THE MODIFIED RAPID EMERGENCY MEDICINE SCORE: A NOVEL TRAUMA TRIAGING TOOL FOR PREDICTING IN-HOSPITAL MORTALITY

By

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Abstract

Objectives: 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 Score (REMS is a simple, non-invasive, and objective version of the APACHE II 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:** This was a two-part study design. The first part incorporated a retrospective analysis of a local trauma database (3,680 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 GCS was increased. The second part comprised of validating the new mREMS score retrospectively on a U.S. national trauma database that included 429,711 patients admitted with trauma over a 1-year period. The discriminate power of modified REMS (mREMS) was compared to other trauma scores using the area under the receiver operating characteristic (ROC) curve. **Results:** The mREMS score (AUC 0.97) was demonstrated to be higher than RTS (AUC 0.96), ISS (AUC 0.78), mGAP (AUC 0.96), and SI (AUC 0.67) in predicting in-hospital mortality. **Discussion:** 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.

Acknowledgements

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List of Abbreviations

ACS	The American College of Surgeons
AIS	The Abbreviated Injury Score
APACHE	Acute Physiology and Chronic Health Evaluation Score
AUC	Area under the Receiver Operating Characteristic Curve
GCS	Glasgow Coma Scale
HR	Heart Rate
ISS	The Injury Severity Score
MAP	Mean Arterial Pressure
MGAP	The Mechanism of injury, Glasgow Coma Scale, Age, and Pressure Score
mREMS	The Modified Rapid Emergency Medicine Score
NTDB	The National Trauma Data Bank
O2 Sat	Peripheral Oxygen Saturation
REMS	The Rapid Emergency Medicine Score
ROC	The Receiver Operating Characteristic Curve
RR	Respiratory Rate
RTS	The Revised Trauma Score
SBP	Systolic Blood Pressure
SI	Shock Index

Introduction

Trauma is one of the leading causes of death for individuals under the age of 45 and is a significant contributor to disability and health care resource consumption [1, 2]. The mortality rate of trauma patients depends on the severity of the injuries, how rapidly trauma severity is assessed, and how quickly patients are triaged to an appropriate care center. Quick assessment and proper triage can decrease the chances of mortality and long-term disability [3, 4]. Trauma scoring systems provide an instrument to quickly measure injury severity and predict outcomes. Several trauma scoring systems have been developed over the past fifty years that differ in their complexity, design, and accuracy [5, 6]. Although many scoring systems exist, very few studies compare their accuracy in predicting mortality on a national scale.

One of the first known trauma scores was developed in 1971, called the Abbreviated Injury Score (AIS), and it was an anatomic measure of injury severity [7]. In 1974, Baker et al., created an improved AIS score and named it the Injury Severity Score (ISS) [8]. Following the ISS, came the APACHE score, the Revised Trauma Score (RTS), the Shock Index (SI), and the Mechanism of injury, Glasgow Coma Scale, Age, and Systolic Blood Pressure (MGAP) score [9-12]. As there are numerous trauma scoring systems with varying levels of accuracy and clinical usefulness, the trauma setting is in need of a simple, objective and more accurate score that can be used in real time.

The Revised Trauma Score (RTS) is designed to be used pre-hospital, for trauma triage. It includes the variables RR, SBP, and GCS that are each weighted differently and summed up to a maximum score of 12 [9]. 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 [8]. 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 [7] (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 [11]. Since its development in 2010, it has been tested and validated prospectively in Europe, but has yet to be tested in the United States [11, 13]. 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 [10].

A triage score that proved to be a powerful predictor of in-hospital mortality in *medical* (non-trauma) patients was developed in 2004 called the Rapid Emergency Medicine Score (REMS) [14]. 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, previously untested in the trauma population, was recently found to be a simple and accurate predictor of in-hospital mortality in trauma patients. The results showed that there could be room for improvement, to optimize the score for trauma patients. It was hypothesized that the variable age was over weighted and that GCS was under weighted [15].

