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Evaluation and Comparison of Different Prehospital Triage Scores of Trauma Patients on In-Hospital Mortality

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Abstract

Introduction: Several prehospital major trauma patient triage scores have been developed, the triage revised trauma score (T-RTS), Vittel criteria, Mechanism/Glasgow Coma Scale/Age/Systolic blood pressure score (MGAP), and the new trauma score (NTS). These scoring schemes allow a rapid and accurate prognostic assessment of the severity of potential lesions. The aim of our study was to compare these scores with in-hospital mortality predictions in a cohort of consecutive trauma patients admitted in a Level 1 trauma center. **Materials:** Between 2013 and 2016, 1,112 patients were admitted to the "major trauma" spinneret of a Level 1 trauma center in the south of France. All prehospital data needed to calculate the T-RTS, Vittel criteria, the MGAP score, and the NTS were collected. The main evaluation criterion was in-hospital mortality at 30 days for all causes. The predictive performances of these scores were evaluated and compared with each other using the analysis of the receiver operating curves. **Results:** A total of 1,001 patients were included in the analysis, 238 (24%) females, aged 43 ± 19 years with ISS 15 ± 13. The area under the curve was for each score: T-RTS, AUC = 0.84, [0.82–0.87]; Vittel criteria, AUC = 0.87 [0.85–0.89]; MGAP score, AUC = 0.91 [0.89–0.92] and NTS, AUC = 0.90 [0.88–0.92]. By comparing the ROC curves of these scores, the MGAP and NTS scores were statistically higher than the T-RTS. With the current thresholds, the sensitivity, specificity, positive and negative predictive values of these scores were 91%, 35%, 10%, 98% for T-RTS, 100%, 2%, 8%, 100% for Vittel criteria, 91%, 71%, 24%, 99% for MGAP score, 82%, 86%, 33%, 98% for NTS. Only Vittel's criteria allowed undertriage below 5% as recommended by the American College of Surgeons Committee on Trauma (ACSCOT). **Conclusion:** The comparison of these different triage scores concluded with a superiority of the MGAP and NTS scores compared with the T-RTS. Including the calculation of MGAP or NTS scores with the Vittel criteria would reduce the risk of overtriage in the Level 1 trauma centers by further directing patients at low risk of death to a lower-level trauma facility. **Key words:** trauma scores; mortality; prehospital care; overtriage; MGAP

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Introduction

Prehospital emergency medical systems must provide the most appropriate orientation for trauma patients. This process, known as field triage, includes an assessment of the physiology, anatomy, and mechanism of injury, as well as the context and circumstances of the injury (1). One of the challenges of prehospital care is to orient patients according to their level of severity (2). The most severe should be referred to trauma centers with sufficient technical infrastructure and a high level of expertise (3). Since 1986, the American College of Surgeons Committee on Trauma (ACSCOT) has published a regularly updated resource manual providing guidance for field triage of trauma patients. Several triage scores and decision algorithms have been developed to facilitate prehospital organization and predict in-hospital mortality of severe trauma patients (4–6). The ideal prehospital triage score should optimize the resources of referral trauma centers and other hospitals by limiting undertriage (increased risk of death for misclassified patients) and overtriage (orientation to a referral center for patients who do not need it) (7, 8). Undertriage is dangerous for patients while overtriage increases costs, geographic constraints for patients and their families and generates overload in referral centers (9). A good triage algorithm should result in an undertriage of less than 5% with an overtriage of 25–50% (1, 3, 10). This objective of less than 5% undertriage is preferred at the rate of overtriage and enabled a reasonable limit of the number of deaths (11). The judgment criteria usually used to evaluate overtriage and undertriage are in-hospital mortality or ISS (Injury Severity Score) greater than 15 (12). Several prehospital triage scores exist, each with different advantages and disadvantages. The Triage-Revised Trauma Score (T-RTS) is the oldest (1989) score for assessing hospital mortality and the most used by paramedics in the United States (10, 13). This score was implemented in countries where paramedics led the prehospital setting and T-RTS may not apply to physician-staffed prehospital settings, which are more frequent in Europe (14). The Vittel criteria were adopted in 2002 and are commonly used by prehospital teams in France (4). They have never been evaluated in the prediction of in-hospital mortality. The Mechanism, Glasgow Coma Scale, Age, and systolic arterial Pressure (MGAP) score were developed and validated in 2010 (11). This score seems to have a better performance than the T-RTS in the prehospital setting and is better adapted to the evaluation of severity during prehospital medical care (14). The New Trauma Score (NTS) derives from the T-RTS, which seems to be less relevant on the prediction of mortality (15). As NTS is relatively recent, no study has confirmed its external validity. The main objective of our study was to compare the T-RTS, Vittel criteria, MGAP score, and NTS on the prediction of in-hospital mortality.

