American Journal of Emergency Medicine 35 (2017) 1882–1886

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Original Contribution

# The Revised Trauma Score plus serum albumin level improves the prediction of mortality in trauma patients

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ARTICLE INFO

*Article history:*
Received 12 April 2017
Received in revised form 6 June 2017
Accepted 13 June 2017

*Keywords:*
Revised Trauma Score
Trauma and Injury Severity Score
The emergency trauma score
Albumin
Mortality

ABSTRACT

*Introduction:* The Revised Trauma Score (RTS) is used worldwide in prehospital practice and in the emergency department (ED) settings to triage trauma patients. The main purpose of this study was to evaluate the value of the RTS plus serum albumin (RTS-A) and to compare it with other existing trauma scores as well as to compare the predictive performance of the Trauma and Injury Severity Score with the RTS-A (TRISS-A) with the original TRISS.

*Methods:* This was a single center, trauma registry based observational cohort study. Data were collected from consecutive patients with blunt or penetrating injuries who presented to the emergency department of a tertiary referral hospital, between January 2012 and June 2016. 3145 and 2447 patients were assigned to the derivation group and validation group, respectively. Main outcome was in-hospital mortality.

*Results:* Among patients in the derivation group, the median [interquartile range] age was 59 [43–73] years, and 66.7% were male. The area under the receiver operating characteristic curves (AUC) of the RTS-A (0.948; 95% CI: 0.939–0.955) was higher than that of the RTS (0.919; 95% CI: 0.909–0.929). In patients with blunt trauma, the AUC of the TRISS-A (0.960; 95% CI: 0.952–0.967) was significantly higher than that of the original TRISS (0.949; 95% CI: 0.941–0.957).

*Conclusion:* The value of the RTS-A predicts the in-hospital mortality of trauma patients better than the RTS, and the TRISS-A is a better mortality predictor compared to the original TRISS in patients with blunt trauma.



## 1. Introduction

The Revised Trauma Score (RTS) is used worldwide in prehospital practice and in the emergency department (ED) settings to triage trauma patients. The RTS is composed of physiological patient parameters: systolic blood pressure (SBP), respiratory rate (RR), and the Glasgow Coma Scale (GCS) [1]. While those parameters are easily obtainable during the early phase of trauma, the RTS almost always yields definite scores that guarantee clear decisions in triage settings. Whereas the physiological scoring system is readily influenced by many external and internal factors, it can produce many false positives. Because there was a need for a more accurate prediction of survival of trauma patients, the Trauma and Injury Severity Score (TRISS) was developed from the Major Trauma Outcome Study (MTOS). The TRISS consisted of the RTS, Injury Severity Score (ISS), mechanisms of injury and age [2]. It showed a better predictive power of the survival of trauma patients than the RTS and remains the most prominent survival predictor in research for the quality control of trauma management and prevention.

The BIG score (Admission base deficit, International normalized ratio, and Glasgow Coma Scale) was developed to predict trauma mortality in children [3]. The BIG showed a good predictive performance in the adult trauma population [4]. The emergency trauma score (EMTRAS) is a validated trauma score using age, GCS, and the initial results of base excess and prothrombin time [5,6]. Both scoring systems were focused on quick triage in the early period of trauma management and included biochemical markers to improve the predictive ability.

Hypoalbuminemia has been shown to be closely related to adverse outcomes in various medical and surgical settings [7–10]. The most convincing explanation is that hypoalbuminemia is caused by a condition of protein-energy malnutrition (PEM); PEM contributes to impaired wound healing, increased susceptibility to infection, multiorgan dysfunction, prolonged hospitalization, and in-hospital mortality [11]. Practically, the patients with chronic underlying diseases, such as cancer, liver cirrhosis, or chronic renal failure, showed poorer clinical outcomes than previously healthy patients [12-15]. In other words, the serum

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http://dx.doi.org/10.1016/j.ajem.2017.06.027
0735-6757/

albumin level represents the status of a patient's chronic illness, nutrition, and immunocompetence. We postulated that the serum albumin level may provide an important clinical insight on the prognosis of trauma victims, and the additive value of serum albumin levels combined with the RTS may improve the predictive power of the RTS. Furthermore, the predictive performance of the original TRISS may be improved when the singular value of the RTS was replaced with the value of the RTS and serum albumin.