The modified Rapid Emergency Medicine Score (mREMS) is an adapted version of the point based non-trauma REMS score [14]. It was designed and hypothesized to be a practical triage score that could be used in real time and a more accurate predictor of in-hospital mortality than scores that are often more complex and require invasive measurements. The purpose of this study was to modify the REMS for the trauma population to create the mREMS score and validate it on a nationally representative dataset. Secondary objectives include comparing the predictive ability of the new mREMS score to the existing trauma scores, RTS, ISS, MGAP and SI, and examining the scores predictive accuracy when stratified by blunt or penetrating trauma.

Methods

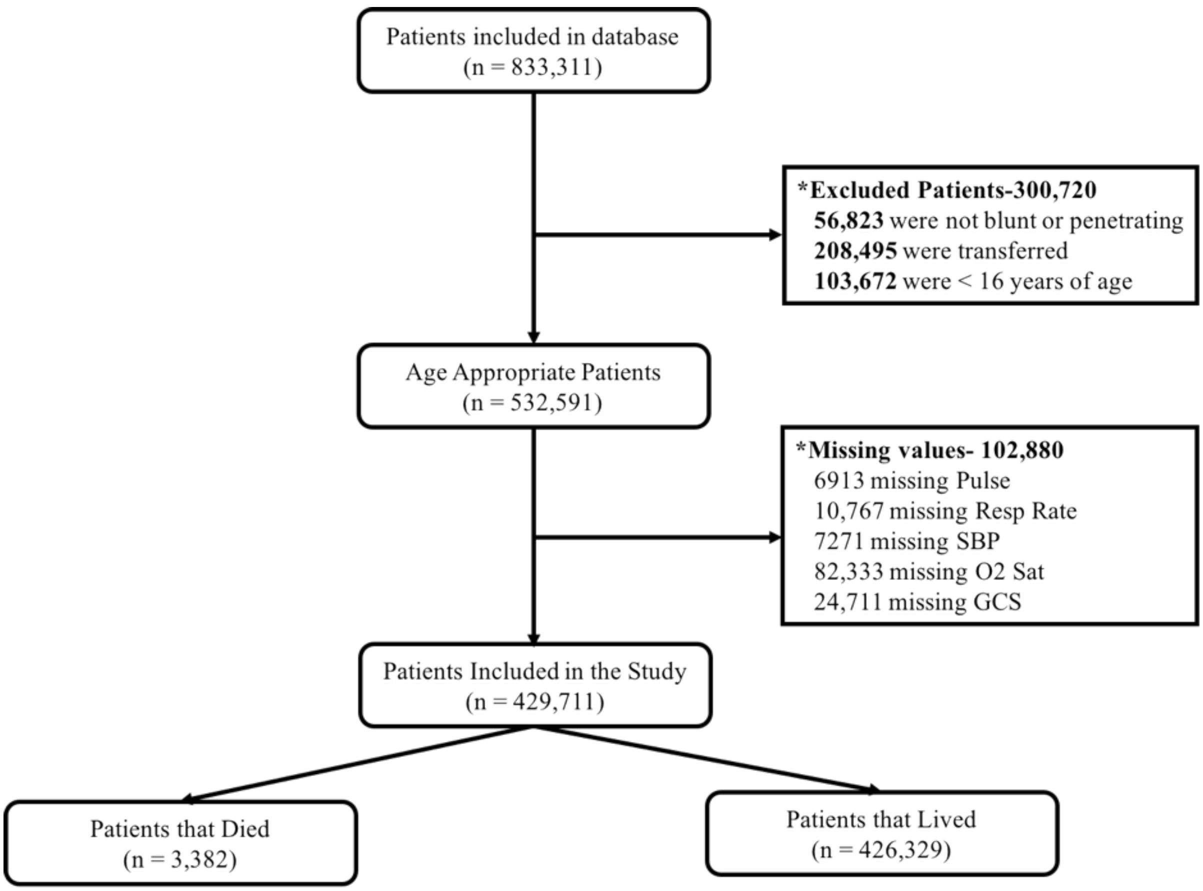
Part I Modification of REMS

The original REMS was modified, and mREMS was derived, on an urban trauma database at the University of Kansas Hospital (level I trauma center) over a 4 year period with 3,680 patients. A previous study by our group evaluated the REMS in a trauma population and hypothesized that the weighting of GCS was too low, the weighting of age was too high, and that mechanism of injury might be able to be incorporated into the score, to better represent trauma patients [15]. For the mREMS score the relative weighting of age has been decreased and the weighting of GCS has been increased, to provide a more accurate predictor of mortality in trauma patients. While the original non-trauma REMS score includes MAP, the mREMS score includes SBP in its place because it has been the most commonly used and recorded measurement of blood pressure and a proven indicator of trauma severity [6]. Furthermore, SBP is often the only available measurement of blood pressure in trauma registries. Also, as the mechanism of injury, blunt or penetrating, has been included into field triage tools, this study looked at the effectiveness of incorporating mechanism of injury into the score [16].

Part II Validation of mREMS

The validation of the mREMS score was a retrospective analysis of level I-IV trauma centers that contributed to the National Trauma Data Bank (NTDB), a nationwide registry managed by the American College of Surgeons (ACS) [17]. The sample included 758 U.S. hospitals from the year 2012. The study included patients 16 years and older who were treated at a level I-IV trauma center, with either blunt or penetrating injuries. The study excluded patients with missing vital signs necessary for the mREMS score, those who were transferred from another facility, and those that were reported as a burn and/or drowning victim. During the one-year study period, 429,711 patients were included in the analysis after meeting the inclusion and exclusion criteria (Figure 1). The study and design was reviewed and approved by the University of Kansas Medical Center Institutional Review Board.