MATERIALS AND METHODS

Type of Study

We performed a monocentric retrospective study in a Level 1 trauma center in southern France. The Sainte Anne Military Hospital in Toulon is a Level 1 trauma center with medical and surgical specialties to treat any type of traumatic injury. It receives 300 major trauma patients per year on average. For each traumatized patient, demographic, physiological, and outcome data are prospectively computed in a registry by the doctors of the intensive care unit. This registry has collected medical data relating to the whole process of trauma management from the scene to admission in the intensive care unit. A clinical research assistant regularly verifies the integrity and completeness of the data and collects patient outcome at discharge. All patients recorded in the registry over a 4-year period (2013–2016) were included if severe trauma was suspected in the prehospital setting. The calculation of mortality scores for each patient (T-RTS, number of Vittel criteria, MGAP score, and NTS) was calculated retrospectively from the registry data by a single physician operator. The majority of the doctors and the head of the intensive care unit department involved in the realization of this register have agreed to carry out this study. All agreements required for the realization of the study were obtained according to the French laws and approvals from the Regional Committee for Research Ethics and the Data Protection Official were granted (ref. no. 2018/006, CNIL n° 2002878V0).

Studied Scores

T-RTS uses 3 components: the Glasgow Coma Scale, systolic blood pressure, and respiratory rate. T-RTS < 12 would allow under-triage below 5% (13). The Vittel criteria are used to identify the factors of severity present during the care to determine if the trauma patient must be transferred to a level 1 trauma center. These criteria include 5 parameters: failure of vital signs, elements indicating violent kinetics, type of anatomical lesions, prehospital resuscitation, and special considerations. The presence of only one Vittel criterion justifies patient care in a Level 1 trauma center. Undertriage (based on mortality) related to the use of this algorithm has never been evaluated. The MGAP score uses several physiological variables: Glasgow Coma Scale, systolic blood pressure, type of trauma (blunt or penetrating trauma), and age. It makes it possible to predict the risk of mortality from the pre-hospital phase onwards: high risk (3–17), intermediate risk (18–22), and low risk (23–29). An MGAP score ≥ 23 is associated with a mortality risk of less than 5% (11). The NTS combines oxygen saturation, systolic blood pressure and the Glasgow Coma Scale. It also allows the risk of mortality to be evaluated: very high risk (3–5), high risk (6–11), intermediate risk (12–17), and low risk (18–23). An NTS ≥ 18 is associated with a mortality risk of less than 5% (15).

Epidemiological Analysis

Data collected during prehospital care were: age, sex, type of trauma, mechanism of trauma, Glasgow Coma Scale, heart rate, systolic blood pressure, respiratory rate, pulse oximetry, and prehospital resuscitation (mechanical ventilation, catecholamine, and total fluid loading). These variables enable to calculate the T-RTS, MGAP scores, and NTS. The presence of Vittel criteria was retained according to

