Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure (MGAP): A new simple prehospital triage score to predict mortality in trauma patients*

Danielle Sartorius, MD; Yannick Le Manach, MD; Jean-Stéphane David, MD, PhD; Elisabeth Rancurel, MD; Nadia Smail, MD; Michel Thicoïpé, MD; Eric Wiel, MD, PhD; Agnès Ricard-Hibon, MD, PhD; Frédéric Berthier, MD; Pierre-Yves Gueugniaud, MD, PhD; Bruno Riou, MD, PhD

Objectives: **Prehospital triage of trauma patients is of paramount importance because adequate trauma center referral improves survival. We developed a simple score that is easy to calculate in the prehospital phase.**

Design: **Multicenter prospective observational study.**

Setting: **Prehospital physician-staffed emergency system in university and nonuniversity hospitals.**

Interventions: **We evaluated 1360 trauma patients receiving care from a prehospital mobile intensive care unit in 22 centers in France during 2002. The association of prehospital variables with in-hospital death was tested using logistic regression, and a simple score (the Mechanism, Glasgow coma scale, Age, and Arterial Pressure [MGAP] score) was created and compared with the triage Revised Trauma Score, Revised Trauma Score, and Trauma Related Injury Severity Score. The model was validated in 1003 patients from 2003 through 2005.**

Measurements and Main Results: **Four independent variables were identified, and each was assigned a number of points proportional to its regression coefficient to provide the MGAP score: Glasgow Coma Scale (from 3–15 points), blunt trauma (4 points), systolic arterial blood pressure (>120 mm Hg: 5 points, 60 to 120 mm Hg: 3 points), and age <60 yrs (5 points). The area under the receiver operating characteristic curve of MGAP was not significantly different from that of the triage Revised Trauma Score or Revised Trauma Score, but when sensitivity was fixed >0.95 (undertriage of 0.05), the MGAP score was more specific and accurate than triage Revised Trauma Score and Revised Trauma Score, approaching those of Trauma Related Injury Severity Score. We defined three risk groups: low (23–29 points), intermediate (18–22 points), and high risk (<18 points). In the derivation cohort, the mortality was 2.8%, 15%, and 48%, respectively. Comparable characteristics of the MGAP score were observed in the validation cohort.**

Conclusion: **The MGAP score can accurately predict in-hospital death in trauma patients. (Crit Care Med 2010; 38:831–837)**

Key Words: trauma; score; mortality; prehospital

Trauma is the first cause of death before 40 yrs of age and is responsible for numerous definitive handicaps and high costs (1). In most developed countries, a regional trauma system has been developed that categorizes hospitals according to the resources required to provide various levels of care for traumatic injuries. It has recently been demonstrated that the overall risk of death was 25% lower when care was provided at a trauma center (2), emphasizing the importance of appropriate prehospital triage of trauma patients.

Many prehospital trauma scores have been developed, of which the Revised Trauma Score (RTS) remains the most widely cited (3). The RTS has been incorporated into the Trauma Related Injury Severity Score (TRISS), which remains the most recognized score for predicting mortality in trauma patients (4). The variables that are taken into consideration in the RTS are respiratory rate, systolic arterial blood pressure, and the Glasgow Coma Scale. These can all be evaluated on-site, but calculation relies on formulas that are too complicated to be used in a stressful situation such as a prehospital setting. The triage RTS (T-RTS) is based on the same coded intervals of the same variables used in the RTS but is simpler to calculate. T-RTS has gained general acceptance as a triage score (5), although the most recent guidelines recommend a decision scheme rather than a particular score (6).

There are many methodologic concerns in most studies proposing a prehospital triage score in trauma patients. First, most studies are performed in a paramedic-staffed prehospital setting as-

***See also p. 992.**

From the Department of Emergency Medicine and Surgery (DS, BR), Université Lyon 1 and Hospices Civils de Lyon, Department of Anesthesiology, Critical Care, and Emergency (JSD), CHU Lyon Sud, Pierre Benite, and Service d'Aide Médicale Urgente (SAMU) de Lyon and Department of Emergency, CHU Edouard Herriot (PYG), Lyon, France; Department of Anesthesiology and Critical Care (YL), Centre Hospitalo-Universitaire (CHU) Pitié-Salpêtrière, Paris, France; Université Lyon 1, Service d'Aide Médicale Urgente-(SAMU) de Lyon and Department of Anesthesiology and Critical Care, and Emergency Department (JSD), Hospices Civils de Lyon, CHU Lyon Sud, Pierre Benite, Lyon, France; CHU Edouard Herriot (PYG), Lyon, France; SAMU 38 (ER), CHU de Grenoble, Grenoble, France; the Department of Anesthesiology and Critical Care (NS), CHU Purpan, Toulouse, France; SAMU 33 and Department of Anesthesiology and Critical Care (MT), CHU Pellegrin, Bordeaux, France; Université Lille 2 (EW), SAMU 59, CHU de Lille, Lille, France; SMUR Beaujon and Department of Anesthesiology and Critical Care (ARH), CHU Beaujon, Clichy, France; and SAMU 44 (FB), CHU de Nantes, Nantes, France.

The authors have not disclosed any potential conflicts of interest.