Figure 1: Inclusion and Exclusion Criteria



* Not mutually exclusive

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. While the ISS score was calculated and obtained by the NTDB database, all other scores were calculated during the data analysis phase.

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).

Table 1. mREMS Scoring System

	Score						
Variable	**0**	**+1**	**+2**	**+3**	**+4**	**+5**	**+6**
Age (years)	≤ 44	45-64		65-74	> 74		
SBP	110-159	160-199 90-109	≥ 200 80-89	130-159	≤ 79		
HR (beats/min)	70-109		110-139 55-69	140-179 40-54	>179 ≤39		
RR (breaths/min)	12-24	25-34 10-11	6-9	35-49	>49 ≤ 5		
O_2 Saturation (%)	>89	86-89		75-85	<75		
GCS	14 or 15		8-13			5-7	3 or 4

In the preliminary score modification, odds ratios of age and GCS score assignments were calculated, as well as injury type (blunt or penetrating) 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 second part of this study validated the newly modified score, mREMS, on a national database and compared it to currently utilized trauma scoring systems, to determine which scoring method was superior in its ability to predict in-hospital mortality. We compared mREMS to other injury scoring systems, including RTS, ISS, MGAP and SI.

Statistical Analysis

For this study, patients were split into two groups, those who survived and those who died. The NTDB database contains all necessary data to calculate each of the scores for the purpose of this comparison. While the ISS score for each patient was already provided, all other scores were calculated using their respective formulas. While categorical variables are described by frequency and percentage, normally distributed continuous variables are described by mean and standard deviation, using the t-test. For comparisons between groups, parametric testing is used. The Chi-square test is used for categorical variables. Correlations were tested using the Spearman method. Logistic regression models were used to calculate odds ratios. The discriminate predictive power of mREMS, RTS, ISS, MGAP, and SI are 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 statistical level of significance was set at $p < 0.05$ for this study. All analyses on collected data are conducted using SAS V.9.4.