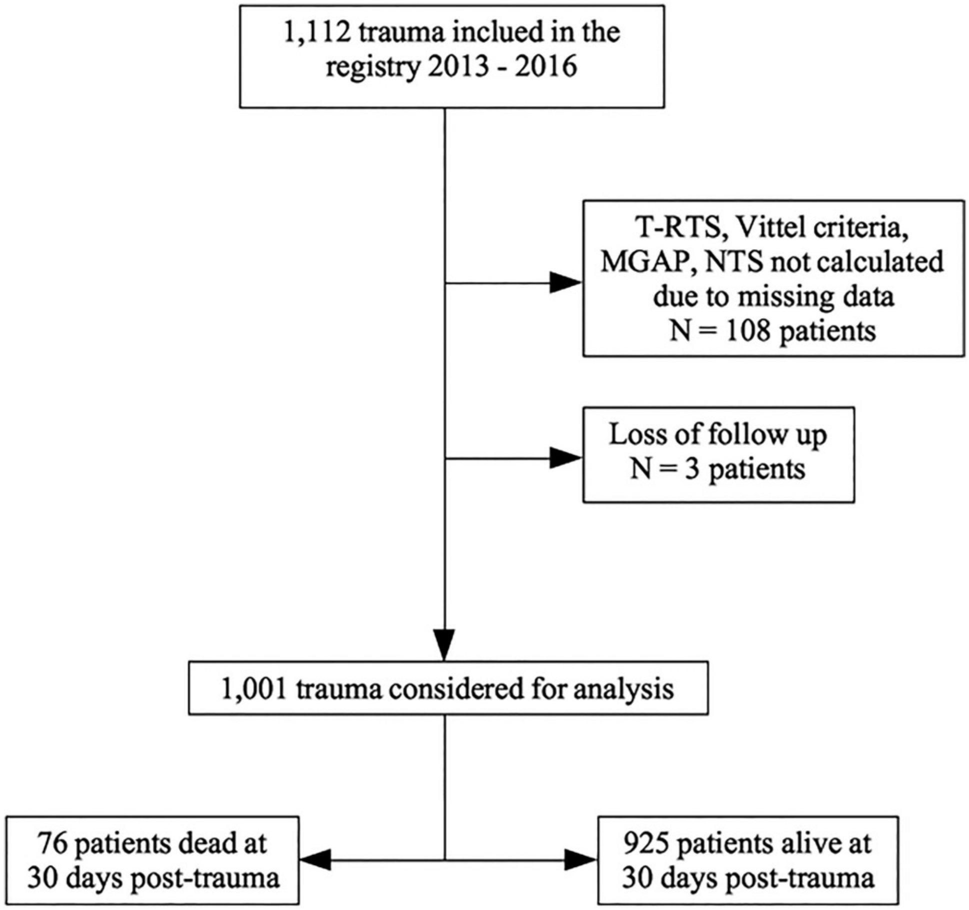

Figure 1. Flowchart of the study population. T-RTS = *Triage Revised Trauma Score*; MGAP = *Mechanism, Glasgow Coma Scale, Age, systolic arterial Pressure*; NTS = *New Trauma Score*.

the data collected in the prehospital stage. The Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) were calculated after a complete evaluation of the trauma patients during hospital care at the Sainte Anne Military Hospital. The main evaluation criterion was 30-day in-hospital mortality, defined as death whatever its cause.

Statistical Analysis

Quantitative variables are expressed as mean standard deviation. Qualitative variables are expressed as numbers and percentages. To study risk factors for mortality, we calculated the Hazard Ratio (HR) and their confidence intervals (95% CI) using univariate Cox models to determine the association of characteristics of patients and 30-day mortality. The diagnostic performance of each score to predict in-hospital mortality was assessed using receiver efficiency curve analysis (ROC curve). To test the ability of each score to be used for triage, sensitivity, specificity, positive predictive value, and negative predictive value were calculated at their usual thresholds (T-RTS <12, Vittel criteria ≥ 1, MGAP < 23, NTS < 18) (4, 11, 14, 15). In agreement with the ACSCOT, an effective score should detect more than 95% of patients at risk of death (sensitivity $> 95\%$) corresponding to less than 5% of undertriage. Conversely, the specificity of a score indicates the risk of overtriage. The software used was SAS 9.4 for the computation of the statistics in univariate analysis and MEDCALC v-17.8.6 for the realization of the curves of ROC. The comparison of these ROC curves was done according to the method of Delong et al. (16). A p-value of 0.05 or less was considered statistically significant.

