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Original research

The modified rapid emergency medicine score: A novel trauma triage tool to predict in-hospital mortality

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ABSTRACT

Background: Trauma systems currently rely on imperfect and subjective tools to prioritize responses and resources, thus there is a critical need to develop a more accurate trauma severity score. Our objective was to modify the Rapid Emergency Medicine (REMS) Score for the trauma population and test its accuracy as a predictor of in-hospital mortality when compared to other currently used scores, including the Revised Trauma Score (RTS), the Injury Severity Score (ISS), the "Mechanism, Glasgow Coma Scale, Age and Arterial Pressure" (MGAP) score, and the Shock Index (SI) score.

Methods: The two-part study design involved both a modification step and a validation step. The first step incorporated a retrospective analysis of a local trauma database (3680 patients) where three components of REMS were modified to more accurately represent the trauma population. Using clinical judgment and goodness-of-fit tests, systolic blood pressure was substituted for mean arterial pressure, the weighting of age was reduced, and the weighting of Glasgow Coma Scale was increased. The second part comprised validating the new modified REMS (mREMS) score retrospectively on a U.S. National Trauma Databank (NTDB) that included 429,711 patients admitted with trauma in 2012. The discriminate power of mREMS was compared to other trauma scores using the area under the receiver operating characteristic (AUC) curve.

Results: Overall the mREMS score with an AUC of 0.967 (95% CI: 0.963–0.971) was demonstrated to be higher than RTS (AUC 0.959 [95% CI: 0.955–0.964]), ISS (AUC 0.780 [95% CI 0.770–0.791]), MGAP (AUC 0.964 [95% CI: 0.959–0.968]), and SI (AUC 0.670 [95% CI: 0.650–0.690]) in predicting in-hospital mortality on the NTDB.

Conclusion: In the trauma population, mREMS is an accurate predictor of in-hospital mortality, outperforming other used scores. Simple and objective, mREMS may hold value in the pre-hospital and emergency department setting in order to guide trauma team responses.

Introduction

Trauma kills over 175,000 Americans every year and is the leading cause of death for individuals under 45 years of age [1]. In addition, trauma results in significant morbidity, disability, and financial and social costs [2,3]. Trauma mortality rates depend on injury severity, time to assessment, and time to reach an appropriate care center. Prompt assessment and appropriate triage can decrease rates of mortality and long-term disability [4,5]. Validated trauma scoring systems can quickly assess injury severity and indicate prognosis. Several such systems have been developed. These differ in their complexity, design, and accuracy but no studies have compared the accuracy of the commonly-used scoring systems in predicting mortality on a national scale in the United States [5,6].

Early trauma scores, such as the Abbreviated Injury Score (AIS) in 1969 and the Injury Severity Scores (ISS) in 1971 focused on anatomical features [6,7]. Later scores, such as the Acute Physiology and Chronic Health Evaluation (APACHE) score, the Revised Trauma Score (RTS), the Shock Index (SI), and the "Mechanism of injury, Glasgow Coma Scale, Age, and Systolic

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Blood Pressure" (MGAP) score incorporated measures of functional status [8–11]. A single universally-agreed valid trauma scoring system would greatly benefit trauma services nationwide.

The Revised Trauma Score (RTS) is designed to be used for pre-hospital trauma triage. It includes the variables respiratory rate (RR), systolic blood pressure (SBP), and the Glasgow Coma Scale (GCS) that are each weighted differently and summed up to a maximum score of 12 [8]. As one of the oldest trauma scores, the Injury Severity Score (ISS) is an anatomically based scoring system that was designed to predict outcomes of automobile crash victims with multiple injuries [7]. The ISS divides the human body into 6 regions, head/neck, face, chest, abdomen and pelvic contents, extremities or pelvic girdle, and external surfaces. The score is based off of the Abbreviated Injury Score [6] (AIS), and includes the highest AIS severity score in the three most severely injured body regions, for a maximum score of 75. The MGAP score was developed as a simple score to be used in the pre-hospital setting. Unlike the other scores, MGAP incorporates mechanism of injury, blunt or penetrating, into its model. It is the sum of points assigned for values of mechanism of injury, Glasgow Coma Scale, age, and systolic arterial blood pressure [10]. Since its development in 2010, it has been tested and validated prospectively in Europe, but has yet to be tested in the United States [10,12]. The Shock Index (SI) is a simple calculation of heart rate divided by blood pressure and has historically been used for prediction of injury severity [9].

The Rapid Emergency Medicine Score (REMS) (2004) is a triage score that has proved to be a powerful predictor of in-hospital mortality for medical (non-trauma) hospital admissions [13]. The composite score consists of the variables age, mean arterial pressure (MAP), heart rate (HR), respiratory rate (RR), oxygen saturation (O_2 sat), and Glasgow Coma Scale (GCS). This score was shown to be a simple and accurate predictor of in-hospital mortality in trauma patients. (15) This retrospective study indicated areas for improvement and ways to optimize the score for trauma patients. In particular, the age appeared to be over-weighted and the GCS under-weighted when REMS was applied to trauma patients [14].