For information regarding this article, E-mail: bruno.riou@psl.aphp.fr

DOI: 10.1097/CCM.0b013e3181cc4a67

sociated with a relatively high number of missing values (7). These scores may not apply in a physician-staffed prehospital response, which is more frequent in Europe. For example, we recently observed that respiratory rate provides less information than modern oxygen saturation monitoring in trauma patients, and that it does not add more information to other variables used in the RTS and TRISS scores (8). Second, weighting coefficients from the Major Trauma Outcome Study (4) population used for RTS and TRISS are probably out of date because of medical progress (5). Third, the necessity of both internal and external validation of a score is often lacking. Lastly, although a global assessment of the score using receiver operating characteristic (ROC) curve is now more widely used, it should not be considered as a definite answer. Besides the global accuracy of the score, a precise assessment of its diagnostic performance at a given sensitivity is mandatory, because one of the most important decisions is to decide whether this trauma condition is severe and whether this decision is associated with a threshold of the score. Because we wish to favor sensitivity (to decrease undertriage) over specificity (to limit overtriage), defining a high value for sensitivity (i.e., at least 95%, indicating an undertriage less than 5%) is recommended (5, 6).

The purpose of this study was to develop a triage tool to predict mortality for multiple trauma patients that would be objective and easy to use in the prehospital setting. We made the hypothesis that such a score should be at least better than the T-RTS (and at least as efficient as the RTS). We assessed the diagnostic performance of this score at a given sensitivity (95%) and compared it with that of the T-RTS and RTS, and TRISS, this last score being considered as the reference standard because it incorporates definite information about trauma lesions (5). This score was then validated in a separate cohort.

MATERIALS AND METHODS

This prospective epidemiologic study was devoted to the analysis of prehospital variables associated with mortality in trauma patients. It involved 22 centers (14 university and eight nonuniversity centers) in France and each center was asked to record consecutive cases of trauma patients from January 1 through December 31, 2002 (see the Appendix). Institutional approval was obtained from Comité pour la Protection des Personnes Pitié-Salpêtrière (Paris, France); waived written informed consent was authorized because the study was solely observational. An ancillary study has been published previously on respiratory rate and pulse oximetry in a subgroup of patients (8). This cohort was used to derive the score and thus is considered the derivation cohort. Our study followed the Standard for Reporting of Diagnostic Accuracy recommendations concerning the report of studies of diagnostic accuracy (9).

All these trauma patients were cared for by a mobile intensive care unit because the severity of trauma was considered high enough to warrant medical prehospital care after the alert had been received (through a unique national emergency phone number, 15). The French mobile intensive care unit system has been described elsewhere, and its main characteristic is the presence of an emergency physician in each ambulance (10). The on-scene triage (i.e., the decision to send the patient to a trauma center) was based on the clinical assessment of the trauma patient (11, 12). Patients pronounced dead on the scene were excluded. The following data were recorded during the prehospital phase: age; sex; trauma characteristics; initial systolic arterial blood pressure; heart rate; respiratory rate; Glasgow Coma Scale; peripheral oxygen saturation measured by the physician; care provided during the prehospital phase; and systolic arterial blood pressure, heart rate, SpO_2, and Glasgow Coma Scale at time of arrival in the hospital. The following scores were determined: Abbreviated Injury Scale (13), Injury Severity Score (ISS) (14), and RTS (3). The probability of survival was calculated using the TRISS score (4). Abbreviated Injury Scale, ISS, and TRISS are calculated when precise anatomic injury information is available and thus cannot be calculated in the field. The primary end point was death, defined as death from any cause occurring within 30 days after trauma. The aim of the present study was to define a score that was able to predict 95% of deaths (i.e., an undertriage of 5%).

Three steps were followed in the score construction. First, a multiple forward stepwise logistic regression was performed to assess prehospital variables associated with death. We used a semiparsimonious approach, and only unbiased variables, which were available on the injury scene, were included. Interactions between the variables were systematically searched, and colinearity between variables was considered when $r > .8$ (Spearman coefficient matrix correlation). Discrimination of the final models was assessed by c-statistics and calibration by the Hosmer-Lemeshow statistic. An internal validation was performed using tenfold crossvalidation (15) and expressed as the difference of c-index. This method is recognized to be less awkward than the leave-one-out crossvalidation (or jackknife crossvalidation). Second, we tried to transform the continuous variables selected by the model. Third, we tried to simplify as much as possible the weight allocated to each variable retained in the model. Because ROC analyses have shown an advantage for a score with variable weights compared with a score with equal weights for all variables (data not shown), the weight of each variable included in the score was derived from the logistic regression coefficients. However, several methods were tested: direct sum of the odds ratio, sum of the logistic coefficient, and the process of converting the logistic regression output into a risk index (16). Lastly, because it could be important to assess a risk score beyond a dichotomous approach, the population was divided into three categories: trauma patients at low (<5%), intermediate, and high (>50%) risk for death. To provide an unbiased estimate of the mortality in each stratum of risk, a bootstrap method was used (1500 populations of 1360 patients were created by random selection with replacement). We performed an external validation using a new cohort of trauma patients, which consisted of 1003 consecutive trauma patients from the same town (Lyon, France) and during the period, 2003 through 2005. The criteria for inclusion and exclusion were similar to those of the derivation cohort.

Statistical Analyses. Data are mean ± SD or median (25–75 interquartile) for non-Gaussian variables (D'Agostino-Pearson omnibus test). Comparison of two groups was performed using the unpaired Student's *t*- test, Mann-Whitney *U* test, and Fisher's exact method. Areas under the ROC curve were compared using a paired nonparametric technique (17). To transform a continuous variable, the best threshold of a ROC curve was chosen as that which minimizes the distance to the ideal point (i.e., sensitivity - specificity - 1) (18). In contrast, for death prediction, the threshold was *a priori* determined to obtain a sensitivity of at least 95%.