### 1.1. Goals of This Investigation

The purposes of this study were to evaluate the predictive performance of a value of the RTS plus serum albumin (RTS-A) and the TRISS using the RTS-A (TRISS-A) as well as to compare these scores with the RTS, the BIG, the EMTRAS, and the TRISS.

## 2. Materials and methods

### 2.1. Study design and setting

This is a prospectively recorded registry-based observational study using data from the trauma registry of a tertiary hospital located in Jinju, Republic of Korea. Our hospital is the only tertiary referral hospital, not a specialized trauma facility, located in the southcentral region of the Republic of Korea covering a relatively small area of 70 km in radius. The annual ED census is approximately 33,000. The Gyeongsang National University Hospital Trauma Registry has been established as a part of the National Emergency Department-based Injury In-depth Surveillance funded by the Korea Centers for Disease Control and Prevention. The registry enrolls all injured patients who presented to our ED. The enrolled patients are categorized by mechanism of injury: blunt, penetrating, thermal, asphyxia, poisoning, and others. A total of 240 items were prospectively recorded from the prehospital period to the hospital discharge. Items included demographic characteristics, initial physiological parameters, initial laboratory findings, the results from ED management, and the results from hospital admission. Most of the data were abstracted from the electronic medical records in our hospital. Initial systolic and diastolic blood pressure, heart rate (HR), RR, body temperature, the GCS were collected from ED triage records after being entered by the triage nurses. Abbreviated Injury Scales (AIS) were recorded according to clinical presentation, imaging results, intervention findings and operative records. The RTSs and the ISSs were automatically calculated and were recorded in the registry. Injury descriptions were preliminarily prepared by professional heath information managers and were reviewed by emergency physicians before final confirmation.

### 2.2. Participants and data collection

We used consecutive data from January 2012 to June 2014. Inclusion criteria were an age of 15 years or older, blunt or penetrating mechanism, ISS ≥ 1, and the results from ED management were either admission or death during the ED stay. We did not include patients who were dead on arrival or those who were discharged or transferred from the ED. Demographic characteristics, physiological parameters, international normalized ratios of prothrombin time ($PT_{INR}$) and percent of the reference value of prothrombin time ($PT_{PERCENT}$), base excess (BE) levels, and serum albumin levels (gram/deciliter) were collected. The EMTRAS, the BIG, and the TRISS were calculated for each patient. In-hospital mortality was the outcome measure. For validation of the final predictive model, we used the data from the same registry from July 2014 to June 2016. This study was approved by the Gyeongsang National University hospital institutional review board.

### 2.3. Statistical analysis

Multivariate imputation with chained equations using predictive mean matching was used to control for the missing data [16]. The missing values included the $PT_{INR}$ (4.6%), $PT_{PERCENT}$ (4.3%), BE (10.1%), albumin (4.3%), and the GCS (0.1%). All variables which were needed for the trauma scores as well as sex, age, SBP, HR, RR, ISS, and the outcome variable, which was death, were included in the imputation. Ten imputations were performed and the mean values of $PT_{INR}$, $PT_{PERCENT}$, BE, albumin, and the GCS replaced the missing values. Complete scores of the RTS, the EMTRAS, the BIG, the TRISS, and the RTS-A were calculated with the imputed data set. The same procedure was performed with the validation group.

To verify the adequacy of the RTS-A score in the prediction of in-hospital mortality, we compared the RTS-A with two multivariable logistic regression models. First, after confirmation of the statistical significance of all the variables (age, sex, mechanism, $PT_{INR}$, $PT_{PERCENT}$, BE, albumin, and the RTS) with the univariable analysis, a multivariable analysis was performed with all significant parameters (model 1). The ISS was not included in the analysis due to its lack of availability during the early phase of treatment. Second, a multivariable analysis was conducted using albumin and the RTS (model 2). Third, we added the RTS score and the serum albumin level (model 3), then compared the area under the receiver operating characteristic curves (AUC) of the three models using a nonparametric method [17]. While model 3 was far easier to calculate than either model 1 or model 2, because there were no statistical significances between the models, it was appropriate to choose model 3.