The new modified Rapid Emergency Medicine Score (mREMS) is an adapted version of the REMS score designed to be a practical real-time triage score that could be a more accurate predictor of in-hospital mortality than more complex scores that often require invasive measurements. The purpose of this study was to develop a modified REMS (mREMS) for the trauma population and to validate it on a nationally representative trauma dataset. Secondary objectives include to compare the predictive ability of the new mREMS score to the currently-used trauma scores (RTS, ISS, MGAP and SI) and to examine the predictive accuracy of mREMS for hospital mortality when stratified by blunt or penetrating trauma.

Methods

Development of mREMS

The modification of REMS to mREMS was based on factor analysis of patient information in an urban trauma database of 3680 patients treated over a 4-year period at an academic ACS level 1 trauma center. A pilot study indicated that the weighting of GCS was too low, the weighting of age was too high, and that mechanism of injury should be incorporated into the score to better represent trauma patients [14]. For the mREMS score, the distribution of categories for age and GCS were determined by identifying mortality rates for each incremental value and creating the categories by clinical judgement and confirming the best fit using logistic regression. Using clinical judgement and goodness of fit tests, the relative weighting of age was decreased and the weighting of GCS increased, to provide a more accurate predictor of mortality in trauma patients. The mREMS also replaces MAP with SBP because SBP is almost universally measured and is a proven indicator of trauma severity [15]. The SBP is also often the only measurement of blood pressure recorded in trauma registries. Finally, as the mechanism of injury, blunt or penetrating, has been included in field triage tools, this study looked at the effect of incorporating mechanism of injury into the score [16].

Validation of mREMS

The validation of the mREMS score utilized a retrospective analysis of data from level I–IV trauma centers that contributed to the U.S. National Trauma Data Bank (NTDB), a nationwide registry managed by the American College of Surgeons (ACS) [17]. The databank used for this validation step did not include the data used for the development of the mREMS score. Data were provided by 758 U.S. hospitals from the calendar year 2012. The study included all patients 16 years and older who were treated with blunt and/or penetrating injuries. The only exclusions were patients with missing data necessary to calculate an mREMS score, those who were transferred from another facility, and burn and/or drowning victims. The analysis included 429,711 patients (Fig. 1).

The data collected from each patient included age, gender, race, systolic blood pressure (SBP), respiratory rate (RR), heart rate (HR), peripheral oxygen saturation, Glasgow Coma Scale (GCS), temperature, length of stay time, mechanism of injury, in-hospital mortality, and state trauma level designation. The ISS score was included in the NTDB database; all other scores were calculated during the data analysis phase. The study and design was reviewed and approved by the site Institutional Review Board.

Measurements

The mREMS score is composed of patient age, and the routinely acquired vital signs SBP, HR, RR, peripheral oxygen saturation, and GCS. The mREMS score is calculated with each variable being assigned a scoring range of 0–4 with the exception of GCS, which has a range of 0–6, with an overall maximum mREMS score of 26 (Table 1).

In the preliminary score modification, odds ratios of age, GCS score assignments, and injury type (blunt or penetrating) were calculated against mortality outcomes. Using odds ratios and the area under the receiver operating characteristic (ROC) curve models, age and GCS point assignments were adjusted by modifying the score cutoffs by lowering the overall impact of a high age value and increasing the overall impact of a low GCS value. Odds ratios were also used to evaluate the benefit of adding mechanism of injury to the score. Clinical judgment was used to devise multiple scoring models in order to replace MAP values with SBP. The SBP models were compared to the current MAP model using the Spearman method. Odds ratios and the area under the receiver operating characteristic (ROC) curve were used to identify the SBP scoring method that best predicted mortality.

The modified score, mREMS, was then validated using a national database and its performance compared to currently utilized trauma scoring systems to determine which scoring method best predicts in-hospital mortality. We compared mREMS to the most frequently used scoring systems to predict in-hospital mortality, such as RTS, ISS, MGAP and SI.

Statistical analyses

For this study, patients were divided into two groups, those who survived and those who died in-hospital. The NTDB database contains all necessary data to calculate each of the scores for this comparison. The ISS score for each patient was already provided