Results

Part I Modifications to REMS

The modifications to the score were evaluated based upon their incremental individual increase to the overall AUC (Area under the Curve). The modifications to the variable age, increased the AUC individually to 0.910. The modifications to the variable 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) with the scoring modifications on the single center trauma database. When looking to incorporate the mechanism of injury, we analyzed the point value mean differences between blunt or penetrating trauma. Analysis showed that in the majority of cases, penetrating injuries received more points than blunt injuries in the mREMS score (Table 2).

Table 2. Point Value Mean Differences Blunt vs Penetrating (Blunt - penetrating)

REMS Categories:	Age	SBP	HR	RR	SAO2	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

Part II Validation of mREMS

Of the 429,711 patients in the study, 426,329 (99.2%) lived and 3,382 (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 an average 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 429,711 Trauma Patients

	Total (N=429,711)	**Dead (N=3,382) Mean (SD)**	**Alive (N=426,329) Mean (SD)**
Age (years)	50.3 (22.9)	44.1 (20.5)	50.4 (22.9)
<45 (%)	44.1	44.0	56.7
45-54 (%)	13.8	13.8	13.5
55-64 (%)	12.3	12.3	11.1
65-74 (%)	9.2	9.3	7.4
>74 (%)	20.5	20.6	11.4
Male (%)	61.4	77.4	61.3
Female (%)	38.6	22.6	38.7
Race (%)			
White	72.3	56.5	72.4
Black	15.6	32.4	15.5
Other	12.1	11.2	12.1
Length of Stay (days)	5.2 (7.8)	1.1 (1.1)	5.3 (7.8)
Systolic BP (mmHg)	139.3 (28.6)	42.0 (61.4)	140.1 (26.8)
HR (beats/min)	88.0 (20.6)	36.3 (51.4)	88.4 (19.6)
RR (breaths/min)	18.6 (5.1)	6.0 (9.8)	18.7 (4.9)
O_2 Saturation (%)	96.2 (11.3)	42.2 (46.6)	96.6 (9.4)
GCS	14.2 (2.6)	4.2 (3.4)	14.3 (2.4)
Blunt Trauma (%)	89.3	57.9	89.5
Penetrating Trauma (%)	10.7	42.1	10.5
Trauma Center (%)			
Level I	52.9	58.3	52.8
Level II	35.8	33.2	35.8
Level III, IV, V	11.4	8.5	11.4

The mortality rate for each incremental mREMS score allowed for 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).

Table 4. mREMS Score Characteristics ($p < 0.0001$)			
mREMS	**Alive (N)**	**Dead (N)**	**Mortality (%)**
0-2	**221,614**	**70**	**0.03**
Blunt	*190,381*	*64*	*0.03*
Penetrating	*31,233*	*6*	*0.02*
3-5	**138,818**	**112**	**0.08**
Blunt	*129,576*	*98*	*0.08*
Penetrating	*9,242*	*14*	*0.2*
6-8	**50,663**	**205**	**0.4**
Blunt	*48,410*	*152*	*0.3*
Penetrating	*2,253*	*53*	*2.3*
9-13	**12,776**	**488**	**3.7**
Blunt	*11,425*	*342*	*2.9*
Penetrating	*1,351*	*146*	*9.8*
14-17	**1,993**	**317**	**13.7**
Blunt	*1,676*	*209*	*11.1*
Penetrating	*94*	*170*	*64.4*
18-21	**294**	**409**	**58.2**
Blunt	*200*	*239*	*54.4*
Penetrating	*94*	*170*	*64.4*
22-26	**171**	**1781**	**91.2**
Blunt	*81*	*856*	*91.4*
Penetrating	*90*	*925*	*91.3*
Total	**426,329**	**3,382**	**0.80**
Blunt	***381,749***	***1,960***	***0.51***
Penetrating	***44,580***	***1,422***	***3.09***

An increase of one point in the mREMS score is 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 alive versus dead, to display the level of trauma center that patients in each grouping were taken to (Table 5). Not all patient records included the level of trauma center designation, so the total in for Table 5 is slightly lower than the overall N in the study.