Results

Population

Of the 1,112 trauma patients included between 2013 and 2016 in the registry, 111 (10%) were excluded. The flowchart of the population studied and the reasons for exclusion are presented in Figure 1. A total of 1,001 (90%) patients were

Table 1. Characteristics of the global population ($n = 1{,}001$ patients)

Characteristics	Value
Sex female, n (%)	238 (24)
Age, years	43 (±19)
Blunt trauma, n (%)	922 (92)
Penetrating trauma, n (%)	79 (8)
Prehospital physiological parameters	
Glasgow Coma Scale	13 (±4)
Heart rate, bpm	89 (±22)
Systolic arterial blood pressure, mmHg	121 (±27)
Respiratory rate, cpm	19 (±5)
Pulse oximetry, %	97 (6)
Prehospital resuscitation	
Mechanical ventilation, n (%)	164 (16)
Catecholamine administration, n (%)	92 (9)
Total fluid loading, mL (min-max)	396 (0-3500)
ISS	15 (±13)
ISS > 15, n (%)	460 (46)
T-RTS	11 (±2)
Vittel criteria	2 (±2)
Vittel criteria ≥ 1, n (%)	982 (98)
MGAP score	24 (±5)
MGAP category, n (%)	
3–17	112 (11)
18–22	179 (18)
23–29	710 (71)
NTS	20 (±4)
NTS category, n (%)	
3–5	2 (0.2)
6–11	92 (9)
12–17	97 (10)
18–23	810 (81)
In-hospital mortality, n (%)	
total	82 (8)
at 24 h	48 (5)
Day 1 at Day 7	20 (2)
Day 8 at Day 30	8 (0.8)
> Day 30	6 (0.6)
Length of stay, days	11 (±19)

ISS = *Injury Severity Score*; T-RTS = *Triage Revised Trauma Score*; MGAP = *Mechanism, Glasgow Coma Scale, Age, systolic arterial Pressure*; NTS = *New Trauma Score*.

included in this study. The main characteristics of the study population are listed in Table 1.

Aims

Seventy-six (7%) patients died during the first 30 days after trauma. According to the MGAP scores, 112 (11%) patients were classified at high risk of in-hospital death, 179 (18%) were classified at intermediate risk of death and 710 (71%) were at low risk of death. In-hospital mortality at 30 days for each category of MGAP was 48 (43%), 21 (12%), and 7 (1%) patients. According to the definition of the NTS, 2 (0.2%) patients were classified at very high risk of death, 92 (9%) were classified as high risk, 97 (10%) were classified as intermediate risk and 810 (81%) were considered at low risk of death. In-hospital mortality at 30 days for each category of NTS was 2 (100%), 39 (42%), 21 (22%), and 14 (1.7%) patients. Table 2 showed the different variables associated with in-hospital mortality at day 30 of our cohort in univariate analysis. The ROC curves and the AUC of each score are represented in Figure 2. Table 3 indicated a comparison of the predictive performances on in-hospital mortality for the different scores. Table 4 presented the diagnostic properties at the usual thresholds of the T-RTS, Vittel criteria, MGAP scores and NTS. Considering an acceptable undertriage rate below 5%, only the Vittel criteria met this limit. To detect more than 95% of the patients who will die in our cohort, the threshold of the MGAP score must be set at 25 excluded and the threshold of the NTS must be set at 22 excluded.