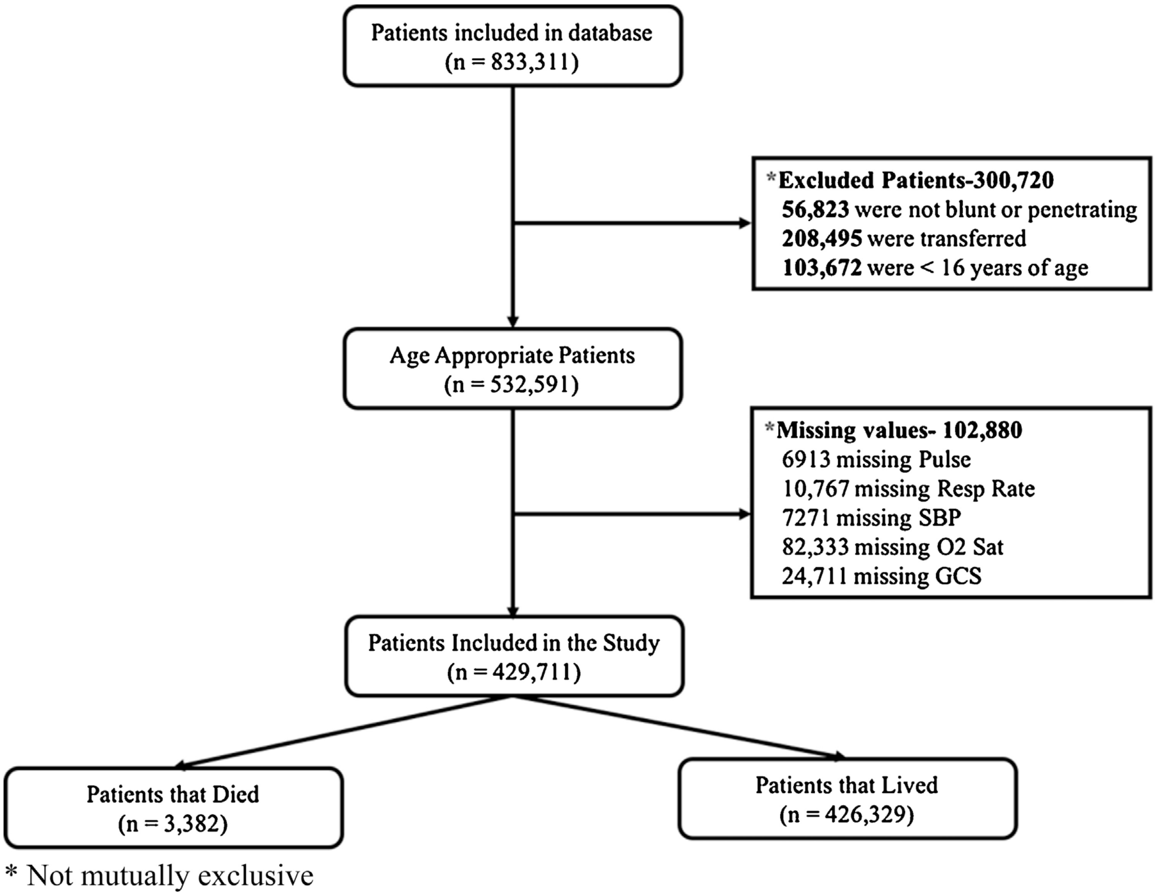


Fig. 1. Study flowchart depicting the Inclusion and Exclusion Criteria.
*Not Mutually Exclusive

Table 1
mREMS Scoring System.

	Score						
Variable	0	+1	+2	+3	+4	+5	+6
Age (years)	≤44	45–64		65–74	>74		
Systolic Blood Pressure (SBP)	110–159	160–199	≥200		≤79		
		90–109	80–89				
Heart Rate	70–109		110–139	140–179	>179		
(HR – beats/min)			55–69	40–54	≤39		
Respiratory Rate	12–24	25–34	6–9	35–49	>49		
(RR – breaths/min)		10–11			≤5		
Oxygen Saturation (%)	>89	86–89		75–85	<75		
Glasgow Coma Scale	14 or 15		8–13			5–7	3 or 4

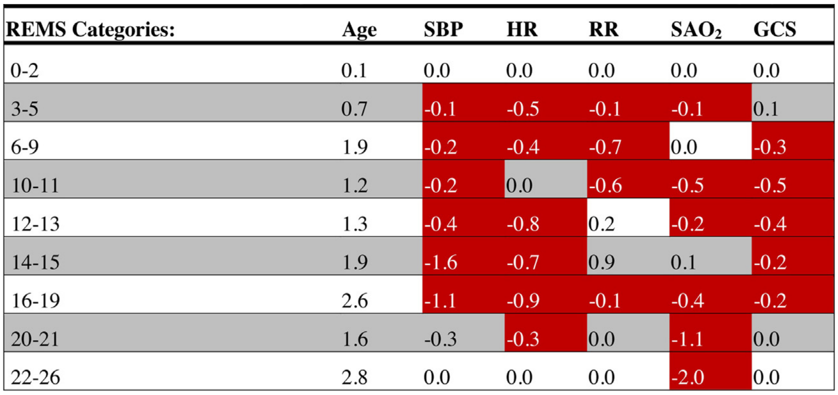
and each other score was calculated using their respective formula. Categorical variables were described by frequency and percentage while normally-distributed continuous variables were described by mean and standard deviation, using the *t*-test. For comparisons between groups, parametric testing was used. The Chi-square test was used for associations between categorical variables. Similarly, means for continuous variables were tested using the *T*-Test. Correlations were tested using the Pearson method. The discriminate predictive power of mREMS, RTS, ISS, MGAP, and SI were compared using the area under the receiver operating characteristic (ROC) curve with a 95% confidence interval. The area under the ROC curve is a comparison of sensitivity and specificity that ranges from 0.5 (indicating it is no better than chance alone) to 1.0 (indicating it is a perfect predictor). The larger the area under the ROC curve, the more accurately the respective trauma score can predict those who died from those who survived. The diagnostic comparisons of the scores compared by sensitivity and specificity were calculated for cutoffs based on approximate sensitivity of 0.95 of overall mortality. All analyses were conducted using SAS V 9.4 (Copyright (c) 2002–2012 by SAS Institute Inc., Cary, NC, USA. All Rights Reserved).

Results

Part I the performance of mREMS compared to REMS

The modifications to the score were evaluated based upon their incremental individual increase to the overall AUC (Area under the

Table 2
Mean Point Value Assignment Differences Between Blunt vs Penetrating Injuries.(For interpretation of the references to colour in this table, the reader is referred to the web version of this article.)