The predictive properties of the value of the RTS-A were evaluated with a receiver operating characteristics (ROC) for discrimination and

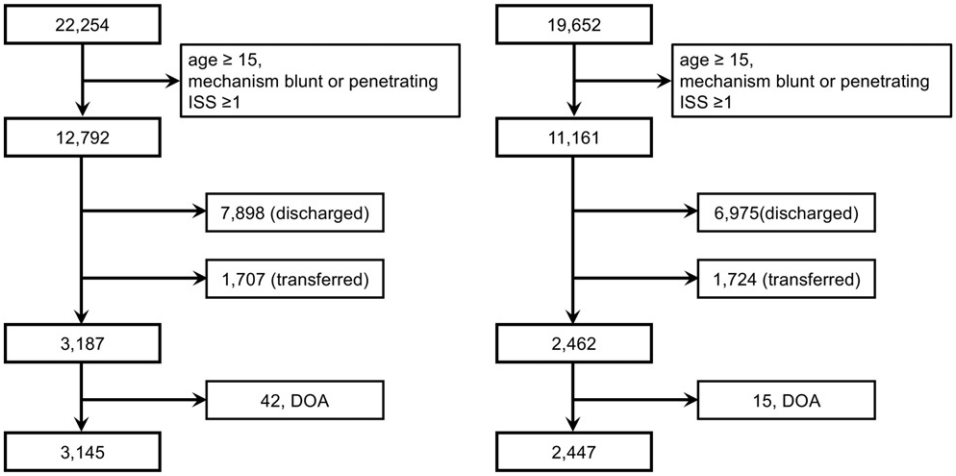


**Fig. 1.** Derivation and validation cohort.

**Table 1**
Baseline characteristics of derivation and validation group.

| | Derivation group | | Validation group | | *p* value |
|---|---|---|---|---|---|
| | Value | Available % | Value | Available % | |
| Number of patients | 3145 | | 2447 | | |
| Age (yrs) | 59 [45–73] | 100 | 60 [46–73] | 100 | 0.1652 |
| ≥65 years, n (%) | 1279 (40.7) | 100 | 997 (40.7) | 100 | 0.9578 |
| Male (%) | 66.7 | 100 | 66.5 | 100 | 0.8750 |
| Mechanism, blunt (%) | 95.7 | 100 | 96.2 | 100 | 0.3485 |
| ED physiological parameters | | | | | |
| SBP (mm Hg) | 135 [117–150] | 100 | 130 [110–140] | 100 | <0.0001 |
| RR (breath/min) | 20 [18–20] | 100 | 20 [18–20] | 100 | 0.8174 |
| HR (beats/min) | 80 [72–92] | 100 | 80 [73–90] | 100 | 0.5088 |
| Glasgow Coma Scale | 15 [15–15] | 99.9 | 15 [15–15] | 99.9 | 0.2084 |
| Laboratory results | | | | | |
| $PT_{INR}$ | 1.04 [0.98–1.12] | 95.4 | 1.04 [0.98–1.12] | 98.2 | 0.3309 |
| $PT_{PERCENT}$ (%) | 93 [83–103] | 95.7 | 93 [83–101] | 96.6 | 0.2427 |
| Base excess | −2.0 [−4.2–0.3] | 89.9 | −1.2 [−3.4–0.6] | 89.4 | <0.0001 |
| Albumin (gram/deciliter) | 4.1 [3.7–4.4] | 95.7 | 4.1 [3.8–4.4] | 98.9 | 0.0044 |
| ISS | 9 [4–13] | 100 | 9 [4–13] | 100 | 0.4464 |
| Mortality (%) | 9.8 | 100 | 9.0 | 100 | 0.3104 |

SBP systolic blood pressure.
RR respiratory rate.
HR heart rate.
$PT_{INR}$ international normalized ratio of prothrombin time.
$PT_{PERCENT}$ percent of the reference value of prothrombin time.
ISS Injury Severity Score.
All continuous variables showed skewed distribution and were expressed in median value [interquartile range].

