to the Swiss Trauma Registry (STR) and are available from the STR on reasonable request.

**Fundings**
None

Consent for publication

Not applicable

Authors’ contributions

A.C., F.X.A. and P.N.C. were involved in study design. A.C. and F.X.A analyzed the data. A.C., F.X.A and I.R. drafted the manuscript. P.N.C., T.B. and I.R. reviewed and contributed to the final manuscript.

References


**Figures**

**Figure 1**

*Receiving Operating Curve (ROC) of bleeding scores*
Figure 2

Graphs of sensitivity/specificity in death from bleeding prediction by score's cut-off
Figure 3

Calibration Curves for external validation of BATT and TASH score

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementaryfiles.docx