Discussion

Main Results

The goal of our study was to evaluate and compare the prediction of the different triage scores and decision algorithms of trauma patients in prehospital medical care on in-hospital mortality at 30 days. We found that the MGAP scores and NTS were significantly better than the T-RTS to predict the mortality of trauma patients. These scores are easy to calculate and can provide reliable and immediate information on patient prognosis before the overall in-hospital assessment. The MGAP score had the highest AUC to predict mortality of trauma patients. In spite of the AUC performance of the MGAP and NTS scores, the sensitivity of the MGAP < 23 and NTS < 18 scores was only 91% and 82%, which is below the 95% recommended by the ACSCOT for limited undertriage to less than 5%. At validated thresholds, only the presence of at least one Vittel criterion enable to respond to this recommendation at the cost of an overtriage of 98% (specificity of 2%). In the management of major trauma patients, high sensitivity is preferred to specificity to best orient these patients to Level 1 trauma centers to avoid deaths related to suboptimal care. Increasingly, studies show that overtriage of trauma patients leads to a waste of socio-economic and medical resources (17, 18). In our cohort, for a fixed rate of undertriage below 5%, the threshold value of the MGAP should be 25 and that of the NTS should be 22. These limits would allow the achievement of an overtriage rate of 35% (specificity of 65%) for the MGAP score and of 41% (specificity of 59%) for the NTS. Other studies also find the necessity to adjust the limits of the MGAP score to 25 in prehospital

TABLE 2. Univariate analysis of the cohort ($n = 1{,}001$) identifying variables associated with death at 30 days post-trauma

	Mortality within 30 day post trauma			
Characteristics	NO $n = 925$	YES $n = 76$	HR [95% CI]	p
Sex male, *n* (%)	708 (77)	55 (72)	0.8 [0.482–1.318]	0.38
Age, years	42 (±19)	54 (±23)	1.02 [1.013–1.036]	<0.01
Mechanism of trauma, *n* (%)				
Car crash	650 (70)	40 (53)	1 [reference]	reference
Stabbing	31 (3.3)	0 (0)	0 [0–1]	1.00
Firearm	29 (3.1)	13 (17)	5.21 [2.783–9.742]	<0.01
Fall	185 (20)	21 (28)	1.68 [0.993–2.856]	0.05
Other	30 (3.2)	2 (2.6)	1.08 [0.262–4.488]	0.91
Type of trauma, *n* (%)				
Blunt	860 (93)	62 (82)	1 [reference]	reference
Penetrating	65 (7)	14 (18)	2.58 [1.442–4.601]	<0.01
Glasgow Coma Scale	14 (±3)	6 (±4)	0.76 [0.722–0.797]	<0.01
Heart rate, bpm	89 (±21)	87 (±32)	0.99 [0.981–1.006]	0.32
Respiratory rate, cpm	19 (±5)	17 (±6)	0.9 [0.832–0.972]	0.01
SBP, mmHg	121 (±26)	117 (±42)	1 [0.989–1.005]	0.47
Pulse oximetry, %	98 (±5)	92 (±15)	0.96 [0.947–0.969]	<0.01
Mechanical ventilation, *n* (%)	112 (12)	52 (68)	10.47 [6.445–16.996]	<0.01
Catecholamine administration, *n* (%)	61 (7)	31 (41)	6.14 [3.873–9.737]	<0.01
Total fluid loading > 1,000 mL, *n* (%)	130 (14)	24 (32)	2.24 [1.379–3.648]	<0.01
T-RTS	11 (±1)	8 (±2)	0.62 [0.575–0.664]	<0.01
Vittel criteria	2 (±1)	5 (±2)	1.63 [1.492–1.771]	<0.01
MGAP score	25 (±4)	16 (±5)	0.79 [0.755–0.818]	<0.01
NTS	21 (±4)	12 (±5)	0.78 [0.747–0.811]	<0.01
ISS	14 (±11)	36 (±19)	1.07 [1.055–1.077]	<0.01

SBP: systolic blood pressure; T-RTS: Triage Revised Trauma Score; MGAP: Mechanism, Glasgow Coma Scale, Age, systolic arterial Pressure; NTS: New Trauma Score; ISS: Injury Severity Score