Hosmer-Lemeshow statistics for calibration. The AUC of the value was compared with those values of the RTS, the EMTRAS, the BIG, and the TRISS. We replaced the RTS in the TRISS with the value of the RTS-A (TRISS with albumin, TRISS-A) and the AUC was compared with the original TRISS. Then, we calculated the regression coefficients of the TRISS–A in a subgroup of patients who had a blunt injury mechanism (the number of patients with a penetrating mechanism of injury were too small), and then we compared those results with the original TRISS in the patients with a blunt injury mechanism.

Independent *t*-tests or the Mann-Whitney *U* tests were used for continuous variables, and chi-square tests were used for categorical variables. All *p* values were two-sided, and a value of $p < 0.05$ was considered statistically significant. Analyses were performed using Stata 12 software (StataCorp, LP, College Station, TX).

## 3. Results

### 3.1. Characteristics of study subject

During the study period from January 2012 to June 2014, a total of 22,254 patients were entered into the Gyeongsang National University Hospital Trauma Registry. Among 3187 eligible patients, 42 patients were excluded because they were confirmed dead on ED arrival, and 3145 patients were included in the study. For validation, 19,652 patients were entered into the registry. Among 2462 eligible patients, 2447 patients were ultimately included (15 were confirmed dead on arrival) (Fig. 1). In-hospital mortality was 9.79% (derivation group) and 9.0% (validation group). Table 1 summarizes the baseline characteristics of both groups.

### 3.2. Verification of the Revised Trauma Score plus serum albumin model

Univariable logistic regressions were performed for age, sex, mechanism, $PT_{INR}$, $PT_{PERCENT}$, BE, and albumin. Age, sex, and all the biomarkers showed statistical significance in predicting in-hospital mortality. We chose $PT_{INR}$ instead of $PT_{PERCENT}$ because it is a more standardized method. Multivariable analyses were performed using age, sex, $PT_{INR}$, BE, albumin, and RTS (model 1). The area under the receiver operating characteristic curve (AUC) was 0.963 (95% confidence interval (CI): 0.956–0.970). The AUC of the multivariable analysis with the RTS and serum albumin level was 0.949 (95%CI: 0.941–0.956) (model 2). The difference between the two models was 0.014, which was statistically non-significant ($p = 0.148$; 95%CI: 0.004–0.024). The regression coefficients of the RTS and serum albumin level in model 2 were similar

**Table 2**
Area under receiver operating characteristic curves (AUC) of the RTS plus albumin compared with other trauma scores.

| Variable | Derivation group | | | H-L $\chi^2$ (*p* value) | Validation group | | |
|---|---|---|---|---|---|---|---|
| | AUC | 95% CI | *p* value[a] | | AUC | 95% CI | *p* value[a] |
| RTS-A | 0.948 | 0.939–0.955 | – | 5.6 (0.70) | 0.953 | 0.944–0.961 | – |
| RTS | 0.919 | 0.909–0.929 | 0.0001 | 6.9 (0.14) | 0.902 | 0.890–0.914 | <0.0001 |
| EMTRAS | 0.959 | 0.952–0.966 | 0.0690 | 4.3 (0.51) | 0.946 | 0.936–0.954 | 0.3283 |
| BIG | 0.932 | 0.923–0.941 | 0.0639 | 8.3 (0.40) | 0.925 | 0.913–0.935 | 0.0030 |
| TRISS | 0.952 | 0.944–0.959 | 0.5433 | 3.4 (0.95) | 0.954 | 0.945–0.962 | 0.8281 |

H-L $\chi^2$ Hosmer-Lemeshow chi-sqaure.
RTS-A Revised Trauma Score plus serum albumin.
RTS Revised Trauma Score.
EMTRAS Emergency trauma score.
BIG Admission base deficit, International normalized ratio, and Glasgow Coma Scale.
TRISS Trauma and Injury Severity Score.
[a] *p* value represents the statistical significance in the difference of the AUC between RTS-A and those of other trauma scores.