Table 5. Trauma Center Designation Breakdown by mREMS Categories*		
mREMS	**Alive (N)**	**Dead (N)**
0-2		
Level I (28.7% of patients)	*106,790 (99.97%)*	*27 (0.03%)*
Level II (17.4% of patients)	*64,667 (99.94%)*	*41 (0.06%)*
Level III (5.5% of patients)	*20,539 (100.00%)*	*1 (0.00%)*
3-5		
Level I (15.8% of patients)	*58,787 (99.91%)*	*51 (0.09%)*
Level II (12.3% of patients)	*45,783 (99.92%)*	*38 (0.08%)*
Level III (4.1% of patients)	*15,126 (99.93%)*	*10 (0.07%)*
6-8		
Level I (5.6% of patients)	*20,664 (99.57%)*	*89 (0.43%)*
Level II (4.7% of patients)	*17,353 (99.67%)*	*57 (0.33%)*
Level III (1.5% of patients)	*5,653 (99.74%)*	*15 (0.26%)*
9-13		
Level I (2.0% of patients)	*7,067 (96.72%)*	*240 (3.28%)*
Level II (1.0% of patients)	*3,501 (95.79%)*	*154 (4.21%)*
Level III (0.2% of patients)	*596 (94.90%)*	*32 (5.10%)*
14-17		
Level I (0.4% of patients)	*1,213 (87.14%)*	*179 (12.86%)*
Level II(0.2% of patients)	*501 (85.64%)*	*84 (14.36%)*
Level III (0.02% of patients)	*65 (77.38%)*	*19 (22.62%)*
18-21		
Level I (0.1% of patients)	*185 (43.43%)*	*241 (56.57%)*
Level II (0.05% of patients)	*74 (40.88%)*	*107 (59.12%)*
Level III (0.01% of patients)	*10 (22.73%)*	*34 (77.27%)*
22-26		
Level I (0.3% of patients)	*92 (9.02%)*	*928 (90.98%)*
Level II (0.2% of patients)	*46 (8.13%)*	*520 (91.87%)*
Level III (0.04% of patients)	*10 (6.45%)*	*145 (93.55%)*
TOTAL	**368,722**	**3,012**

*Level IV and V were combined together with level III.

The number of patients ranges from 106,790 alive patients in the 0-2 mREMS category that were transported to a level I trauma center to 145 dead patients in the 22-26 mREMS category that were transported to a level III, IV, or V trauma center.

As part of the secondary analysis the mREMS mean score was compared to RTS, ISS, MGAP, and SI (Table 6).

Table 6. Comparison of Trauma Scores

	N	Dead Mean (SD)	Dead Mean 95% CI	Alive Mean (SD)	Alive Mean 95% CI	*p*-Value
mREMS	429,711	17.7 (5.4)	17.509 to 17.909	2.9 (2.7)	2.893 to 2.909	<0.0001
RTS	429,711	1.7 (2.5)	1.601 to 1.768	7.6 (0.84)	7.618 to 7.623	<0.0001
ISS	425,735	26.2 (20.1)	25.489 to 26.863	9.8 (8.5)	9.758 to 9.809	<0.0001
MGAP	429,711	11.7 (5.0)	11.508 to 11.848	25.6 (3.4)	25.626 to 25.647	<0.0001
SI	427,149	0.9 (2.1)	0.870 to 1.105	0.6 (0.3)	0.658 to 0.660	<0.0001

The mean mREMS score for those who died was 17.7 and 2.9 for those that lived. The mean MGAP score for those who died was 11.7 and 25.6 for those who lived. The mean RTS score for those who died was 1.7 and 7.6 for those who lived. The mean ISS score for those that died was 26.2 and 9.8 for those that lived. The mean SI score for those that died was 0.9 and 0.7. mREMS (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 (Figure 2). When stratified by blunt or penetrating trauma, mREMS had the highest AUC score (Table 7). 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 (data not shown). Upon further evaluation, when the mechanism of injury was removed from the MGAP score, the overall AUC was 0.966.