The observed survival was compared with the expected survival obtained by summing the individual TRISS values (18, 19), and we calculated the M, W, Z, Ws, and Zs scores (19). A value of $M < 0.88$ indicates a disparity in the severity match between the study group and the Major Trauma Outcome Study (20). The W score is the percentage of survivors more or less than would be expected. A Z score of between -1.96 and -1.96 indicates no significant difference between the actual number of survivors and that expected. The standardized scores (Ws,

Table 1 Main characteristics of the derivation and validation cohorts of trauma patients

	Derivation Cohort (n = 1,360)	Validation Cohort (n = 1003)
Age, yrs	38 ± 17	39 ± 18
Men (%)	1027 (75	763 (76%)
Women (%)	333 (25)	240 (24%)
Blunt trauma (%)	1328 (91%)	858 (86%)[a]
Penetrating trauma (%)	122 (9%)	145 (14%)[a]
RTS	7.55 [5.97–7.84]	7.84 [5.97–7.84][a]
ISS	20 [10–29]	17 [9–30]
ISS >15 (%)	864 (63)	571 (57)[a]
TRISS	0.958 [0.758–0.990]	0.974 [0.824–0.992]
Death (%)	250 (18)	163 (16)
Expected death (%)	277 (20)	182 (18)
W score	+2.0%	+1.8%
Z	2.82[b]	2.28[b]
M	0.71	0.74
Ws score	+0.8%	+1.80%
Zs	1.33	3.10[b]

RTS, Revised trauma score; ISS, Injury Severity Score; TRISS, Trauma Related Injury Severity Score. W, percentage of excess survival observed(as compared to that predicted using TRISS); Z, tests the significance of W score; M: tests disparity in the case mix severity (M < 0.88 indicates disparity); Ws, percentage of excess survival observed with adjusted case mix severity; Zs, tests the significance of Ws score. See text for explanation.

[a]$p < .05$ vs. Derivation cohort; [b]$p < .05$(i.e., Z or Zs > 1.96). Data are mean ± SD or median [25–75 interquartile] or number (percentages).

Zs) represent the scores that would have been observed if the case mix of severity was identical to that of the Major Trauma Outcome Study (19).

The diagnostic value of the score was assessed by sensitivity, specificity, positive and negative predictive values, accuracy, and diagnosis likelihood ratios. These parameters were calculated for cutoffs associated with a sensitivity of at least 0.95. All p values were two-sided, $p < .05$ was considered significant, and SPSS 15.0 software (SPSS Corporation, Chicago, IL) was used.

RESULTS

In the derivation cohort, among 1501 patients who fulfilled the criteria for inclusion, important data were lacking for 141 patients. Therefore, data from 1360 patients were retained for analysis. In the validation cohort, among 1050 patients who fulfilled the criteria for inclusion, important data were lacking for 47 patients. Therefore, data from 1003 patients were retained for analysis.

The main characteristics of the two trauma populations are shown in Table 1. In both groups, the W score was significantly different from zero as shown by a significant Z score. As expected, the M scores indicated a significant disparity in the severity match between the studied groups and the Major Trauma Outcome Study group (19). This disparity was mainly the result of a lower proportion of patients with a very high probability of survival (TRISS > .95) and a higher proportion of patients with a low probability of survival (TRISS < .25) (data not shown). The standardized Ws score indicated that it was significantly different from that of the Major Trauma Outcome Study (Table 1), but there was no significant difference between the derivation and validation cohorts.

Construction of the Score. Table 2 shows the univariate analysis of variables associated with mortality in the derivation cohort. To fulfill the clinical goal of the score, only unbiased variables that were available since the prehospital phase were entered in the initial model. Table 3 reports the final model of the logistic regression with continuous variables. Four independent predictors of in-hospital death were selected: type of trauma, Glasgow Coma Scale, age, and systolic arterial blood pressure, all variables being obtained at the initial prehospital phase. The observed difference between c-index in the entire derivation population and that obtained after tenfold crossvalidation was <0.01 (0.907 ± 0.011 and 0.903 ± 0.011; $p = .68$). Thus, this model may be considered robust.

Predictive results obtained on derivation and validation cohort appeared to be as good as the more complex methods from Sullivan et al (16) (0.91 [95% confidence interval {CI}, 0.89–0.94] vs. 0.90 [95% CI, 0.88–0.92]; $p = .29$) and easier to calculate than the sum of the beta coefficients (0.91 [95% CI, 0.88–0.93]; $p = .63$). This observation was largely the result of the small number of variables included in the MGAP (Mechanism, Glasgow coma scale, Age, and Arterial Pressure) score and the relative linearity of the continuous variables. Table 4 reports the results of the logistic regression using stratified variables. The Glasgow Coma Scale was entered without any change in the model because of its high informative value and its relatively unbiased calculation. Systolic arterial blood pressure was segmented into three categories (<60 mm Hg, between 60 and 120 mm Hg, and >120 mm Hg). These categories were supported by clinical observation because no clear statistical cutoffs could be retrieved. Age was dichotomized using the ROC curve (18). MGAP score calculation was defined using the results of this logistic regression (Table 4). This transformation of the variables was associated with a nonsignificant reduction of the c-statistic between the model with continuous variables and the MGAP score (0.91 ± 0.01 and 0.90 ± 0.01, respectively; $p = .44$) and was justified by the ease of obtaining the MGAP score compared with the model with continuous variables.

