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Prediction of intra-hospital mortality after severe trauma: which pre-hospital score is the most accurate?

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ABSTRACT

Purpose: Computing trauma scores in the field allows immediate severity assessment for appropriate triage. Two pre-hospital scores can be useful in this context: the Triage-Revised Trauma Score (T-RTS) and the Mechanism, Glasgow, Age and arterial Pressure (MGAP) score. The Trauma Revised Injury Severity Score (TRISS), not applicable in the pre-hospital setting, is the reference score to predict in-hospital mortality after severe trauma. The aim of this study was to compare T-RTS, MGAP and TRISS in a cohort of consecutive patients admitted in the Trauma system of the Northern French Alps(TRENAU).
Materials and methods: From 2009 to 2011, 3260 patients with suspected severe trauma according to the Vittel criteria were included in the TRENAU registry. All data necessary to compute T-RTS, MGAP and TRISS were collected in patients admitted to one level-I, two level-II and ten level-III trauma centers. The primary endpoint was death from any cause during hospital stay. Discriminative power of each score to predict mortality was measured using receiver operating curve (ROC) analysis. To test the relevancy of each score for triage, we also tested their sensitivity at usual cut-offs. We expected a sensitivity higher than 95% to limit undertriage.
Results: The TRISS score showed the highest area under the ROC curve (0.95 [CI 95% 0.94–0.97], $p < 0.01$). Pre-hospital MGAP score had significantly higher AUC compared to T-RTS (0.93 [CI 95% 0.91–0.95] vs 0.86 [CI 95% 0.83–0.89], respectively, $p < 0.01$). MGAP score < 23 had a sensitivity of 88% to detect mortality. Sensitivities of T-RTS < 12 and TRISS < 0.91 were 79% and 87%, respectively.
Discussion/conclusion: Pre-hospital calculation of the MGAP score appeared superior to T-RTS score in predicting intra-hospital mortality in a cohort of trauma patients. Although TRISS had the highest AUC, this score can only be available after hospital admission. These findings suggest that the MGAP score could be of interest in the pre-hospital setting to assess patients' severity. However, its lack of sensitivity indicates that MGAP should not replace the decision scheme to direct the most severe patients to level-I trauma center.

Introduction

Adequate triage of severe trauma patients is one of the key issues for trauma care [1]. Appropriate triage aims at directing the most severe patients to level-I trauma centers with high-level technical facilities and expertise to decrease intra-hospital mortality [2]. For this purpose, pre-hospital organization including decision scheme for triage has been developed in many countries [3–7]. Apart from specific algorithms, pre-hospital trauma scores have been implemented to predict intra-hospital mortality and can therefore be computed for pre-hospital triage.

The Triage Revised Trauma Score (T-RTS), which combines respiratory rate, systolic arterial blood pressure and the Glasgow Coma Scale, has gained general acceptance to predict post-traumatic

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mortality [8]. This score is easy to compute in the field and can be useful for the outcome prediction in a broad range of trauma patients. The T-RTS varies from 0 to 12 and is used by paramedics for triage and clinical decision-making in the pre-hospital field. However, this score was implemented in countries where paramedics led the pre-hospital setting and T-RTS may not apply to physician-staffed pre-hospital settings, which are more frequent in Europe. The Mechanism, Glasgow coma scale, Age, and Arterial Pressure (MGAP) score has been created for the pre-hospital setting with physician-staffed ambulance. MGAP was validated in 1003 patients admitted to a single level-I trauma center from 2003 to 2005 [9]. In this validation cohort, the global predictive properties of the MGAP score were equivalent to T-RTS but significantly lower than Trauma Revised Injury Severity Score (TRISS). This last score, not applicable in the pre-hospital setting, is considered as the reference to predict the outcome in trauma patients [8,10]. External validation of the MGAP score was only performed on hospital admission [11,12]. Whether the MGAP score used in the pre-hospital setting might be accurate to predict intra-hospital mortality among unselected trauma patients admitted to level I–III trauma centers is unknown. Our aim was to compare the predictive power of the MGAP, T-RTS and TRISS scores in a cohort of consecutive trauma patients from the Trauma System of the Northern French Alps (TRENAU) registry.