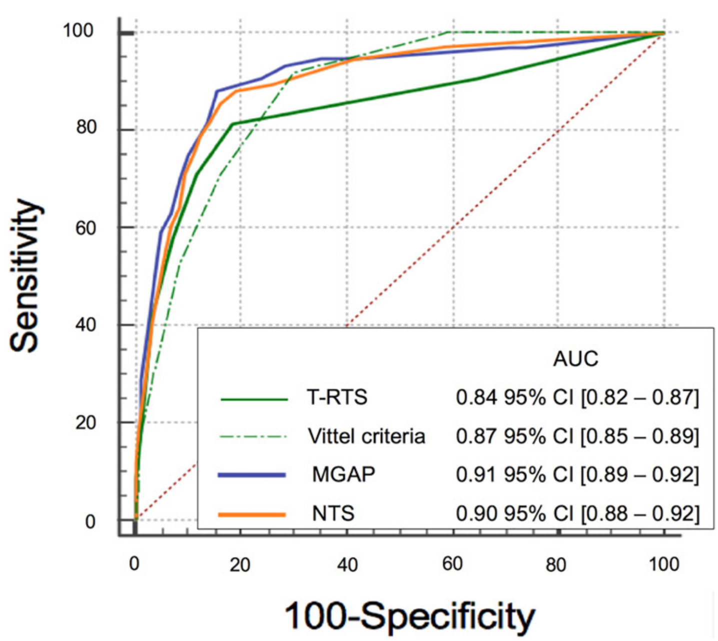

FIGURE 2. Receiving operating curves of the four scores. T-RTS = *Triage Revised Trauma Score*; MGAP = *Mechanism, Glasgow Coma Scale, Age, systolic arterial Pressure*; NTS = *New Trauma Score*.

(14) and 26 in hospital (19) settings to have an undertriage rate below 5%. The calculation of the MGAP score or NTS associated with the use of the Vittel criteria in prehospital would reduce overtriage, while limiting the undertriage below 5%. The performance of the MGAP score has also been

TABLE 3. Comparison of the predictive performance of the T-RTS, Vittel Criteria, MGAP Score, and NTS in the cohort ($n = 1{,}001$ patients)

Scores	AUC difference	95% IC	p value
Vittel criteria vs. T-RTS	0.03	−0.02–0.08	0.20
MGAP vs. T-RTS	0.07	0.02–0.10	<0.01
MGAP vs. Vittel criteria	0.04	−0.01–0.07	0.15
MGAP vs. NTS	0.01	−0.03–0.04	0.69
NTS vs. T-RTS	0.06	0.03–0.09	<0.01
NTS vs. Vittel criteria	0.03	−0.01–0.06	0.17

T-RTS = *Triage Revised Trauma Score*; MGAP = *Mechanism, Glasgow Coma Scale, Age, systolic arterial Pressure*; NTS = *New Trauma Score*.

TABLE 4. Diagnostic properties of each score (T-RTS, Vittel criteria, MGAP, and NTS) at usual thresholds*

	T-RTS	Vittel Criteria	MGAP score	NTS
Thresholds	< 12	≥ 1	< 23	< 18
Sensitivity	0.91	1	0.91	0.82
Specificity	0.35	0.02	0.76	0.86
Positive predictive value	0.1	0.08	0.24	0.33
Negative predictive value	0.98	1	0.99	0.98

*T-RTS < 12, Vittel criteria ≥ 1, MGAP < 23, and NTS < 18. T-RTS = *Triage-Revised Trauma Score*; MGAP = *Mechanism, Glasgow Coma Scale, Age, systolic arterial Pressure*; NTS = *New Trauma Score*.