REMS Categories:	Age	SBP	HR	RR	SAO_2	GCS
0-2	0.1	0.0	0.0	0.0	0.0	0.0
3-5	0.7	-0.1	-0.5	-0.1	-0.1	0.1
6-9	1.9	-0.2	-0.4	-0.7	0.0	-0.3
10-11	1.2	-0.2	0.0	-0.6	-0.5	-0.5
12-13	1.3	-0.4	-0.8	0.2	-0.2	-0.4
14-15	1.9	-1.6	-0.7	0.9	0.1	-0.2
16-19	2.6	-1.1	-0.9	-0.1	-0.4	-0.2
20-21	1.6	-0.3	-0.3	0.0	-1.1	0.0
22-26	2.8	0.0	0.0	0.0	-2.0	0.0

Curve). The modifications to age increased the AUC individually to 0.910 and those to GCS increased the AUC individually to 0.917. The substitution of SBP for MAP increased the AUC individually to 0.920. In the overall model, the AUC increased from 0.911 (REMS) to 0.921 (mREMS) on the database from a single trauma center. Table 2 shows the difference, between blunt and penetrating traumas, of the mean points assigned for each component of the mREMS score. Negative values indicate that for the respective vital sign a penetrating trauma was assigned more points, that contribute to the overall mREMS score, than blunt traumas. In most cases, penetrating injuries received more points than blunt injuries in the mREMS score; however, attempts to add mechanism of injury into the score did not improve the overall AUC. Odds ratios and the AUC models for mREMS showed that mechanism of injury did not improve prediction, and thus was not included in the scoring model.

Part II validation of mREMS

Of the 429,711 patients in the study, 426,329 (99.2%) lived and 3382 (0.8%) died. Patients who lived had a mean age of 50.4 years and a mean mREMS score of 2.9. Patients who died had a mean age of 44.1 and a mean mREMS score of 17.7. 61.4% of the study population were men. 72.3% of the population was white. 89.3% of the population had blunt trauma compared to 10.7% having penetrating trauma (Table 3).

Table 3
Baseline Characteristic for Trauma Patients.

	Total (N = 429,711) N (%)[c]	Died[a] (N = 3382) N (%)[c]	Survived[b] (N = 426,329) N (%)[c]
Age – Mean (SD)	**50.3 (22.9)**	**44.1 (20.5)**	**50.4 (22.9)**
<45	189,642 (44.1)	1919 (44.0)	187,723 (56.7)
45–54	59,475 (13.8)	455 (13.8)	59,020 (13.5)
55–64	52,717 (12.3)	375 (12.3)	52,342 (11.1)
65–74	39,696 (9.2)	249 (9.3)	39,447 (7.4)
>74	88,181 (20.5)	384 (20.6)	87,797 (11.4)
Male	**263,957 (61.4)**	**2615 (77.4)**	**261,342 (61.3)**
Female	**165,656 (38.6)**	**764 (22.6)**	**164,892 (38.7)**
Race			
White	298,213 (72.3)	1835 (56.5)	296,378 (72.4)
Black	64,311 (15.6)	1053 (32.4)	63,258 (15.5)
Other	49,856 (12.1)	360 (11.2)	49, 497 (12.1)
Length of Stay, days – Mean (SD)	5.2 (7.8)	1.1 (1.1)	5.3 (7.8)
Systolic BP – Mean (SD)	139.3 (28.6)	42.0 (61.4)	140.1 (26.8)
HR – Mean (SD)	88.0 (20.6)	36.3 (51.4)	88.4 (19.6)
RR – Mean (SD)	18.6 (5.1)	6.0 (9.8)	18.7 (4.9)
O_2 Saturation – Mean (SD)	96.2 (11.3)	42.2 (46.6)	96.6 (9.4)
GCS – Mean (SD)	14.2 (2.6)	4.2 (3.4)	14.3 (2.4)
Blunt Trauma	383,709 (89.3)	1960 (57.9)	381,749 (89.5)
Penetrating Trauma	46,002 (10.7)	1422 (42.1)	44,580 (10.5)
Trauma Center			
Level I	196,553 (52.9)	1755 (58.3)	194,798 (52.8)
Level II	132, 926 (35.8)	1001 (33.2)	131,925 (35.8)
Level III, IV, V	42,255 (11.4)	256 (8.5)	41,999 (11.4)

[a] In-hospital mortality.
[b] Survived to Hospital Discharge.
[c] Unless specified otherwise.