Patients and methods

The study was conducted in 13 hospitals from the TRENAU network, which gathers university-affiliated and non university-affiliated hospitals in the French Alps. The TRENAU contains one level-I trauma center, two level-II centers and ten level-III centers [3]. For every trauma patient, demographic, physiologic and outcome data are prospectively computed in a registry according to the Utstein template [13,14] and regularly crosschecked for external validity. This registry has collected medical data relating to the whole process of trauma management, from the scene to admission in the intensive care unit. Research assistants regularly check the integrity and completeness of data and collect patient outcome at hospital discharge. The Regional Institutional Ethics Committee approved the implementation of the TRENAU registry (Comité d'Ethique des Centres d'Investigation Clinique de l'inter-région Rhône-Alpes-Auvergne, IRB number 5708) and, given its observational nature, waived the requirements for written informed consent from each patient.

All patients recorded in the registry over a three year period (2009-2011) were included if severe trauma was suspected in the pre-hospital setting using the French Vittel triage criteria. Patients with on-scene cardiac arrest and those with missing data for score calculation were excluded. Age, sex, trauma characteristics, heart rate, initial systolic arterial blood pressure, respiratory rate, Glasgow Coma Scale and pulse oximetry were collected during pre-hospital care. These variables enabled the calculation of T-RTS and MGAP scores obtained on-scene. At admission in the emergency room, systolic arterial blood pressure, pulse oximetry and Glasgow Coma Scale were also collected. Following Sartorius et al. [9], the MGAP score was categorized according to the risk of death as high risk (MGAP scores from 3 to 17), intermediate risk (MGAP scores from 18 to 22) and low risk (MGAP scores from 23 to 29). In addition, the Abbreviated Injury Scale (AIS), Injury Severity Score (ISS) and TRISS were calculated after comprehensive assessment of injuries. The primary endpoint was intra-hospital mortality defined as death from any cause during hospital stay.

Descriptive statistics included frequencies and percentages for categorical variables, and mean (SD or 95% confidence interval, CI) for continuous variables. Diagnosis performance of each score to predict intra-hospital mortality was evaluated using the area under the receiver operating characteristic curve (AUC-ROC). The AUC-ROC curves of the three scores (MGAP, T-RTS and TRISS) were compared using a test for dependent ROC curves (same sample) with Bonferroni's correction for multiple comparisons. To test the ability of each score to be used as triage tool, sensitivity, specificity, positive predictive value and negative predictive value were also calculated at their usual threshold: MGAP <23, T-RTS <12 and TRISS <0.91[9]. In accordance with the American College of Surgeons Committee on Trauma (ACSCOT), an efficient score should detect more than 95% of deceased patients in the field (sensitivity $>$ 95%) corresponding to undertriage lower than 5% [15]. Conversely, specificity of a score indicates overtriage. For each variable, 95% confidence intervals of estimates were provided. Statistical analysis was performed with R software (version 3.1.2, http://www.cran.org). A p-value of 0.05 or less was considered statistically significant.

Results

Out of the 3689 patients included from 2009 to 2011 in the TRENAU registry, 429 patients were excluded. Flowchart of the study population with reasons for exclusion is represented in Fig. 1. Thus, 3260 patients were included in this study. Main characteristics of the studied population are summarized in Table 1. The typical patient was young male suffering from blunt injury. Overall intra-hospital mortality was 5.7% (n = 185 patients). According to the MGAP score definition, 222 (7%) patients were classified as high-risk patients for intra-hospital death, 400 (12%) patients were categorized as intermediate risk for death and 2638 (81%) patients belonged to the low-risk category. Intra-hospital mortality for each MGAP category (50.5%, 13% and 0.8%, respectively), together with previously reported mortalities by Sartorius et al., is presented in Fig. 2. In the TRENAU cohort, mortality was higher in the high-risk and intermediate-risk patients compared to the historical validation cohort while mortality was lower in the low-risk patients.

We found the highest AUC to predict intra-hospital mortality for the TRISS score (0.95 [CI 95% 0.94–0.97], $p < 0.01$). Pre-hospital MGAP score had significantly higher AUC compared to T-RTS score (0.93 [CI 95% 0.91–0.95] vs 0.86 [CI 95% 0.83-0.89], respectively, $p < 0.01$, see Fig. 3). Diagnostic properties at accepted cut-off for MGAP (<23), T-RTS (<12) and TRISS (<0.91) are presented on Table 2. Considering the MGAP score as a triage tool, the accepted threshold of 23 had a sensitivity of 88% (Table 2). In fact, 21 patients with MGAP scores strictly higher than 22 did not survive, i.e. 12% of the overall non-survival population (n = 185 patients). This proportion is higher than the acceptable rate of 5% that defines undertriage. To detect more than 95% of the non-survival patients, the MGAP score threshold should be set at 25.

