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External Validation of mREMS for Mortality Prediction in Road Traffic Injuries at a Tertiary Trauma Center in Bangkok

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ABSTRACT

Road traffic injuries remain a leading cause of preventable death and disability globally. To improve risk stratification and resource allocation, various prognostic scoring tools have been introduced over the years. This study was conducted to assess the ability of the modified Rapid Emergency Medicine Score (mREMS) to predict in-hospital mortality in victims of road traffic crashes and to determine how its performance compares to that of two established trauma scores: the Revised Trauma Score (RTS) and the MGAP (Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure) score. We retrospectively reviewed 1,033 road traffic injury cases from the trauma registry at Vajira Hospital. The modified Rapid Emergency Medicine Score (mREMS) was derived using six physiological and clinical parameters: age, systolic blood pressure, heart rate, respiratory rate, peripheral oxygen saturation, and Glasgow Coma Scale score. Discriminatory performance was evaluated by constructing receiver operating characteristic (ROC) curves and calculating the area under the curve (AUC) with 95% confidence intervals. The AUC of mREMS was directly compared with those of the Revised Trauma Score (RTS) and the MGAP score. Calibration of each model was examined using the Hosmer–Lemeshow goodness-of-fit test. The modified Rapid Emergency Medicine Score (mREMS) outperformed the Revised Trauma Score (RTS) in predicting in-hospital mortality among road traffic injury patients, with an AUC of 0.909 (95% CI 0.866–0.951) versus 0.859 (95% CI 0.791–0.927) for RTS (p = 0.023). When compared to the MGAP score, however, mREMS showed comparable discriminatory power, with no significant difference between their AUCs (p = 0.150). Additionally, mREMS displayed adequate calibration in this population, as indicated by a non-significant Hosmer–Lemeshow test (p = 0.277). In patients with road traffic injuries, the modified Rapid Emergency Medicine Score (mREMS) proved to be a highly effective tool for predicting in-hospital mortality. These findings support its potential use in enhancing triage accuracy at the point of care. Nevertheless, additional external validation across multiple trauma centers is recommended prior to broader or nationwide adoption.

Keywords: Modified rapid emergency medicine score, Road traffic injury, External validation

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Introduction

Injuries constitute one of the leading causes of death and disability worldwide, claiming approximately 5.8 million lives each year; road traffic crashes account for nearly a quarter of these fatalities [1]. Outcomes for injured patients are influenced by injury severity, patient factors, pre-hospital systems, and the quality of care received. Effective triage plays a critical role in optimizing survival, prompting the development of numerous scoring systems designed to predict mortality, morbidity, and guide resource allocation.

Trauma scoring systems are generally categorized as anatomical (e.g., Injury Severity Score, ISS [2]), physiological (e.g., Revised Trauma Score, RTS [3]; Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure — MGAP [4]; modified Rapid Emergency Medicine Score — mREMS [5]), or combined models (e.g., Trauma and Injury Severity Score, TRISS [6]; Kampala Trauma Score, KTS [7]). Although the ISS is widely regarded as the gold standard for outcome prediction [8], it requires detailed anatomical diagnosis, making it

impractical for initial triage. Physiological scores, which rely on parameters available at presentation, are therefore more suitable for early decision-making.
Among physiological tools, the RTS has been extensively adopted and validated internationally [9–11]. Nevertheless, newer scores, including the mREMS, have been proposed as potential improvements. The original Rapid Emergency Medicine Score (REMS) was developed to predict in-hospital mortality in nonsurgical emergency department patients using six variables: age, systolic blood pressure, heart rate, respiratory rate, oxygen saturation, and Glasgow Coma Scale [12]. Subsequent studies showed that REMS also performed well in trauma cohorts, but recalibration of variable weights led to the modified REMS (mREMS), which demonstrated superior discrimination in its derivation population [5, 13]. To date, however, the mREMS has not undergone independent external validation.
In Thailand, the Emergency Severity Index (ESI) remains the sole triage instrument in routine use. Although ISS, RTS, and TRISS are recognized within the Thai trauma community, none are incorporated into frontline triage protocols. Integrating a simple, accurate physiological score could enhance decision-making, particularly for road traffic injuries, which place a heavy burden on the national health system. Because prognostic models often lose performance when applied outside their derivation settings [14], external validation in local populations is essential. Among existing scores, only TRISS has been formally validated in Thailand [15, 16].
Given evidence of superior performance of the mREMS in its original cohort [5], the present study was designed with two primary objectives: (1) to externally validate the mREMS in a Thai population of road traffic injury patients and, if necessary, refine it for local use; and (2) to compare its predictive accuracy against established physiological scores (RTS and MGAP).