The global predictive properties of the MGAP score using ROC curve analysis (0.90; 95% CI, 0.88–0.92) were comparable to that of T-RTS (0.88; 95% CI, 0.86–0.92; $p = .37$) and RTS (0.90; 95% CI, 0.88–0.92; $p = .37$) but significantly lower than that of TRISS (0.94; 95% CI, 0.92–0.95; $p < .001$) (Fig. 1). A cutoff of 23 allowed the predefined clinical goal of 95% undertriage with a 30% overtriage. The predictive properties of the MGAP score according to this cutoff are summarized in Table 5 and compared with those of T-RTS, RTS, and TRISS scores.

We defined three groups of patients: low (MGAP score 23–29), intermediate (MGAP score 18–22), and high (MGAP score 3–17) risk for death. This resulted in the assignment of 45% of the patients to the low-risk group with an observed mortality of 2.8%, 21% of patients to the intermediate-risk group with an observed mortality of 15%, and 33% of patients to the high-risk group with an observed mortality of 48%. The mortality rate of each stratum is represented in Figure 2*A*

Table 2. Univariate analysis of the derivation cohort (n = 1360) identifying variables associated with death

	Dead (n = 250)	Alive (n = 1110)	p Value
Men (%)	175 (70)	852 (77)	.02
Women (%)	75 (30)	258 (23)	—
Age, yrs	42 ± 21	36 ± 17	<.001
Prehospital phase			
Systolic arterial blood pressure, mm Hg[a]	80 ± 60	120 ± 30	<.001
Heart rate, beats/min[a]	77 ± 50	90 ± 20	<.001
Respiratory rate, cpm[a]	13 ± 11	20 ± 7	<.001
Glasgow Coma Score[a]	3 [3–7]	15 [11–15]	<.001
Peripheral oxygen saturation, %[a]	91 [0–99]	98 [95–100]	<.001
Duration of prehospital period, mins[b]	70 [55–95]	63 [45–90]	.02
Cardiac arrest (%)	69 (28)	11 (1)	<.001
Prehospital resuscitation			
Total fluid resuscitation, mL	667 [500–1096]	500 [250–718]	<.001
Colloids, mL	1000 [500–1500]	500 [0–750]	<.001
Crystalloids, mL	500 [0–500]	300 [100–500]	.01
Catecholamine administration (%)	210 (84)	267 (24)	<.001
Mechanical ventilation (%)	222 (88)	347 (31)	<.001
Type of trauma			
Blunt (%)	218 (87)	1020 (92)	.01
Penetrating (%)	33 (13)	91 (8)	—
Mechanism			
Fall (%)	65 (26)	216 (19)	.02
Car crash (%)	152 (61)	749 (67)	.04
Gunshot (%)	21 (8)	29 (3)	<.001
Stab wound (%)	5 (2)	46 (4)	.03
Other (%)	7 (3)	70 (6)	—
Localization of trauma			
Head (%)	194 (78)	632 (57)	<.001
Spine (%)	48 (19)	255 (23)	.19
Thorax (%)	189 (76)	689 (62)	<.001
Abdomen (%)	95 (38)	254 (23)	<.001
Pelvis (%)	69 (28)	213 (19)	.003
Limb (%)	101 (40)	657 (59)	<.001

[a]Variables obtained at the initial prehospital phase; [b]from the arrival of the emergency physician to the arrival into the hospital. Data are mean ± SD, median [25–75 interquartile], or number (percentages).

Table 3. Multivariate analysis of prehospital predictors of in-hospital death[a]

	Odds Ratio	95% Confidence Interval
Glasgow Coma Scale by point increase	0.71	0.68–0.75
Systolic arterial blood pressure by mm Hg increase	0.98	0.98–0.99
Penetrating trauma	4.11	2.24–7.73
Age by year increase	1.03	1.02–1.04

[a]Predictors were analyzed as continuous variables. Hosmer Lemeshow statistic: $\chi^2 = 3.56$; $p = .89$. c-index = 0.91.

in the derivation cohort. In a bootstrap analysis, the unbiased estimate of mortality was 2.8% (95% CI, 1.6%–4.1%) in the low-risk group, 15% (95% CI, 11%–20%) in the intermediate-risk group, and 50% (95% CI, 45%–55%) in the high-risk group.

External Validation of the Score. The global predictive properties of the MGAP score using ROC curve analysis in the validation cohort was not significantly different from that of the derivation cohort (0.91; 95% CI, 0.88–0.93 vs. 0.91; 95% CI, 0.89–0.92; $p = .54$). In the validation cohort, the global predictive properties of the MGAP score using ROC curve analysis was higher than that of T-RTS (0.88; 95% CI, 0.85–0.91; $p = .04$) and RTS (0.88; 95% CI, 0.85–0.91; $p = .04$) but significantly lower than that of TRISS (0.95; 95% CI, 0.93–0.96; $p < .001$). The MGAP score provided a comparable stratification in the risk for death (Fig. 2*B*) despite a significantly different assignment to the low-, intermediate-, and high-risk groups, respectively (55%, 19%, and 26%, $p < .001$ vs. derivation cohort). In the validation cohort, mortality rate was 2.0% (95% CI, 1.0%–3.5%) in patients with a MGAP score ≥23 with no significant difference compared with the derivation cohort ($p = .19$).

DISCUSSION

The goal of our study was to develop a score that could accurately predict death and could be applied easily in the field. The MGAP score predicted mortality better than the T-RTS and as did the RTS, which is not easy to calculate. In addition, when the objective of 5% undertriage was fixed, the MGAP score was more specific than T-RTS and RTS, approaching the specificity of the reference standard, TRISS, which incorporates information concerning all trauma lesions not available initially. The MGAP score was also able to clearly delineate patients with low, intermediate, and high risk of mortality. Furthermore, these characteristics were validated both internally and externally, which is considered essential before implementing predictive models in clinical practice (21).