Discussion

In a French pre-hospital multicenter cohort from the TRENAU registry, the MGAP score was superior to T-RTS to predict intra-hospital mortality whereas TRISS had the highest AUC for outcome prediction. Since TRISS is only available after hospital admission, the MGAP score is particularly relevant in the pre-hospital setting to detect high-risk patients. This score is easy to compute in the field and can provide immediate reliable information about patients' evolution before intra-hospital comprehensive assessment.

In the initial single-center validation cohort of Sartorius et al., MGAP and T-RTS had similar AUC (0.90 and 0.88, respectively) that clearly hindered the interest of the MGAP score [9]. Interestingly in our multicenter trauma population, AUC of the MGAP score was higher than the T-RTS, which indicated better prognostication with

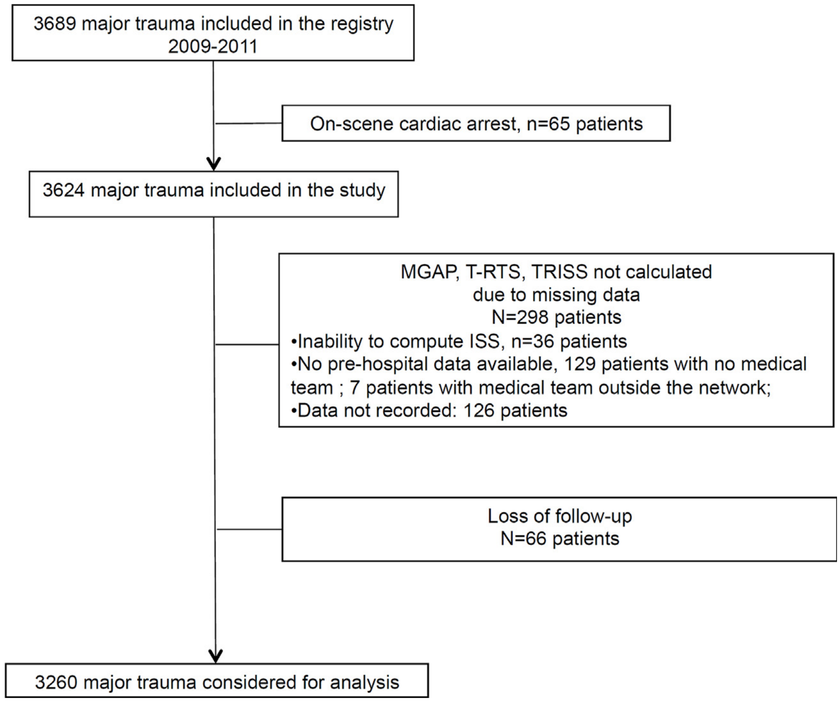

Fig. 1. Flowchart of the study population.

the MGAP score. Improved accuracy with the MGAP score maybe explained by the replacement of the least useful component of T-RTS (respiratory rate) with two more potent predictors of survival, i.e. age and mechanism of injury. Because these two factors are always available in the field, our study provides new evidence that they should be included in pre-hospital score to further predict mortality. In-hospital MGAP performance was also studied in Europe. From 2000 to 2010, 79,824 patients were included in 160 trauma centers in the United Kingdom to compute the MGAP score at hospital admission [11]. With acceptable value for the AUC (0.86 95% CI 0.86–0.87) to predict intra-hospital mortality, the MGAP score was found to be a valid triage tool to stratify emergency department patients according to their risk of death. Of note, British trauma system did not include pre-hospital medical management and pre-hospital assessment of the MGAP score was not performed in this study. The authors also found similar mortality as compared to Sartorius et al. for the three MGAP categories (low, intermediate and high risk of death). In the TRENAU cohort, we found different repartition between the three MGAP categories. For instance, 80% of the global population was classified as low risk in our cohort vs 50% in the historical cohort. In fact, in the present cohort, the proportion of patients with ISS higher than 15 was 48% ($n = 1560$ patients) vs 63% ($n = 864$ patients) in the historical cohort [9]. This high proportion of low-risk patients relied on the criteria used for the TRENAU registry: all patients with suspected severe trauma according to the French Vittel triage criteria were included [16], even those with isolated high-kinetic accident. Accordingly, mortality in the low-risk population was lower than the initial report from Sartorius et al.