**Table 3**
Regression coefficients of original TRISS and the reestimated regression coefficients of the TRISS with albumin (TRISS-A) in patients with blunt trauma.

| Coefficient | TRISS | TRISS-A |
|---|---|---|
| b0 | −0.4499 | −9.3882 |
| b1 | 0.8085 | 1.2764 |
| b2 | −0.0835 | −0.0899 |
| b3 | −1.7430 | −0.8140 |

Trauma and Injury Severity Score = Probability of survival = $1/(1 + e^{-b})$.
b = b0 + (b1 × RTS) + (b2 × ISS) + (b3 × Ageindex).
Trauma and Injury Severity Score with albumin = Probability of survival = $1/(1 + e^{-b})$.
b = b0 + (b1 × RTS-A) + (b2 × ISS) + (b3 × Ageindex).

(−1.556 and −1.002). For this reason, we simply added the RTS and the serum albumin level (model 3), then compared the results of the two multivariable regression models. The AUC of model 3 (AUC = 0.948; 95%CI: 0.939–0.955) showed no significant difference compared to those from models 1 and 2 (AUC differences = 0.014 and 0.001; $p$ = 0.148 and 0.930; 95%CI: 0.004–0.024 and −0.010–0.012, respectively). Model 3 was easier to calculate and was not statistically different from model 1 or model 2. Therefore, model 3 was chosen as our final model.

### 3.3. Comparison between RTS-A and other trauma scores

The RTS-A ranged from 0.3000 to 13.0408. The AUC of the RTS-A was 0.948 and showed feasible calibration (H-L $\chi^2 = 5.6$, $p = 0.70$). The AUC of the RTS-A was significantly higher than that of the RTS (0.919) and showed a non-significant difference compared to the EMTRAS (0.959), the BIG (0.932), and the TRISS (0.952) (Table 2).

The RTS-A was added into the TRISS, replacing the RTS, and a multivariable logistic regression was performed to re-estimate the regression coefficients. The sample of patients with a penetrating injury mechanism was too small ($n = 135$, 4.3%); therefore, we analyzed the patients with blunt trauma only ($n = 3010$). The re-estimated regression coefficients are exhibited in Table 3. The AUC of the TRISS-A was 0.960 and was significantly higher than those of the RTS-A, the RTS, the BIG, and the TRISS models. Although the AUC of the TRISS-A was higher than the EMTRAS, it failed to show significance (Table 4). In the validation group, the AUC of the RTS-A was significantly higher than those of the RTS and the BIG (Table 2). The AUC of TRISS-A was significantly higher than those of other scores (Table 4).

## 4. Discussion

In our study, the RTS-A showed a superior performance when compared to the RTS and the TRISS-A that used the RTS-A instead of the RTS alone predicted mortality better than the original TRISS and other trauma scoring systems with physiological and biochemical parameters.

The TRISS, as the gold standard predictor of trauma mortality, contains physiological (RTS), anatomical (ISS), and demographic (age) variables. Recent studies have shown that combinations of physiological and biochemical information might be more feasible tools to estimate the mortality risk of patients with trauma [3,5]. In this study, the EMTRAS was the best method among previously developed trauma scores. However, the EMTRAS cannot be included into the TRISS whereas the RTS-A can. Our intentions were to add a simple biochemical marker that is easily and quickly obtainable in early phase of trauma management to the RTS and to improve the predictive ability of the gold-standard TRISS.

Serum lactate level is the most rigorously cited biomarker in trauma mortality [18-20]. While very few studies (if any) have addressed the albumin issue in trauma mortality, those studies were confined to specific injuries, such as traumatic brain injury, hip injury, or burns [21-24]. Albumin has several advantages over other biomarkers: it is one of the most available and low-cost biomarkers worldwide, and is almost always included in initial routine work-up for major trauma; and it provides clinical insight that represents the baseline patient status that is not comprehensible from physiological parameters.