Table 4
Distribution of mortality for blunt vs. penetrating injury across mREMS Score groupings.[a]

mREMS	Total Number Per Group	Deaths (%)
0–2	**221,684**	**70 (0.03)**
Blunt	*190,445*	*64 (0.03)*
Penetrating	*31,239*	*6 (0.02)*
3–5	**138,930**	**112 (0.08)**
Blunt	*129,674*	*98 (0.08)*
Penetrating	*9256*	*14 (0.15)*
6–8	**50,868**	**205 (0.4)**
Blunt	*48,562*	*152 (0.3)*
Penetrating	*2306*	*53 (2.3)*
9–13	**13,264**	**488 (3.7)**
Blunt	*11,767*	*342 (2.9)*
Penetrating	*1497*	*146 (9.8)*
14–17	**2310**	**317 (13.7)**
Blunt	*1885*	*209 (11.1)*
Penetrating	*425*	*108 (25.4)*
18–21	**703**	**409 (58.2)**
Blunt	*439*	*239 (54.4)*
Penetrating	*264*	*170 (64.4)*
22–26	**1952**	**1781 (91.2)**
Blunt	*937*	*856 (91.4)*
Penetrating	*1015*	*925 (91.3)*
Total	**426,329**	**3382 (0.80)**
Blunt	***381,749***	***1960 (0.51)***
Penetrating	***44,580***	***1422 (3.09)***

[a] A significant difference ($p < 0.0001$) was found between overall blunt vs penetrating injuries.

The mortality rate for each incremental mREMS score allowed a natural distribution of mREMS groupings to be created. A higher mREMS was associated with increased mortality, both overall and when stratified by injury type, blunt vs penetrating ($p < 0.0001$, Table 4).

An increase of one point in the mREMS score was associated with an Odds Ratio (OR) of 1.62 (95% CI 1.603 to 1.630) for the outcome of mortality. The mREMS groupings were also stratified by the number of survived versus dead, to display the level of trauma center that managed patients in each group (Table 5). Not all patient records included the level of trauma center designation, as reflected in the numbers in Table 5. The number of patients ranged from 106,790 survived patients in the 0–2 mREMS category who were transported to a level I trauma center to 145 dead patients in the 22–26 mREMS category who were transported to a level III, IV, or V trauma center.

Table 5
Trauma Center Designation Breakdown by mREMS score Categories.

mREMS	Number Survived	Number Died
0–2		
Level I (28.7% of patients)	*106,790*	*27 (0.03%)*
Level II (17.4% of patients)	*64,667*	*41 (0.06%)*
Level III (5.5% of patients)	*20,539*	*1 (0.00%)*
3–5		
Level I (15.8% of patients)	*58,787*	*51 (0.09%)*
Level II (12.3% of patients)	*45,783*	*38 (0.08%)*
Level III (4.1% of patients)	*15,126*	*10 (0.07%)*
6–8		
Level I (5.6% of patients)	*20,664*	*89 (0.43%)*
Level II (4.7% of patients)	*17,353*	*57 (0.33%)*
Level III (1.5% of patients)	*5653*	*15 (0.26%)*
9–13		
Level I (2.0% of patients)	*7067*	*240 (3.28%)*
Level II (1.0% of patients)	*3501*	*154 (4.21%)*
Level III (0.2% of patients)	*596*	*32 (5.10%)*
14–17		
Level I (0.4% of patients)	*1213*	*179 (12.86%)*
Level II(0.2% of patients)	*501*	*84 (14.36%)*
Level III (0.02% of patients)	*65*	*19 (22.62%)*
18–21		
Level I (0.1% of patients)	*185*	*241 (56.57%)*
Level II (0.05% of patients)	*74*	*107 (59.12%)*
Level III (0.01% of patients)	*10*	*34 (77.27%)*
22–26		
Level I (0.3% of patients)	*92*	*928 (90.98%)*
Level II (0.2% of patients)	*46*	*520 (91.87%)*
Level III (0.04% of patients)	*10*	*145 (93.55%)*
TOTAL	**368,722**	**3012 (0.8%)**

As part of the secondary analysis, the mREMS mean score was compared to RTS, ISS, MGAP, and SI (Table 6). The mREMS score (AUC of 0.967) was found to be higher than MGAP (AUC of 0.964) and RTS (AUC of 0.959) and found to be superior to ISS (0.780), and SI (0.670) in its ability to accurately predict in hospital mortality (Fig. 2). Overall, and when stratified by blunt or penetrating trauma, mREMS had the highest AUC (Table 7). The Triage Revised Trauma Score (t-RTS) was also compared to mREMS and the other trauma scores and was found to have a nearly identical AUC and confidence interval as RTS both overall and when stratified by blunt vs penetrating trauma, thus was not incorporated into the final tables and discussion [18]. In an attempt to evaluate mREMS on a sicker patient population, a sub analysis when the ISS was greater than 15 was performed. The mREMS continued to show a minor improvement in the AUC when compared to RTS and MGAP. The AUC for mREMS was 0.949 with a 95% CI of (0.944, 0.954), MGAP was 0.943 with a 95% CI of (0.938, 0.949) and RTS was 0.938 with a 95% CI of (0.933, 0.944). The difference in the AUC for mREMS compared to MGAP was 0.003 in the overall group and 0.005 in the ISS >15 group. The difference in the AUC for mREMS compared to RTS was 0.008 in the overall group and 0.010 in the ISS >15 group. The mREMS AUC was also compared to that of TRISS [19] as part of a sub-analyses; the overall TRISS AUC was found to be 0.972 with a 95% CI of (0.968, 0.975).