Materials and Methods

Study setting
This research was performed at Vajira Hospital, a 774-bed university hospital in Bangkok that serves as one of the city's designated level I trauma referral centers. The facility handles more than 500 major trauma activations each year, with roughly 200–300 patients requiring hospital admission.

Data collection
The modified Rapid Emergency Medicine Score (mREMS) was externally validated using data from road traffic injury patients treated at Vajira Hospital. Cases were identified through ICD-10 codes V00–V89, capturing all road transport-related injuries. A retrospective review was conducted of adult trauma patients (aged ≥15 years) admitted between January 1, 2015, and December 31, 2018. Only those with complete initial physiological data required for mREMS, RTS, and MGAP calculations were retained; patients with any missing predictor variables were excluded. Pregnant women, individuals under 15 years of age, and patients transferred solely for postoperative management or rehabilitation were also excluded.
Demographic details (age, sex) and injury mechanism were recorded. All parameters needed to compute mREMS, RTS, and MGAP were extracted from measurements taken upon emergency department arrival. The primary endpoint was in-hospital mortality occurring within 30 days of admission. The study protocol received approval from the Vajira Institutional Review Board (COA 047/2563) prior to data collection

Sample size estimation
According to data from Vajira, the mortality rate for trauma hospitalizations is 3%. The mREMS model, based on this cohort, was expected to have an Area Under the Receiver Operating Characteristic (ROC) curve (AUC) of 0.900. The null hypothesis for the AUC was set at 0.500, but the lowest acceptable AUC for the mREMS to be deemed viable for implementation was agreed upon as 0.750, based on consensus among researchers. The study set the Type I error rate (α) at 0.05 and the statistical power ($1 - \beta$) at 0.80. Using the sample size calculation method proposed by Hanley and McNeil, it was determined that a sample of 800 patients—comprising 24 deaths and 776 survivors—was required. This sample size was calculated using the SciStat.com web-based tool.

Statistical analysis
Categorical variables such as sex, injury mechanism, and head injury severity were summarized as counts and percentages, and differences between groups were analyzed using chi-square tests. Continuous variables,

including age, physiological measures, and trauma scores, were described using either means with standard deviations (SD) or medians with interquartile ranges (IQR), depending on the distribution. For data that followed a normal distribution, independent t-tests were employed; for non-normally distributed data, the Mann–Whitney U test was used.

Age and physiological parameters—such as systolic blood pressure (SBP), heart rate (HR), respiratory rate (RR), oxygen saturation (SpO2), and Glasgow Coma Scale (GCS)—were scored according to the mREMS system. The mREMS was then stratified as per the original study methodology, with mortality rates reported for each stratum. RTS and MGAP scores were also calculated using their respective formulas.

Logistic regression was used to model death outcomes for each trauma score. ROC curves were plotted for each score, with false-positive rates (1 – specificity) on the x-axis and sensitivity on the y-axis. Optimal cutoff values for each score were determined based on ROC curve analysis, taking into account the likelihood ratios suggested in the original study. Sensitivity, specificity, positive and negative predictive values (PPV and NPV), and positive and negative likelihood ratios (LR+ and LR-) were calculated at each cutoff. The AUC of the mREMS was compared to that of the RTS and MGAP scores using the DeLong *et al*. method.

The model's fit was evaluated using the Hosmer–Lemeshow chi-square test. Calibration was assessed by calculating the observed-to-expected (O/E) ratio and plotting observed versus expected values. A ratio close to 1 and a fitted line near the reference line indicated good model calibration. To enhance the model, recalibration was done by adjusting the intercept (baseline risk) and multiplying the mREMS score by a correction factor derived from logistic regression of the death outcome.