We enrolled patients regardless of trauma severity. The ISS of the enrolled data was ≥1, while most of previous studies enrolled patients with severe trauma, such as those with an ISS ≥ 16. Additionally, our study was based on an emergency department, not a trauma center. In the reasons, our results seem more applicable in developing countries or regions where the trauma care system is not fully established.

The median age of our study population was 59 and 60 years in the derivation and validation group respectively, and the proportion of patients ≥65 years of age was 40.7% in both groups. This age distribution was much higher compared to the MTOS data (8.2%) in which the patient data were submitted from 1982 through 1986 [2,25]. About twenty years later, American College of Surgeons reported the proportion of patients ≥65 among adult trauma population (≥15 years of age) was 17.3% in 2004. It has been rapidly increasing by about 1.5% per year, and reached to 34.4% in 2016 [26]. This trend of increase in the incidence of elderly trauma was also observed in European population. Kehoe et al. showed the average age of the patients from the Trauma Audit Research Network in UK was 36.1 in 1990 and increased up to 53.8 in 2013. Annual increase in the study was 1.43 years, which was faster twice than that of the previous decade [27]. These previous findings consistently suggest that global trauma population is rapidly getting older. Therefore, we believe our model could be applicable to other trauma population, despite our result that serum albumin provides additional discriminative power to the RTS might be exaggerated by frequent comorbidities in old patients.

This study has some limitations. First, selection bias was concerning. In total, there were 1729 patients among the eligible 22,254 patients in the derivation group, and 1782 patients among the 19,652 in the validation group who were transferred to other facilities. We did not enroll these patients because the final outcome could not be measured. Second, this was a single-center study. External validation in a multicenter study is warranted. Third, we enrolled patients who were ≥15 years of age, so this model may not be used for pediatric patients. Fourth, the TRISS-A was not evaluated in patients with penetrating trauma due to the small number of patients.

**Table 4**
Area under receiver operating characteristic curves (AUC) of the TRISS with albumin (TRISS-A) compared with other trauma scores.

| Variable | Derivation group | | | Validation group | | |
|---|---|---|---|---|---|---|
| | AUC | 95% CI | $p$ value[a] | AUC | 95% CI | $p$ value[a] |
| TRISS-A | 0.960 | 0.952–0.967 | – | 0.968 | 0.960–0.975 | – |
| RTS-A | 0.946 | 0.938–0.954 | 0.0011 | 0.953 | 0.943–0.961 | 0.0001 |
| BIG | 0.931 | 0.922–0.940 | 0.0004 | 0.925 | 0.914–0.936 | <0.0001 |
| EMTRAS | 0.959 | 0.951–0.966 | 0.8427 | 0.946 | 0.936–0.954 | 0.0012 |
| RTS | 0.918 | 0.907–0.927 | <0.0001 | 0.903 | 0.891–0.915 | <0.0001 |
| TRISS | 0.949 | 0.941–0.957 | 0.0109 | 0.955 | 0.946–0.963 | 0.0038 |

TRISS-A TRISS with albumin.
RTS-A Revised Trauma Score plus serum albumin.
RTS Revised Trauma Score.
EMTRAS Emergency trauma score.
BIG Admission base deficit, International normalized ratio, and Glasgow Coma Scale.
TRISS Trauma and Injury Severity Score.
[a] $p$ value represents the statistical significance in the difference of the AUC between the TRISS-A and those of other trauma scores.

## 5. Conclusion

The value of the RTS plus serum albumin (RTS-A) predicts the in-hospital mortality of trauma patients better than the RTS, and the TRISS using the RTS-A (TRISS-A) is a better mortality predictor compared with the original TRISS in patients with blunt trauma.

## Funding

The authors have no financial relationships relevant to this article to disclose.

## Competing interests

The authors have no conflicts of interest to disclose.

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