Despite performing AUC, sensitivity of MGAP score < 23 was only 88%, which was significantly lower than 95% described by

Table 1
Characteristics of the global population ($n = 3260$ patients).

Variable	Value
Sex male, *n* (%)	2478 (76%)
Age, years	37 (± 19)
Blunt trauma, *n* (%)	3044 (93%)
Pre-hospital physiological parameters	
Heart rate, bpm	90 (± 22)
Systolic arterial blood pressure, mmHg	124 (± 25)
Respiratory rate, cpm	20 (± 6)
Pulse oximetry, %	96 (± 6)
Glasgow Coma Scale	13 (± 3)
Admission physiological parameters	
Hear rate, bpm	86 (± 21)
Systolic arterial blood pressure, mmHg	124 (± 24)
Respiratory rate, cpm	18 (± 5)
Pulse oximetry, %	98% (± 4.5)
Glasgow Coma Scale	13 (4)
ISS	17 (± 13)
ISS > 15	1560 (48%)
MGAP score	26 (± 4)
MGAP category	
3 to 17	222 (7%)
18 to 22	400 (12%)
23 to 29	2638 (81%)
T-RTS	11.4 [1.1]
TRISS	0.92 [0.17]
Intra-hospital mortality	5.7%

ISS, Injury Severity Score; MGAP, Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure; T-RTS, triage Revised Trauma Score; TRISS, Trauma Related Injury Severity Score. Data are value (± SD).

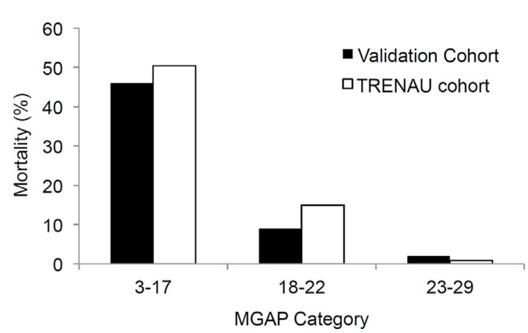

Fig. 2. Mortality according to Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure (MGAP) score in the TRENAU cohort (black columns, $n = 3260$ patients) and the validation cohort (white columns, $n = 1003$ patients).