The model's performance was reported with a 95% confidence interval (95% CI), and statistical significance was set at a p-value less than 0.05 unless otherwise noted. All statistical analyses were performed using Stata version 16 (StataCorp, Texas, USA). The study adhered to the STARD guidelines for reporting diagnostic accuracy studies.

Results and Discussion

The study included 1,033 patients injured in road traffic accidents, of whom 43 (4.2%) died. The median age of the cohort was 35 years, with an interquartile range (IQR) of 21 to 49 years. The majority of patients, 78.7%, were male. There were no significant differences in age or gender between those who survived and those who died. The predominant injury mechanisms were bicycle and motorcycle accidents, which together accounted for 84.7% of the injuries. Pedestrian accidents and motor vehicle collisions made up 12.9% and 2.4% of the cases, respectively. A larger proportion of fatalities involved pedestrian injuries and motor vehicle accidents compared to the survivors **(Table 1).**

Table 1. Baseline characteristics, physiological parameters, and trauma scores.

	Survived (N = 990)	**Died (N = 43)**	**p-value**
Age, years (Median, IQR)	35 (21, 49)	36 (25, 49)	0.306
Sex			
Male, N (%)	781 (78.9)	32 (74.4)	0.483
Mechanism of injury, N (%)			
Pedestrian	123 (12.4)	10 (23.3)	0.012
Bicycle/Motorcycle	845 (85.4)	30 (69.8)	
Motor vehicle	22 (2.2)	3 (7.0)	
SBP, mmHg (Mean ± SD)	136 ± 26	119 ± 59	0.061
HR, beats/min (Mean ± SD)	89 ± 16	79 ± 38	0.077
RR, breaths/min (Mean ± SD)	20 ± 3	20 ± 10	0.960
SpO_2, % (Median, IQR)	99 (98, 100)	97 (88, 100)	<0.001
Head injury severity, N (%)			
Mild (GCS 14–15)	902 (91.1)	12 (27.9)	<0.001
Moderate-Severe (GCS 3–13)	88 (8.9)	31 (72.1)	
mREMS			
Overall score (Median, IQR)	1 (0, 2)	6 (5, 10)	<0.001
Age score (Median, IQR)	0 (0, 1)	0 (0, 1)	0.446
SBP score (Median, IQR)	0 (0, 1)	0 (0, 1)	<0.001

HR score (Median, IQR)	0 (0, 0)	2 (0, 2)	<0.001
RR score (Median, IQR)	0 (0, 0)	0 (0, 1)	<0.001
SpO_2 score (Median, IQR)	0 (0, 0)	0 (0, 1)	<0.001
GCS score (Median, IQR)	0 (0, 0)	5 (0, 6)	<0.001
RTS (Median, IQR)	7.8408 (7.8408, 7.8408)	5.9672 (4.0936, 7.5500)	<0.001
MGAP (Median, IQR)	29 (27, 29)	19 (17, 23)	<0.001

GCS: Glasgow Coma Scale; HR: Heart Rate; IQR: Interquartile Range; MGAP: Mechanism of Injury, Glasgow Coma Scale, Age, and Systolic Blood Pressure; min: Minute; mmHg: Millimeters of Mercury; mREMS: Modified Rapid Emergency Medicine Score; RR: Respiratory Rate; RTS: Revised Trauma Score; SBP: Systolic Blood Pressure; SD: Standard Deviation; SpO2: Pulse Oxygen Saturation.

For most physiological factors, significant differences were observed between survivors and those who died, except for SpO2 levels and the severity of head injuries. Among the notable differences, SBP, HR, RR, GCS, and SpO2, as part of the mREMS scoring system, showed marked variation between the two groups. The median mREMS score was considerably higher in the deceased group, with a value of 6 (IQR: 5–10) versus 1 (IQR: 0–2) in survivors. Similarly, both RTS and MGAP scores were significantly lower for the deceased compared to the survivors **(Table 1)**.