The most common outcomes predicted by trauma triage scoring systems are the risk of requiring specialized trauma center services and the risk of death. Emphasis is given to reliability and ease of use while minimizing overtriage of minor trauma and undertriage of major trauma or death. The American College of Surgeons suggested an overtriage rate of 50% to attain an acceptable level of undertriage (22). We used mortality as the primary end point, although several studies and the most recent guidelines (6) were based on an ISS >15 taken as a criteria for severe trauma for three main reasons. First, the ISS criteria should be considered an intermediate end point compared with mortality. Second, it has been recently emphasized that ISS can misrepresent the injury severity assessment and mortality estimates (23). Third, the relationship between ISS and mortality is modified in penetrating vs. blunt trauma patients and, particularly, in elderly vs. young patients (24).

The MGAP score included both the Glasgow Coma Scale and systolic arterial pressure and these physiological variables have been included in most, if not all, published severity scores in trauma. However, systolic arterial blood pressure was more often dichotomized around a threshold of 90 mm Hg, and this threshold has been kept in the more recent recommendations (6). However, there is growing evidence that a higher threshold should define hypotension in trauma pa-

Table 4. Multivariate analysis of prehospital predictors of in-hospital death

	Odds Ratio [95% CI]	Points of the MGAP Score
Glasgow Coma Scale by point increase	0.71 [0.68–0.74]	GCS value
Systolic arterial blood pressure		
>120 mm Hg	1	+5
60–120 mm Hg	2.7 [2.0–3.6]	+3
<60 mm Hg	5.4 [4.1–7.3]	0
Blunt trauma (vs. penetrating)	0.24 [0.13–0.45][a]	+4
Age	0.21 [0.13–0.35][a]	+5
<60 yrs		
		Total: 3 to 29

MGAP, Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure; GCS, Glasgow Coma Scale; OR, odds ratio; CI, confidence interval.

[a]The OR associated with penetrating trauma was 4.1 [2.3–7.6] and that associated with age >60 yrs, 4.7 [2.9—7.9], explaining the +4 and +5 points of the score. Lower MGAP scores are associated with higher mortality rate (Hosmer Lemeshow statistic: $\chi^2 = 5.16$; $p = .65$. c-index = 0.90).

tients; Eastridge et al (25) recently proposed the value of 110 mm Hg, close to that retained in our final logistic model (Table 4). Furthermore, it is also clear that more severe hypotension is associated with a dramatic increase in mortality, highly supporting the need for additional classes (12). Nevertheless, it should be recognized that our decision to provide three different categories for systolic arterial pressure (<60, 60–120, >120 mm Hg) was supported mainly by clinical observation, because no clear cutoffs could be retrieved with this variable. The continuous increase in mortality as systolic arterial blood pressure decreased has been recognized previously (26). The MGAP score included the type of trauma (i.e., blunt vs. penetrating). This is in agreement with previous suggestions that the RTS coefficients must be separated for blunt and penetrating injuries (25, 26) and is also supported by the inclusion of this variable in the TRISS (4). The MGAP score also incorporated the age of the patient. A substantial body of literature has shown the increased mortality and morbidity in elderly trauma patients. Increased mortality has been demonstrated as early as age 40 or 45 yrs (19, 27). This point might be important because it has been reported that elderly patients are consistently less likely to be considered for transport to a trauma center (28) and because the proportion of elderly trauma patients is increasing because of aging populations in developed countries.

The MGAP score does not include some variables that are obviously associated with a poor prognosis, i.e., requirement for important fluid loading, mechanical ventilation, or administration of catecholamines (28). Two hypotheses can be proposed: 1) the statistical weight associated with these variables has been outlined by the statistical weight of other variables such as systolic arterial blood pressure or Glasgow Coma Scale; and 2) because these variables reflect important therapeutic interventions, they could have a marked impact on the patient prognosis. Although the precise role of fluid loading in the prehospital phase remains a matter of debate, and although the use of catecholamines remains poorly studied in the prehospital phase (29), several studies have emphasized the beneficial role of prehospital mechanical ventilation in patients with brain injury (30).

It is likely that prehospital triage should not be limited to only one score whatever its accuracy. This might be particularly true when the prehospital system is staffed by physicians who are able to obtain highly relevant information for triage either by anamnesis or rapid physical examination. It should be noted that algorithms or decision schemes have been proposed by expert panels and used in the majority of emergency medical system in the United States (6) and have also been proposed in France for Service d'Aide Médicale Urgente triage (12). These two algorithms incorporate all items considered in the MGAP score, although the threshold may be different. However, it should be pointed out that these algorithms are only expert panel opinions and have not been validated and compared with other scores. Furthermore, prehospital personnel may fail to adhere to guidelines (31). Thus, it is possible that an algorithm based on these decision schemes and incorporating the MGAP score could be a useful solution. It could also be important to assess a risk score beyond a dichotomous approach, and the MGAP score was able to clearly delineate patients with low, intermediate, and high risk of death. This might be important for future research or to help