studied for triage of trauma patients in emergency departments in 180 trauma centers in the United Kingdom between 2000 and 2010, including 79,824 patients (19). With an AUC of 0.868 (95% CI 0.862–0.873) the MGAP score was found to be a valuable triage tool for hospital use to classify patients with major trauma based on their risk of death. Currently, the TRISS (Trauma Related Injury Severity Score) is the most widely used model for predicting mortality for major trauma (20–24). It calculates a probability of survival based on the physiological variables of the RTS, the anatomical lesions of the ISS and the age of the patient. It is used by comparing the probability of overall survival to observed survival. The complexity of its calculation makes the use of this score inconceivable in the prehospital phase. The MGAP score already includes the age and mechanism of trauma and the NTS includes the same elements as the RTS. In addition to its use as a triage tool in clinical practice, NTS can play an important role in trauma research because of its potential relevance as a substitute for RTS in TRISS (15). In the risk factors for death in our cohort, the mean systolic blood pressure values were not different between the living and the deceased. Arterial hypertension in severe trauma patients is a risk factor for mortality as relevant as low blood pressure (19, 25). It would have been interesting in our study to limit the values of blood pressure and not to evaluate their averages. The decrease in SpO2 is associated with an increase of mortality in our study and the literature (26), especially when it is associated with arterial hypotension (27). It would be interesting to include this parameter in the MGAP score for the development of a more sensitive and specific score. Penetrating trauma appears as risk a factor for death (HR: 2.58, $p < 0.01$). In our study, penetrating trauma includes ballistic trauma, stab wounds and other types of penetrating trauma. No deaths were found for stab wounds in comparison to ballistic injuries that were at high risk of death (HR: 5.21, $p < 0.01$). It would be interesting to dissociate the ballistic traumas from other penetrating traumas in the calculation of the scores evaluating the risks of in-hospital deaths. Like Sartorius et al., it was not surprising that prehospital resuscitation care (mechanical ventilation, catecholamine, and total fluid loading greater than 1,000 mL) appeared to be risk factors for death (11). Indeed, these therapeutic measures applied only to the most serious patients with a high risk of mortality. The ISS is a score based on anatomical lesions and must be calculated after hospital admission and all injuries have been identified and compiled (28). Each injury is assigned an abbreviated injury rating (AIS) and an injury rating assigned to one of the 6 body regions (head and neck, face, chest, abdomen, extremities, external); the 3 highest AIS values are squared and added together to obtain the total IST score from 0 to 75. An ISS > 15 defines a severe trauma (gold standard) (29, 30). The T-RTS and MGAP scores, which are based more on physiological criteria, have a poor correlation with the anatomical severity of the lesions calculated by the ISS (31). In our cohort, 46% of patients had an ISS > 15. It would have been interesting to study these predictive mortality scores in patients with an ISS < 15 versus ISS > 15. It seems reasonable to specify that these scores and algorithms are an support in the choice of referral for trauma patients during prehospital management and should not replace clinical common sense. Two recent U.S. studies found that the implementation of field triage algorithms had minimal effect on hospital destinations, EMS decision-making and efficiency (32, 33). It is required to know the technical platform of the hospital to which the major trauma patient is referred in order to limit undertriage as much as possible (34). The interest is to accompany the right patient to the right place at the right time (35).

Limitations

However, our study has limitations. First, it is a monocentric study in a Level 1 trauma center. All undertriaged patients referred to lower-level trauma centers are not represented. Second, the calculation of scores was done *a posteriori* on prehospital recorded data. Even if these scores are based on objective data, one can always wonder if prehospital actors would have calculated the same in the field. Moreover, the scores were calculated by single physician. Third, the goals of these scores are to be applied to triage patients and reduce mortality. Our study does not allow implying the impact of the application of each score. Finally, the study population is not only major trauma (46% of ISS > 15). The accuracy of each score for only major trauma population would have been different.

CONCLUSION

Assessing the severity of prehospital trauma patients and the optimal orientation of these patients to appropriate centers is a complex process. Our study concluded that the MGAP and NTS scores are superior to T-RTS to predict in-hospital mortality. However, the low sensitivities of these scores with the current limitations do not allow them to be used alone for triage and the decision to refer a patient to a Level 1 trauma center. In combination with the Vittel criteria, the use of the MGAP score or the NTS could decrease the rate of overtriage of Level 1 trauma centers by further directing patients at low risk of death to lower-level trauma centers.

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