When the mREMS scoring system was tested on Vajira's dataset for road traffic injuries, it showed impressive discriminatory power, yielding an AUC of 0.909 (95% CI: 0.866–0.951). In comparison, the RTS and MGAP scores had AUCs of 0.859 (95% CI: 0.791–0.927) and 0.878 (95% CI: 0.810–0.946), respectively. The mREMS AUC was significantly greater than the RTS ($p = 0.023$), but the difference between mREMS and MGAP was not statistically significant ($p = 0.150$). The ROC curves for all trauma scores are displayed in **Figure 1.**

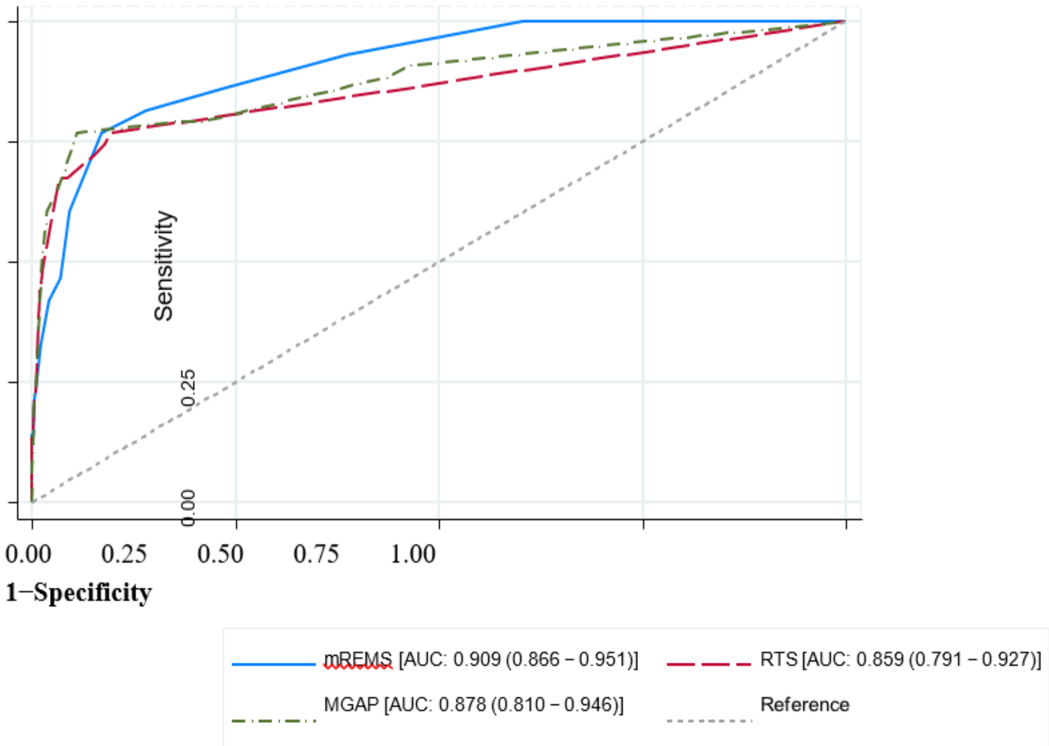

Figure 1. Receiver operating characteristic curve of trauma scores.

When we classified patients in our cohort using the same method as the original mREMS study, we observed that higher mREMS scores corresponded to higher mortality rates. However, the mortality rate for each mREMS group in our cohort was significantly higher than that seen in the original mREMS cohort **(Table 2)**. Only seven patients in our cohort had mREMS scores greater than 13, and all of them unfortunately died. The performance metrics—such as sensitivity, specificity, positive predictive values (PPVs), negative predictive values (NPVs), and both positive and negative likelihood ratios (LR+ and LR-)—were influenced by the chosen score cutoffs, as shown in **Table 3**.