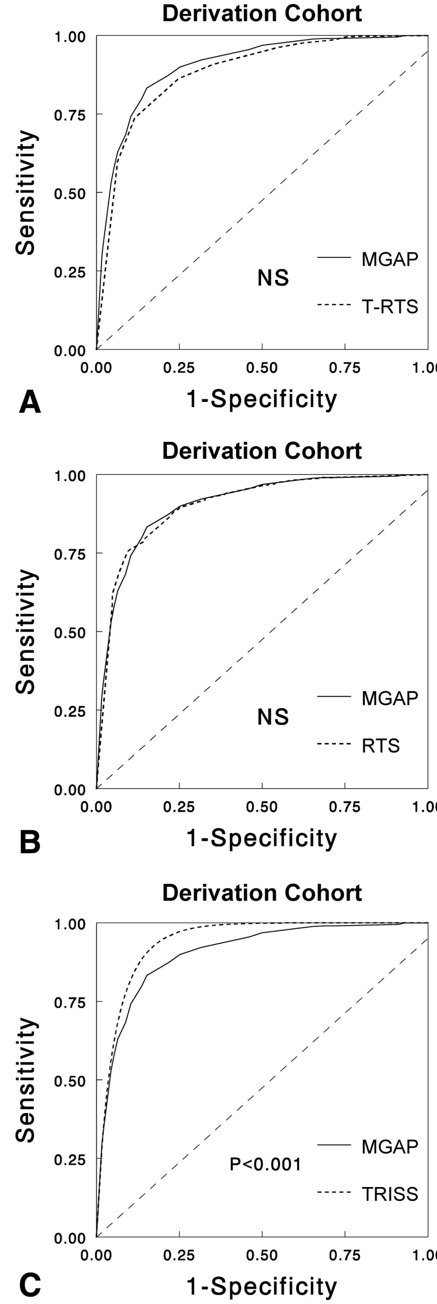

Figure 1. Comparison of the receiving operating characteristics curves of the Mechanism, Glasgow coma scale, Age, and Arterial Pressure (*MGAP*) and triage Revised Trauma Score (*T-RTS*) (*A*), RTS (*B*), and Trauma Related Injury Severity Score (*TRISS*) (*C*) scores as predictors of death in the derivation cohort (n = 1360). *p* values refer to the comparison of the areas under the receiver operating characteristics curve. The dotted line corresponds to the nondiscrimination curve. *NS*, nonsignificant.

Table 5. Comparison of the diagnostic properties of the Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure; Revised Trauma Score; and triage Revised Trauma Score scores at a sensitivity threshold of 95% (or the nearest possible value)

Score	MGAP	T-RTS	RTS	TRISS
Threshold	<23	<12	<7.5	<0.91
Sensitivity	0.95 [0.91–0.97]	0.96 [0.93–0.98]	0.95 [0.92–0.97]	0.96 [0.92–0.97]
Specificity	0.70 [0.67–0.73]	0.42 [0.39–0.45][a]	0.38 [0.35–0.41][a]	0.74 [0.71–0.76][a]
Positive predictive value	0.47 [0.43–0.52]	0.27 [0.24–0.30][a]	0.26 [0.23–0.29][a]	0.45 [0.41–0.50]
Negative predictive value	0.98 [0.96–0.99]	0.98 [0.96–0.99]	0.97 [0.95–0.98]	0.99 [0.98–0.99]
Accuracy	0.45 [0.43–0.48]	0.35 [0.32–0.38][a]	0.32 [0.30–0.35][a]	0.61 [0.59–0.64][a]
Positive diagnostic likelihood ratio	3.13 [2.82–3.48]	1.65 [1.56–1.75][a]	1.54 [1.46–1.63][a]	3.68 [3.32–4.08][a]
Negative diagnostic likelihood ratio	0.07 [0.04–0.13]	0.09 [0.05–0.18]	0.12 [0.07–0.22]	0.06 [0.03–0.11]

MGAP, Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure; T-RTS, triage Revised Trauma Score; RTS, Revised Trauma Score; TRISS, Trauma Related Injury Severity Score.

[a] $p < .05$ vs. MGAP. Data are value [95% confidence interval].

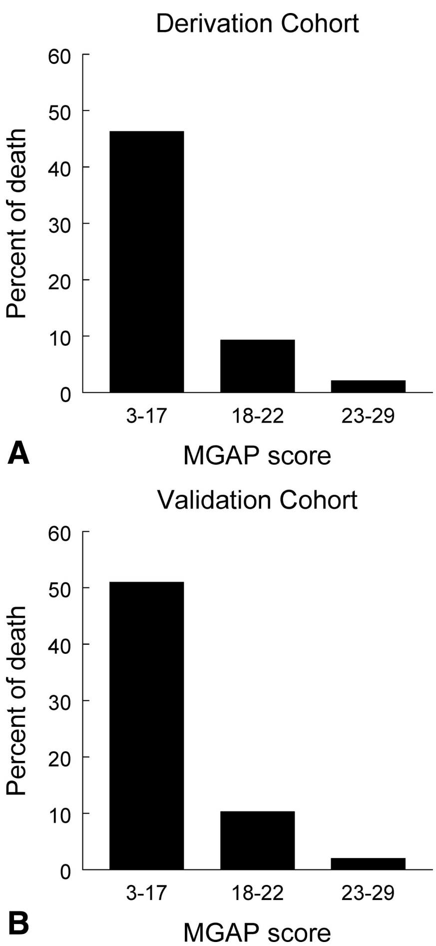

Figure 2. Percentage of death observed according to Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure (*MGAP*) score in the derivation cohort (*A*, n = 1360) and the validation cohort (*B*, n = 1003).

in-hospital physicians to more rapidly make some important decisions concerning activation of the trauma team. Further studies are required to validate these hypotheses.