Figure 2 Modified Rapid Emergency Medicine Score (mREMS) receiver operating characteristic curve (area under the curve=0.967)

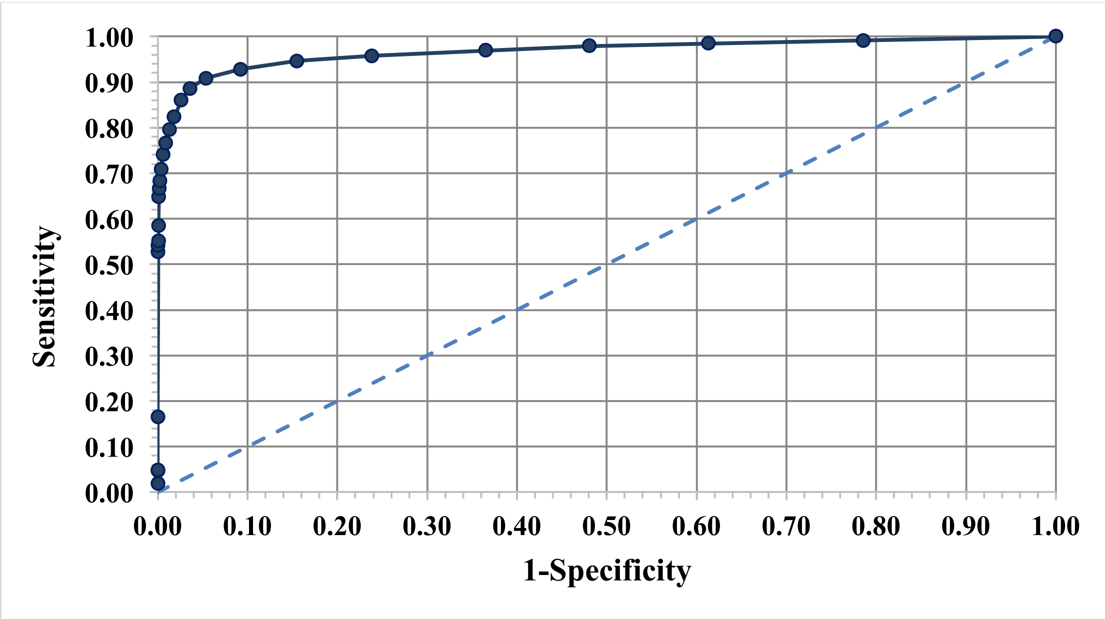


Table 7. Scoring Systems' Area Under the Curve with 95% Confidence Interval			
Scoring System	**Overall AUC**	**Blunt AUC**	**Penetrating AUC**
mREMS	0.967 (0.963, 0.971)	0.950 (0.943, 0.957)	0.989 (0.987, 0.992)
MGAP	0.964 (0.959, 0.968)	0.945 (0.939, 0.952)	0.986 (0.983, 0.989)
RTS	0.959 (0.955,0.964)	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)

The regression analysis performed on each individual variable of the mREMS score indicated that respiratory rate was the only variable that did not individually predict mortality (Table 8). GCS was found to be the strongest predictor of mortality (OR 0.688, 95% CI 0.679, 0.697) and heart rate (OR 0.993, 95% CI 0.991, 0.995) was the weakest predictor of mortality.