Discussion

Over the last 10 years there has been a 22% increase in trauma deaths, suggesting that there is an opportunity for simple and more accurate trauma scoring prediction and triage models to have impact on decreasing mortality [2]. Quick and accurate identification of trauma injury severity is crucial in the management of trauma patients [20]. There is a critical need to have a rapid, accurate, and practically prognostic scoring system that is easy to use by anyone involved in patient care. Several current scoring systems, such as APACHE, require multiple physiologic measurements and patient previous health status [6,11,21], making them too complex to use in urgent situations. Conversely, mREMS is an easy to use objective scoring model that does not require any invasive or additional measurements over those routinely obtained by emergency personnel. This study validates the performance of mREMS on a nationally representative database and sets the stage for future studies to determine potential outcome benefits by incorporating more accurate risk stratification methods to guide trauma triage. When compared to an anatomically based scoring

Table 6
Comparison of Trauma Scores.

Score name	N	Dead Mean (SD) (95% CI)	Alive Mean (SD) (95% CI)
mREMS	429,711	17.7 (5.4) (17.509, 17.909)	2.9 (2.7) (2.893, 2.909)
RTS	429,711	1.7 (2.5) (1.601, 1.768)	7.6 (0.84) (7.618, 7.623)
ISS	425,735	26.2 (20.1) (25.489, 26.863)	9.8 (8.5) (9.758, 9.809)
MGAP	429,711	11.7 (5.0) (11.508, 11.848)	25.6 (3.4) (25.626, 25.647)
SI	427,149	0.9 (2.1) (0.870, 1.105)	0.6 (0.3) (0.658, 0.660)

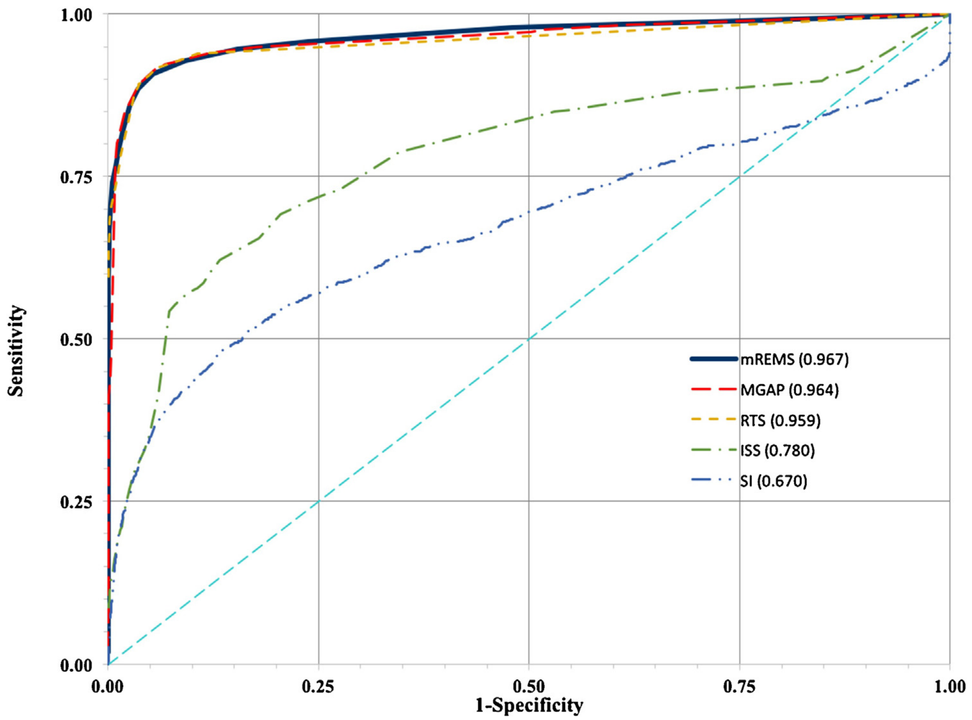


Fig. 2. AUC Comparison Graph.

Table 7
Scoring Systems' AUC with 95% Confidence Interval.

Scoring System	Overall AUC^	Blunt AUC^	Penetrating AUC^
mREMS	0.967 (0.963, 0.971)	0.950 (0.943, 0.957)	0.989 (0.987, 0.992)
MGAP	0.964 (0.959, 0.968)	0.945 (0.939, 0.952)	0.986 (0.983, 0.989)
RTS	0.959 (0.955,0.964)	0.938 (0.930, 0.945)	0.987 (0.984, 0.990)
ISS	0.780 (0.770, 0.791)	0.791 (0.778,0.804)	0.802 (0.788, 0.816)
SI	0.670 (0.650, 0.690)	0.675 (0.652, 0.698)	0.616 (0.575, 0.657)

^Area Under the Curve.

model (ISS), the mREMS score is less subjective and requires less time to calculate, while providing more accuracy as a predictor of mortality.