Some limitations in our study deserve consideration. First, this score was built in an adult population and thus may not apply to pediatric patients (32). Second, the MGAP score was elaborated in a physician-staffed prehospital system and thus its impact on the whole triage process might be different in a paramedic-staffed prehospital system. The prediction of severe anatomic injuries by paramedics did not assist in the triage of patients, whereas this may not be the case in a physician-staffed system (33). Nevertheless, it should be pointed out that variables needed to calculate the MGAP score are already assessed by paramedics. Third, the proportion of penetrating trauma (9%) or gunshot wounds was relatively low, although the MGAP score did well in the validation cohort with a more important proportion of penetrating trauma (14%). Fourth, further studies are required to investigate the precise role of the MGAP score in the global process of prehospital triage because this last one probably may not rely only on a given score. Fifth, some variables were not taken into account in the predictive model, probably because of insufficient power because they concerned few patients. This is probably the case of associated chronic disease and chronic medication such as anticoagulant (34). The small number of gunshot wounds did not enable us to conclude on the role of this injury mechanism. Sixth, we did not assess the consequence of MGAP scoring on secondary triage (35). Seventh, we did not assess the reproducibility of MGAP score (8). In a hospital setting, the variability of cardiac pulse measurement can be expected to differ between two observers as much as 10% to 15%, respiratory rate by more than 35%, and diastolic and systolic arterial blood pressure measurements by 20% to 25% (36). The reproducibility may be limited by significant interobserver variability, which can be expected to worsen in the field. Thus, further studies are required to assess the reproducibility of the MGAP score, although the reproducibility of T-RTS and RTS has not yet been determined. Lastly, a simplification of the MGAP score might be envisaged because several studies indicated that the motor component of the Glasgow Coma Scale provides most of the relevant prognostic information (37). Nevertheless, we could not test this hypothesis in our study because the details of the Glasgow Coma Score were not available.

CONCLUSIONS

Addressing trauma patients to appropriate trauma centers is the first step to adequate care and improved survival. We believe that the MGAP score will lead to an improvement in prehospital triage in trauma patients, although prehospital triage probably cannot rely on a unique score. The MGAP score should probably be incorporated into future decision schemes proposed in paramedic-staffed (6) as well as physician-staffed (12) prehospital systems.

ACKNOWLEDGMENTS

The authors thank SAMU de France for support of the Vittel Trauma Group; David Baker, DM, FRCA (Department of Anesthesiology and Critical Care, CHU Necker-Enfants, Malades, Paris, France) for reviewing the manuscript; and Paul Landais, MD, PhD (Department of Biostatistics, CHU Necker-Enfants, Malades, Paris, France) for statistical advice.

REFERENCES

1. Sauaia A, Moore FA, Moore EE, et al: Epidemiology of trauma deaths: A reassessment. *J Trauma* 1995; 38:185–193
2. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al: A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med* 2006; 354:366–378
3. Champion HR, Sacco WJ, Copes WS, et al: A revision of the trauma score. *J Trauma* 1989; 29:623–629
4. Boyd CR, Tolson MA, Copes WS: Evaluating trauma care: The TRISS method. *J Trauma* 1987; 27:370–378
5. Moore L, Lavoie A, Abdous B, et al: Unifica-