Table 2. Comparison of mortality rates by modified Rapid Emergency Medicine Score (mREMS) categories versus those reported in the original study.

mREMS	Total N	Deaths N (%)	% Death (Original study)
0–2	761	6 (0.8)	0.03
3–5	198	11 (5.6)	0.08
6–8	48	12 (25.0)	0.3
9–13	19	7 (36.8)	2.9
14–17	1	1 (100)	11.1
18–21	1	1 (100)	54.4
22–26	5	5 (100)	91.4

Table 3. Predictive performance of the modified Rapid Emergency Medicine Score (mREMS) at various cutoff values

Cut off	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	LR+ (95% CI)	LR– (95% CI)
≥3	86.1 (72.1, 94.7)	76.3 (73.5, 78.9)	13.6 (11.8, 15.6)	99.2 (98.4, 99.6)	3.6 (3.1, 4.3)	0.2 (0.1, 0.4)
≥6	60.5 (44.4, 75.0)	95.2 (93.6, 96.4)	35.1 (27.3, 43.9)	98.2 (97.5, 98.8)	12.5 (8.6, 18.0)	0.4 (0.3, 0.6)
≥9	32.6 (19.1, 48.5)	98.8 (97.9, 99.4)	53.8 (36.5, 70.3)	97.1 (96.5, 97.6)	26.9 (13.2, 54.5)	0.7 (0.6, 0.8)
≥15	16.3 (6.8, 30.7)	100.0 (99.6, 100.0)	100.0 (N/A)	96.5 (96.0, 96.9)	N/A	0.8 (0.7, 1.0)

CI: confidence interval; LR: likelihood ratio; N/A: not available; NPV: negative predictive value; PPV: positive predictive value.

The mREMS demonstrated good calibration, with a Hosmer–Lemeshow chi-square statistic of 3.86 (p = 0.277). Additional evidence of excellent calibration was provided by an observed-to-expected (O/E) mortality ratio of 1.015 (95% CI: 0.886–1.144) and the calibration plot **(Figure 2)**. Attempts to recalibrate the model by adjusting the intercept or applying an overall correction factor to the mREMS did not yield any improvement in performance.

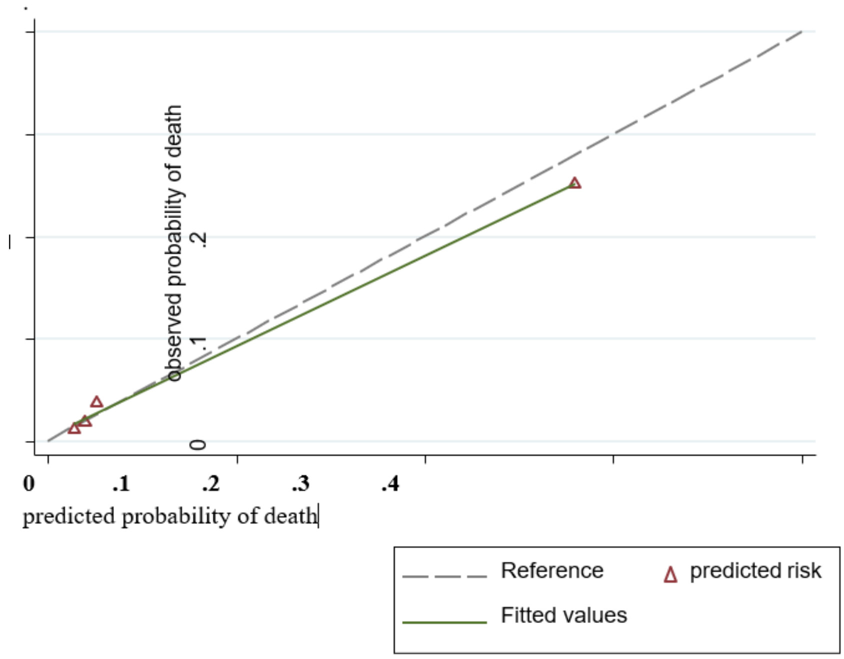

Figure 2. Calibration plot for the modified Rapid Emergency Medicine Score (mREMS).