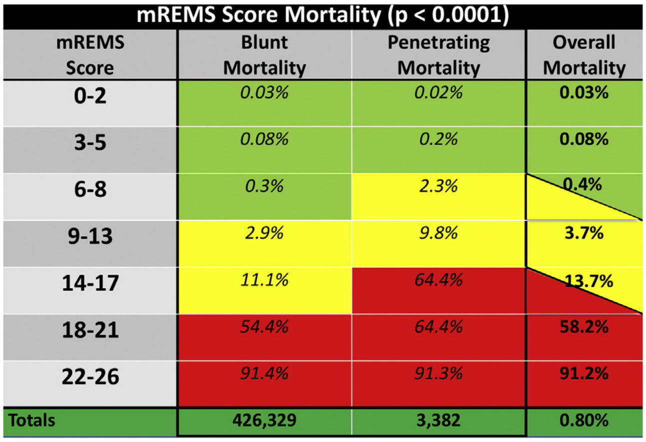
The mREMS is a modified version of the Rapid Emergency Medicine Score (REMS) [13]. While REMS has been shown to be an accurate predictor of mortality in the non-surgical non-trauma medicine population [13], the score needed to be adjusted to accurately predict mortality in trauma patients. When evaluated in the trauma population, it was suggested that the GCS was underweighted and that age was over weighted [14]. As SBP is the most widely used and recorded indicator of trauma severity, mREMS was designed to include SBP instead of MAP, which was included in the original REMS score. These modifications of the original REMS score proved to benefit the mREMS in its power to predict trauma mortality, as evidenced by the analysis.

The mREMS had the highest AUC (0.967) when compared to RTS, ISS, MGAP, and SI. The mREMS also scored the highest when stratified by blunt vs penetrating injury. Sub-analyses showed that the performance of mREMS improved when the ISS was greater than 15, indicating that mREMS may be better at predicting mortality in more severely injured patients. This should be validated on another large trauma dataset with a higher baseline mortality rate. Although mREMS scored higher than the other scores, it wasn't statistically significantly different from MGAP or RTS, but was superior to ISS and SI. The Trauma and Injury Severity Score (TRISS) is a trauma score originally developed in 1987 that is a weighted combination of patient age, the Injury Severity Score (ISS) and the Revised Trauma Score (RTS) [19]. Although the AUC of TRISS was higher than mREMS (not statistically different) TRISS was designed as a retrospective trauma score for evaluating care and outcomes [22]. Despite ISS being the most commonly used tool to evaluate injury severity worldwide [21], it is also a retrospective system whose score can only be determined after diagnosis. ISS and TRISS are therefore better suited as benchmarks for comparison (between patient groups or trauma centers) and not useful clinically in real time as triage tools [23]. Although SI is a very simple score that utilizes only 2 variables (HR and SBP), its performance was significantly lower than any of the other scoring models, suggesting that the SI is not a good predictor of mortality for all patients in this setting. Rather, SI appears to be useful in a subset of patients when it is elevated or increasing from baseline at the time of field transport [23]. The RTS performed very similar to mREMS and MGAP, possibly suggesting that the shared in-common variables of GCS and SBP are important factors in determining trauma outcomes. While the RTS is simple and consists of only 3 variables (GCS, SBP, and RR), it was slightly lower in its AUC overall and in blunt vs penetrating populations. MGAP is a simple score that includes GCS and SBP, but also includes mechanism of injury.

To our knowledge, this is the first time MGAP has been validated in the United States on a large dataset, as the score was originally developed and validated on a European sample. As injury type, blunt vs penetrating, has implications on both treatment strategies and outcomes, it seems reasonable to incorporate this into a trauma score. However, as in the original article on MGAP, it does not appear that adding mechanism adds any incremental benefit to mortality prediction over the other elements of the score [10]. Our analysis showed that when the mechanism of injury was removed from MGAP, the overall AUC went up, indicating that MGAP is a better predictor without the inclusion of mechanism of injury. Our results were consistent with other studies, showing that GAP (MGAP without the mechanism of injury) was a better predictor of in-hospital mortality [10,12].

When attempting to incorporate the mechanism of injury into the mREMS score, we noted that regardless of the amount of additional points given for a penetrating trauma compared to a blunt trauma, the logistic models and the area under the curve showed no improvement over the score without the mechanism incorporated. Sub-analysis suggests this is likely because the potential impact from mechanism of injury may already be reflected in abnormalities/changes in the other mREMS variables. Patients with a penetrating injury are more likely to have a higher mREMS score because they are likely bleeding, either internally or externally, increasing the HR, decreasing the SBP and oxygen saturation, and increasing the respiratory rate (Table 2). This suggests that scores do not have to be overly complicated with incorporating the mechanism of injury, as sometimes it is difficult to identify the mechanism and should not give a false sense of security if it appears to be non-penetrating. Furthermore, over half the patients in this national trauma dataset had an mREMS ≤ 2 with low predicted mortalities. In this large subset, blunt trauma patients had a higher overall mortality rate than penetrating patients.

While there are other outcomes to consider for triage decision making, such as predicting ISS >15, the need for hospital admission, ICU LOS >2 days, or requiring a blood transfusion, we choose to use mortality as our primary outcome. The majority of other trauma scores, including RTS, ISS, MGAP, and SI have been validated on the outcome of mortality [25]. This allows for a more objective and thus accurate comparison between scores. Unfortunately, other possible outcome measures like hospital admission, ICU LOS, and blood transfusion requirements are often subjective and differ from not only institution to institution but also between providers. This subjectivity makes it difficult at this time to accurately compare scores based on these particular intermediate outcomes. While the ISS >15 has often been used in the literature as a cut-off point for severe injury, it has been shown to misrepresent the assessment of injury severity and mortality predictions [10].



mREMS Score Mortality (p < 0.0001)			
mREMS Score	Blunt Mortality	Penetrating Mortality	Overall Mortality
0-2	0.03%	0.02%	0.03%
3-5	0.08%	0.2%	0.08%
6-8	0.3%	2.3%	0.4%
9-13	2.9%	9.8%	3.7%
14-17	11.1%	64.4%	13.7%
18-21	54.4%	64.4%	58.2%
22-26	91.4%	91.3%	91.2%
Totals	426,329	3,382	0.80%

Fig. 3. mREMS Risk Stratification Categories Based on Mortality Rates. (For interpretation of the references to colour in this Figure, the reader is referred to the web version of this article).