tion of the revised trauma score. *J Trauma* 2006; 61:718–722
6. Sasser SM, Hunt RC, Sullivent EE, et al: Guidelines for field triage of injured patients recommendations of the National Expert Panel on Field Triage. *MMWR Morb Mortal Wkly Rep* 2009; 58:1–35
7. Glance LG, Osler TM, Mukamel DB, et al: Impact of statistical approaches for handling missing data on trauma center quality. *Ann Surg* 2009; 249:143–148
8. Raux M, Thicoïpé M, Wiel E, et al: Comparison of respiratory rate and peripheral oxygen saturation to assess severity in trauma patients. *Intensive Care Med* 2006; 32: 405–412
9. Bossuyt PM, Reitsma JR, Bruns DE, et al: The STARD statement for reporting studies of diagnostic accuracy: Explanation and elaboration. *Ann Intern Med* 2003; 138:W1–W12
10. Nathens AB, Brunet FP, Maier RV: Development of trauma systems and effect on outcomes after injury. *Lancet* 2004; 363: 1794–1801
11. Alexander RH, Proctor HJ: Advanced Trauma Life Support Course for Physicians. Resource Document 2. Prehospital Triage Criteria. Chicago, IL, American College of Surgeons, 1993, pp 317–318
12. Riou B, Thicoïpé M, Atain-Kouadio P, et al: Comment évaluer la gravité ? *In*: Actualités en réanimation préhospitalière: le traumatisé grave. SAMU de France (Ed). Paris, France, SFEM Editions, 2002, pp 115–128
13. Association for the Advancement of Automotive Medicine: The Abbreviated Injury Scale. 1990 Revision. Des Plaines, IL, Association for the Advancement of Automotive Medicine, 1990
14. Baker SP, O'Neill B, Haddon W, et al: The Injury Severity Score: A method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974; 14: 187–196
15. Molinaro AM, Simon R, Pfeiffer RM: Prediction error estimation: A comparison of resampling methods. *Bioinformatics* 2005; 21: 3301–3307
16. Sullivan LM, Massaro JM, D'Agostino RB: Presentation of multivariate data for clinical use: The Framingham Study risk score functions. *Stat Med* 2004; 23:1631–1660
17. Hanley JA, McNeil BJ: A method of comparing the areas under receiver operating characteristic (ROC) curves derived from the same cases. *Radiology* 1982; 148:839–843
18. Jebali MA, Hausfater P, Abbes Z, et al: Assessment of the accuracy of procalcitonin to diagnose postoperative infection after cardiac surgery. *Anesthesiology* 2007; 107:232–238
19. Hollis S, Yates DW, Woodford M, Foster P: Standardized comparison of performance indicators in trauma: A new approach to casemix variation. *J Trauma* 1995; 38:763–766
20. Champion HR, Copes WS, Sacco WJ, et al: The Major Trauma Outcome Study: Establishing national norms for trauma care. *J Trauma* 1990; 30:1356–1365
21. Bleejker SE, Moll HA, Steyerberg EW, et al: External validation is necessary in prediction research: A clinical example. *J Clin Epidemiol* 2003; 56:826–832
22. American College of Surgeons Committee on Trauma: Resources for Optimal Care of the Injured Patient: 1999. Chicago, IL, American College of Surgeons, 1998
23. Kilgo PD, Meredith JW, Hensberry R, et al: A note of the disjointed nature of the Injury Severity Score. *J Trauma* 2004; 57:479–487
24. Sharma OP, Oswanski MF, Sharma V, et al: An appraisal of trauma in the elderly. *Am Surg* 2007; 73:354–358
25. Eastridge BJ, Salinas J, McManus JG, et al: Hypotension begins at 110 mmHg: Redefining 'hypotension' with data. *J Trauma* 2007; 63:291–299
26. Skaga NO, Eken T, Steen PA: Assessing quality of care in a trauma referral center: Benchmarking performance by TRISS-based statistics or by analysis of stratified ISS data? *J Trauma* 2006; 60:538–547
27. Riou B, Landais P, Vivien B, et al: The distribution of the probability of survival is a strategic issue in randomized trial in trauma. *Anesthesiology* 2001; 95:56–63
28. Chang DC, Bass RR, Cornwell EE, et al: Undertriage of elderly trauma patients to state-designed trauma centers. *Arch Surg* 2008; 143:776–781
29. Pouloujadoff MP, Borron SW, Amathieu R, et al: Improved survival after resuscitation with norepinephrine in a murine model of uncontrolled hemorrhagic shock. *Anesthesiology* 2007; 107:529–530
30. Warner KJ, Cuschieri J, Copass MK, et al: The impact of prehospital ventilation on outcome after severe traumatic brain injury. *J Trauma* 2007; 62:1330–1336
31. Rehn M, Eken T, Krüger AJ, et al: Precision of field triage in patients brought to a trauma center after introducing trauma team activation guidelines. *Scand J Trauma Resuscit Emerg Med* 2009; 17:1–10
32. Orliaguet G, Meyer P, Blanot S, et al: Validity of applying TRISS analysis to paediatric trauma patients managed in a French paediatric level 1 trauma center. *Intensive Care Med* 2001; 27:743–750
33. Mulholand SA, Cameron PA, Gabbe BJ, et al: Prehospital prediction of the severity of blunt anatomic injury. *J Trauma* 2008; 64: 754–760
34. Williams TM, Sadjadi J, Harken AH, et al: The necessity to assess anticoagulation status in elderly injured patients. *J Trauma* 2008; 65: 772–776
35. Ciesla DJ, Sava JA, Street JH, et al: Secondary overtriage: A consequence of an immature trauma system. *J Am Coll Surg* 2008; 206: 131–137
36. Edmonds ZV, Mower WR, Lovato LM, et al: The reliability of vital signs measurements. *Ann Emerg Med* 2002; 39:233–237
37. Healey C, Osler TM, Rogers FB, et al: Improving the Glasgow Coma Scale: Motor score alone is a better predictor. *J Trauma* 2003; 54:671–678

APPENDIX

List of Other Investigators of the Vittel Trauma Group

M. Raux (Départment d'anesthésie-réanimation, CHU Pitié-Salpêtrière, Paris); J. M. Dindart (SAMU 33, Départment d'anesthésie-réanimation, CHU Pellegrin, Bordeaux); P. Goldstein (SAMU 59, CHU de Lille, Lille); E. Menthonnex (SAMU 38, CHU de Grenoble, Grenoble); J. P. Perfus (SAMU 74-SMUR d'Annecy, CH d'Annecy, Annecy); P. Y. Dubien (SAMU de Lyon, CHU Edouard Herriot, Lyon); F. Arnault (SAMU 44, CHU de Nantes, Nantes); C. Chollet (SMUR and Départment d'anesthésie-réanimation, CHU Beaujon, Clichy); V. Jacob (SAMU 56, CH de Vannes, Vannes); O. de Palézieux (SAMU 29, CHU de Brest, Brest); O. Stibbe and S. Saintonge (Service d'Accueil des Urgences-SMUR, CH de Lagny sur Marne, Lagny sur Marne); F. Dissait and M. Rascol (SAMU 63, CHU de Clermont-Ferrand, Clermont-Ferrand); J. Y. Lardeur (SAMU and Départment d'anesthésie-réanimation, CHU La Miletrie, Poitiers); A. Darhalhon (SAMU et Fédération Anesthesie-réanimation-Urgences-Douleur, CHU Carémeau, Nîmes); J. S. Marx and B. Vivien (SAMU de Paris and Départment d'anesthésie-réanimation, CHU Necker-Enfants Malades, Paris); P. Cavagna (Service Anesthésie-SMUR, CH de Montfermeil, Montfermeil); T. Desmettre (Fédération Réanimation-Urgences-SMUR, CH de Bethune-Beuvry, Bethune); P. Portecop (Service d'Accueil des urgences, CH de Pointe à Pitre, Guadeloupe); O. Capel (SAMU 49, CHU d'Angers, Angers); I. Messant (SAMU and Départment d'anesthésie-réanimation, CHU, Dijon); and M. Maget (SAMU 08, CH de Charleville-Mézière, Charleville-Mézière), all in France.