Table 2. Multiple Logistic Regression for All Parameters in mREMS			
Variable	**OR**	**95% CI**	***p*-Value**
GCS	0.688	0.679, 0.697	<0.0001
O_2 Saturation (%)	0.977	0.975, 0.979	<0.0001
SBP (mm Hg)	0.979	0.977, 0.980	<0.0001
Age	1.021	1.018, 1.023	<0.0001
Heart rate (bpm)	0.993	0.991, 0.995	<0.0001
RR (breaths/min)	1.002	0.996, 1.008	0.5615

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 [1]. Quick and accurate identification of trauma injury severity is crucial in the management of trauma patients, as time plays such an important role in the outcome [18]. There is a critical need to have a scoring system that will accurately predict outcomes, while still being easy to use and clinically practical in real time. While some scoring systems, like the APACHE score which requires 12 physiologic measurements and patients' previous health status, [7, 12, 19] are too complex to be quickly utilized or require invasive procedures to calculate, mREMS is an easy to use objective scoring model that does not require any invasive or additional measurements other than vital signs that are already taken by emergency personnel. The goal of the study was to modify a previously utilized scoring system that was designed for the non-surgical medical population (REMS) to create mREMS. The mREMS score was then optimized for trauma patients and then validated on a nationally representative database. When compared to an anatomically based scoring model (ISS), the mREMS score is less subjective and requires less time to calculate, while providing more accuracy.

The mREMS is a modified version of the Rapid Emergency Medicine Score (REMS) [14]. While REMS has been shown to be an accurate predictor of mortality in the non-surgical non-trauma medicine population [14], 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 [15]. 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.

Logistic regression analysis showed that on a national database with a large sample size mREMS had the highest AUC (0.967) when compared to RTS, ISS, MGAP, and SI. mREMS also scored the highest when stratified by blunt vs penetrating injury. 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. Despite ISS being the most commonly used tool to evaluate injury severity worldwide [19], complicated scores such as ISS and TRISS (calculated from ISS and RTS) are retrospective systems whose scores 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. 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 [20]. 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. This can be substantiated by the multiple logistic regression models, showing the odds ratios of each variable. GCS, oxygen saturation and systolic blood pressure were the top 3 strongest predictors of mortality. 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 [11]. 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 [11, 13].

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 actually had a higher overall mortality rate than penetrating patients.

The mREMS score was categorized into sub-groups based upon the natural distribution of mortality rates. While the buckets are useful in showing the increasing mortality rate for each increasing mREMS score, overall and stratified by blunt vs penetrating trauma, the buckets may serve as a useful model for risk category assignment. Based upon clinical judgment and mortality rates, the mREMS categories could be classified into risk categories in future studies. These risk categories could even be used to help guide prehospital triage decisions when selecting the necessary level of trauma center for transport.

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 have usefulness in both the pre-hospital and hospital setting. 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 by risk category automatically on EMS and/or hospital EMR systems. An auto-calculated mREMS score would provide pre-hospital personnel and providers the ability to quickly and accurately understand the patient severity and the predicted risk of mortality. The score can 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 its ability to identify seriously injured patients [21]. 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 to a level I trauma center, whereas less severe patients could perhaps be taken to a closer or more appropriate level of healthcare center, not taxing resources more than necessary.

This study, while generalizable with a large number of patients from a nationwide sample, does contain some limitations as a retrospective analysis. While these trauma scores run on the assumption that mortality is not influenced by the treating facility, they are unable to differentiate mortality caused by trauma versus the hospital due to less than optimal treatment. 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. On the other side, 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 they likely should have been brought to a level I center. 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. Nearly 25% of patients were excluded in this study because they were transferred, thus there might have been 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 is not generalizable in patients with a trauma poisoning or overdose situation, as alcohol and drug consumption can confound scoring systems [22]. 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 and evaluating the change in score during the time of transport. The NTDB database lacked vital sign data necessary to calculate the mREMS score at the transferring 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 for the identification of the appropriate level of trauma center based upon risk.

Conclusion

In conclusion, mREMS proved to be a simple and objective method to quickly and accurately predict trauma outcomes. 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 as efficient. 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 future potential to guide trauma patient triage to appropriate healthcare facilities to ensure appropriate allocation of resources and may help decrease trauma related mortality.

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