The REMS (Revised Emergency Medical Score), introduced in 2004 and modified in 2017 for use with trauma patients, has never been externally validated until this study. This research marks the first external validation of the modified REMS (mREMS) using data from Thai road traffic injury patients. When applied to this cohort, the mREMS showed a slightly lower AUC (0.909) compared to the original study (0.967) [5], which was expected due to differences in the population characteristics between the original mREMS cohort and the Vajira cohort. Although most individual predictor variables did not differ between deceased patients and survivors in this dataset, the transformed variables used in the mREMS did show differences. This is a positive outcome from the perspective of the score's practical application.

In trauma scoring, anatomical scores like the ISS (Injury Severity Score) are not immediately usable because they require a clear diagnosis of organ injury, which is time-consuming and relies on complex diagnostics. Other scores, like TRISS and KTS, also have similar limitations, as they depend on anatomical information. Physiological scores, which rely on easily measurable variables, are more practical in early trauma care, especially in developing countries where timely, comprehensive diagnostic workups may not be feasible. This study compared the mREMS to other physiological scores, though it was originally compared to ISS in its development. The mREMS outperformed both ISS and other scores like RTS (Revised Trauma Score) in predicting mortality. While there was no statistically significant difference between mREMS and MGAP (Modified Glascow Coma Scale, Age, and Systolic Blood Pressure) in predicting in-hospital death, the mREMS performed better overall, which aligns with the results of the original study [5].

Several physiological trauma scores, such as GCS (Glasgow Coma Scale), SBP (Systolic Blood Pressure), and RR (Respiratory Rate), are commonly used in trauma prediction models, and the mREMS includes these factors along with others. However, the mREMS outperformed RTS in predicting mortality, and its performance was similar to MGAP. This difference in performance can be attributed to the different weightings of predictors like GCS in each model. Notably, the EMTRAS score, which incorporates additional laboratory data such as base excess and prothrombin time, has also shown strong mortality prediction. However, this score was not examined in this study, mainly due to limited data availability for laboratory parameters.

In the Vajira cohort, the mREMS showed excellent performance but also revealed a higher mortality rate compared to the original mREMS study. When patients were stratified according to the mREMS categories from the original study, the death rates in each stratum were significantly higher. This could be due to a higher baseline risk of death in Thai road traffic injury patients. In the original study, patients with scores above 14 had a 100% mortality rate, but in the Vajira cohort, this same score threshold resulted in the same mortality. Therefore, the authors chose to categorize mREMS into five levels of risk, with death rates ranging from 0.8% to 100%.

Severe head injuries, indicated by a low GCS, were present in 63% of those who died, whereas only 14% of deaths were associated with severe hypotension. This suggests that head injuries could be a target area for improving care and implementing preventive strategies. A limitation of trauma scores in general is that they do not consider pre-hospital care factors such as transport time and resuscitation quality, which significantly affect outcomes. Additionally, co-morbidities, which also impact mortality, are not accounted for in these models. The lack of information about co-morbidities and pre-hospital factors in the present study may limit the utility of these scores in early mortality prediction.

This study has some limitations: the sample included few patients with mREMS scores above 13, all of whom died, leading to potential inaccuracies in mortality rates at these high score levels. Model performance could potentially be improved by revising the mREMS model, but the authors did not have access to the original equation. The study was also based on complete case analysis, which could introduce selection bias. Furthermore, the analysis did not consider factors such as transport time, which may affect mortality rates. Finally, the single-center nature of the study limits its generalizability to other trauma centers.

Despite these limitations, the study offers several strengths. It is the first external validation of the mREMS, providing strong evidence for its performance in predicting in-hospital mortality in trauma patients. Given that road traffic injuries are a major health issue in Thailand, the mREMS appears to be a highly reliable tool for this group of patients. This is also the first time the mREMS has been validated in Thailand, and its implementation should be further evaluated in future studies.

Conclusion

In conclusion, this study represents the first external validation of the mREMS, confirming its excellent performance in predicting in-hospital mortality for trauma patients. The mREMS showed superior discrimination between survivors and non-survivors compared to other scores like RTS, making it a valuable tool in road traffic injury cases in Thailand. Further research, particularly in multi-center studies, is needed to solidify its utility and impact.

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Conflict of Interest: None

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Ethics Statement: None

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