To be practical and clinically useful, a trauma score needs to perform well across the entire range of injury severity. The mREMS score was categorized into categories based upon the natural distribution of mortality rates (Fig. 3). These potential triage cutpoints will vary depending on the population mortality rate, as evidenced by Bouzat et al., who described how these differences in thresholds can change depending on the baseline mortality rate of the study sample [24]. This need to determine thresholds to guide trauma triage needs further evaluation and comparison to existing triage models to determine the appropriate cutoff points based upon different trauma system populations. While the mREMS categories are useful in showing the increasing mortality rate for each increasing mREMS score, overall and stratified by blunt vs penetrating trauma, they may also serve as a useful model for risk category assignment.

Although mREMS proved to be similar in its predictive ability to both MGAP and RTS, with a slightly higher area under the curve, the score may be useful both the pre-hospital and hospital setting. Based upon future analysis, the mREMS risk categories could be classified as criteria for triage to the various levels of trauma center designation (i.e. I–IV). These risk categories would thus help guide prehospital triage decisions and aid healthcare providers in determining the necessary level of trauma center for transport. Since the mREMS score consists of variables that are already required to be taken by EMS or triage personnel, the score can be easily calculated and classified into risk categories automatically on EMS and/or hospital electronic medical record systems. An auto-calculated mREMS score would provide pre-hospital providers the ability to quickly and accurately appreciate the patient severity and the predicted risk of mortality. The score could then help trauma patients be quickly triaged to the appropriate healthcare facility, based upon objective criteria, instead of the loosely utilized CDC field triage guidelines, which have been shown as insensitive in their ability to identify seriously injured patients [26]. The recommendations of the National Expert Panel on Field Triage in 2011 noted that improved field triage of injured patient can have a profound impact on the costs associated with trauma care and on the lives of the millions of persons injured every year in the United States [27]. With a statistically proven trauma score driving the triage of trauma patients, the CDC field triage guidelines could be supplemented or perhaps replaced with an objective algorithm, such as the mREMS score, to increase the likelihood that patients are taken to the most appropriate trauma facility. A highly predictive score could ensure that severely injured and critical patients would be taken the highest level of trauma care within that system, whereas less severe patients could perhaps be taken to a closer or more appropriate level of trauma center, not taxing resources more than necessary.

Limitations

This study, while generalizable with a large number of patients from a nationwide sample, does contain some limitations as a retrospective analysis. Trauma scores are unable to differentiate mortality attributable directly by the trauma versus indirectly by subsequent management issues during the related hospital stay, thus these scores cannot control for the differences in treatment provided by different facilities. Second, the analysis (Table 5) showed that a high percentage of people who were categorized with a low mREMS score, 0–2, were sent to a level I trauma center, when many could have likely been sent to a lower level of trauma center, relieving resources and saving costs. Conversely, over 700 patients with a mREMS score greater than or equal to 14 (estimated mean mortality rate of 54.4%) were sent to a level II, or lower, trauma center, when a level I center care might have been more appropriate. The time at which patient vital signs were recorded at the hospital were not at fixed time intervals, as there are delays and differences in transport time in the pre-hospital setting. The authors did not control for differences in care among hospitals and the analysis did not compare rural populations to urban populations to control for the differences in the level of trauma centers available or time to transport. Nearly 25% of patients were excluded in this study because they were transferred, thus there might have been even more patients that were sent to a less than optimal care center. The study is unlikely to be generalizable to the pediatric population as the mREMS score components were not physiologically derived for pediatrics, and it was not tested on those under age 16. The study also may not be generalizable in patients with a trauma poisoning or overdose situation, as alcohol and drug consumption can confound scoring systems [28]. Future research could perform a similar study, but include transfer patients to identify if there is a significant difference of patients that were initially triaged to a different level than expected. The score could also be calculated both pre-hospital and upon arrival to evaluate the impact of the change in score during the time of transport. While the NTDB database contained data on the facility patients were transferred to, it lacked vital sign data necessary to calculate the mREMS score at the originating facility. The mREMS categories could also be evaluated to identify the optimal level of trauma center designation to be transported to for each mREMS category. The mREMS score could then be prospectively studied as a triage tool in the field for the identification of the appropriate level of trauma center based upon risk.

Conclusions

The mREMS proved to be a simple and valid method to quickly predict trauma in-hospital mortality. The score performed similarly to MGAP and RTS but proved superior to several other established trauma scores, showing that more complex, subjective, and time consuming trauma scores may not be necessary. The mREMS score can guide providers in stratifying the severity of injury and in clinical decision making, even in a setting of limited resources. The score has potential to guide trauma patient triage in the field to improved transport to the most appropriate facility.

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Competing interests

The author(s) attest that they have no competing or conflicting interests to declare.

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