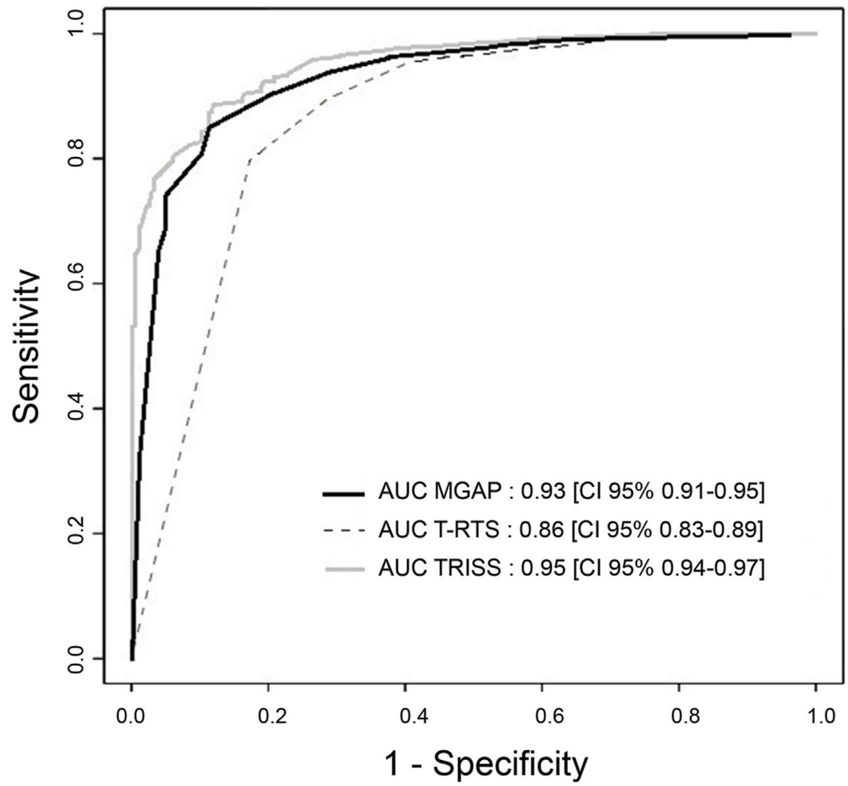

Fig. 3. Receiving operating curves of the Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure (MGAP) and triage Revised Trauma Score (T-RTS), and Trauma Related Injury Severity Score (TRISS) scores to predict mortality in the TRENAU cohort (n = 3260 patients).

Sartorius et al. Since detecting severity in the field is crucial for appropriate triage, high sensitivity of the MGAP threshold is mandatory to decrease undertriage. According to the American College of Surgeons Committee on Trauma, the sensitivity should be at least 95%, indicating undertriage less than 5% [15]. In our study, the threshold for the MGAP score should be set at 25 to reach this aim. The poor sensitivity of MGAP at the accepted threshold hindered its use for triage. The lowest sensitivities observed in the TRENAU cohort could be explained by the non-selected characteristic of the trauma population. Indeed, Sartorius et al. validated their score with highly selected patients admitted to level-I trauma center [9]. These patients presented higher mortality rate (18%) as compared to the TRENAU cohort (5.7%). The decrease in mortality rate in our cohort logically affected the sensitivity of the MGAP score. Accordingly, the Trauma Audit and Research Network found lower sensitivity (66%) of MGAP at hospital admission in 79,807 non-selected trauma patients [11]. Taken together, these findings limit the use of isolated trauma score for pre-hospital triage. Independently of early assessment of mortality in trauma patients, decision schemes for triage should be developed to reduce undertriage. Recently, in the TRENAU network, the combination of grading system and triage algorithm in the pre-hospital setting decreased undertriage from 25% to 8% [3]. None of these procedures were based upon the calculation of trauma scores. Nevertheless, the MGAP score could be integrated to initial medical assessment to further predict mortality after severe trauma.

Table 2
Diagnostic properties of each score (MGAP, T-RTS and TRISS) at usual thresholds: MGAP <23, T-RTS <12 and TRISS <0.91.

Score	MGAP	T-RTS	TRISS
Threshold	< 23	< 12	< 0.91
Sensitivity	0.88 [0.87– 0.89]	0.79 [0.78– 0.80]	0.87 [0.86– 0.88]
Specificity	0.82 [0.81– 0.83]	0.88 [0.87– 0.89]	0.85 [0.84 –0.86]
Positive predictive value	0.26 [0.24– 0.28]	0.19 [0.18– 0.20]	0.29 [0.27– 0.31]
Negative predictive value	0.99 [0.99– 0.99]	0.98 [0.98–0.98]	0.99 [0.99– 0.99]

Our study had several limitations. First, 429 patients were excluded from the study. Reasons for exclusion included on-scene cardiac arrest, loss of follow-up to assess mortality or missing data that were necessary to compute one of the scores. Missing data are often observed in trauma registry and occur despite regular checking by research assistants. Second, this study was retrospective although data collection was prospective. Finally, outcomes can be discussed. Beyond mortality, score abilities to predict the need for emergency treatment could be of interest. Our study was not designed to test the relevancy of trauma scores in this context. However, risk factors for emergency treatments (massive transfusion, chest tube insertion and/or embolization) were already reported in France and did not fit the MGAP items [17].

In conclusion, the MGAP score adequately predicted intra-hospital mortality in our cohort. In a physician-staffed ambulance response, this score had better performance than T-RTS used by paramedics in the pre-hospital setting. Higher accuracy for the MGAP score to predict mortality may promote its preferential use for early outcome prediction in the pre-hospital field. However, poor sensitivity questioned the usefulness of the MGAP score for triage after severe trauma. This score could be used in combination with triage algorithms to further indicate patients' severity at the early phase of severe trauma and should not replace decision scheme to direct the most severe patients to level-I trauma center.

Conflict of interest statement

The authors have no conflict of interest to declare.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.injury.2015.10.035.

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