Afshari et al. BMC Emergency Medicine (2024) 24:139
https://doi.org/10.1186/s12873-024-01063-1

BMC Emergency Medicine

RESEARCH

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Unveiling the performance of the prehospital Rapid Emergency Medicine Score (pREMS): How the predictive score impacts in-hospital outcomes in traumatic brain injury (TBI): A retrospective observational cohort study

Ali Afshari[1], Mohammad Torabi[2], Afshin Khazaei[3*], Sasan Navkhasi[3], Marzieh Aslani[4] and Vahid Molaee[3]

Abstract

Introduction This study aimed to evaluate the predictive accuracy of the prehospital rapid emergency medicine score (pREMS) for predicting the outcomes of hospitalized patients with traumatic brain injury (TBI) who died, were discharged, were admitted to the intensive care unit (ICU), or were admitted to the operating room (OR) within 72 h.

Methods A retrospective cohort analysis was performed on a sample of 513 TBI patients admitted to the emergency department (ED) of Besat Hospital in 2023. Only patients of both sexes aged 18 years or older who were not pregnant and had adequate documentation of vital signs were included in the analysis. Patients who died during transport and patients who were transferred from other hospitals were excluded. The predictive power of the pREMS for each outcome was assessed by calculating the sensitivity and specificity curves and by analyzing the area under the receiver operating characteristic curve (AUROC).

Results The mean pREMS scores for hospital discharge, death, ICU admission and OR admission were 11.97 ± 3.84, 6.32 ± 3.15, 8.24 ± 5.17 and 9.88 ± 2.02, respectively. pREMS accurately predicted hospital discharge and death (AOR = 1.62, $P < 0.001$) but was not a good predictor of ICU or OR admission (AOR = 1.085, $P = 0.603$). The AUROCs for the ability of the pREMS to predict outcomes in hospitalized TBI patients were 0.618 (optimal cutoff point = 7) for ICU admission and OR and 0.877 (optimal cutoff point = 9.5) for hospital discharge and death at 72 h.

Conclusion The results indicate that the pREMS, a new preclinical trauma score for traumatic brain injury, is a useful tool for prehospital risk stratification (RST) in TBI patients. The pREMS showed good discriminatory power for predicting in-hospital mortality within 72 h in patients with traumatic brain injury.

Keywords Early warning score (EWS), Traumatic brain injury (TBI), Emergency Medical Services (EMS), Emergency medical technicians (EMTs), Intensive care unit (ICU)

*Correspondence:
Afshin Khazaei
A.khazaei91@gmail.com
Full list of author information is available at the end of the article

Introduction

Traumatic brain injuries (TBIs) pose a major challenge to the healthcare system, as evidenced by the staggering number of hospitalizations and deaths in recent years. In 2020, 214,110 hospitalizations related to TBIs were reported, and by 2021, 69,473 people had died as a result of these injuries [1]. In industrialized countries, the mortality rate for TBI within the first month after injury is approximately 21%, but in developing countries, this rate rises to 50% [2]. A systematic study carried out in Iran showed that most injuries in accidents are concentrated on the head and not on other organs [2]. Emergency medical technicians (EMTs) are responsible for the recognition and timely assessment of brain injury, effective triage, initiation of interventions, and stabilization and transport of patients to appropriate healthcare facilities, which can reduce mortality and long-term disability rates [3, 4]. The fact that EMTs have to make important decisions on the basis of sparse information and an unclear medical history is one of the greatest obstacles in the prehospital treatment of patients with TBI [5–7]. Accurate and reliable data on patients with TBI in the initial phase of emergency care are essential. This information not only helps to identify severely affected patients but also to predict their future health outcomes. In addition, it provides emergency services with important knowledge that enables them to make informed clinical decisions [8, 9]. The implementation of this approach leads to an efficient distribution of resources, enhances the utilization of prehospital assets, maximizes the timely administration of critical treatments, advances the overall level of care provided to patients with TBI, and prompts the immediate mobilization of hospital rapid response teams within the prehospital environment [10].

Given the importance of informed decision-making, it is essential to explore tools to help EMTs make accurate and safe clinical decisions in patients with TBI. Therefore, any tool that accelerates and improves diagnostic accuracy, provides the ability to raise the alarm for critical illness, promotes a safe prehospital environment, and facilitates efficient triage and decision-making when transferring a TBI patient to the hospital must be considered [8, 11–14]. Traditional single methods (such as the GCS and AVPU) for assessing TBI severity have limitations and often need to be considered, along with other physiological measurements [15, 16]. In 2003, the Rapid Emergency Medicine Score (REMS) was created as an early warning system (EWS) to forecast the risk of in-hospital death in patients without trauma [17]. It includes several physiological variables, including age, mean arterial pressure (MAP), heart rate (HR), respiratory rate (RR), pulse oxygen saturation (SpO2), and Glasgow Coma Scale (GCS) score. The cumulative score derived from these variables is used to predict patient outcomes, identify patients at risk of deterioration, and direct medical attention to vital signs [18]. The use of REMS can improve care, reduce resource utilization, and improve treatment effectiveness, which particularly supports patient prognosis [19–21].

A consensus regarding the most suitable EWS for predicting the outcomes of TBI patients in a prehospital setting in Iran has yet to be reached. To address this concern, we utilized the pREMS system in this study because of its adaptability and regular employment of vital signs in Hamedan Province. Consequently, this study aimed to assess the predictive efficacy of the pREMS for determining the outcomes of hospitalized patients with TBI.

Materials and methods

Study design and participants

The authors of this retrospective observational cohort study were conducted from March 21, 2023, to September 23, 2023. The participants included prehospital TBI patients admitted to the emergency department (ED) of an urban teaching hospital in Hamadan Province (Level 1 trauma center), Iran. To minimize bias, patients with TBI without other injured body parts who were transported by EMTs and patients of both sexes aged ≥ 18 years who were not pregnant and who had adequate documentation of vital signs were included in the calculation of pREMS and ED outcomes. Patients who died during transportation or were transferred from other hospitals were excluded from the study. The primary objective of this study was to evaluate the accuracy of the pREMS in predicting the overall health status of patients who were discharged or died within 72 h of hospitalization (Fig. 1). The secondary endpoint focused on patients admitted to the hospital, including those admitted to the operating room (OR) or intensive care unit (ICU).

Data collection

All ambulances used prehospital medical records, including patient information and vital signs. The outcomes of the TBI patients were retrospectively extracted from the prehospital and ED electronic medical records by two authors who were blinded to the outcomes of the TBI patients. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [22], head injury or other mechanisms involving rapid movement or displacement of the brain within the skull are diagnostic criteria for patients with traumatic brain injury (TBI). Other criteria include loss of consciousness, post-traumatic amnesia, disorientation and confusion, and neurological signs (e.g., visual field cuts, anosmia (loss of smell), hemiparesis, new onset of seizures, or marked worsening of an existing seizure disorder). Therefore,

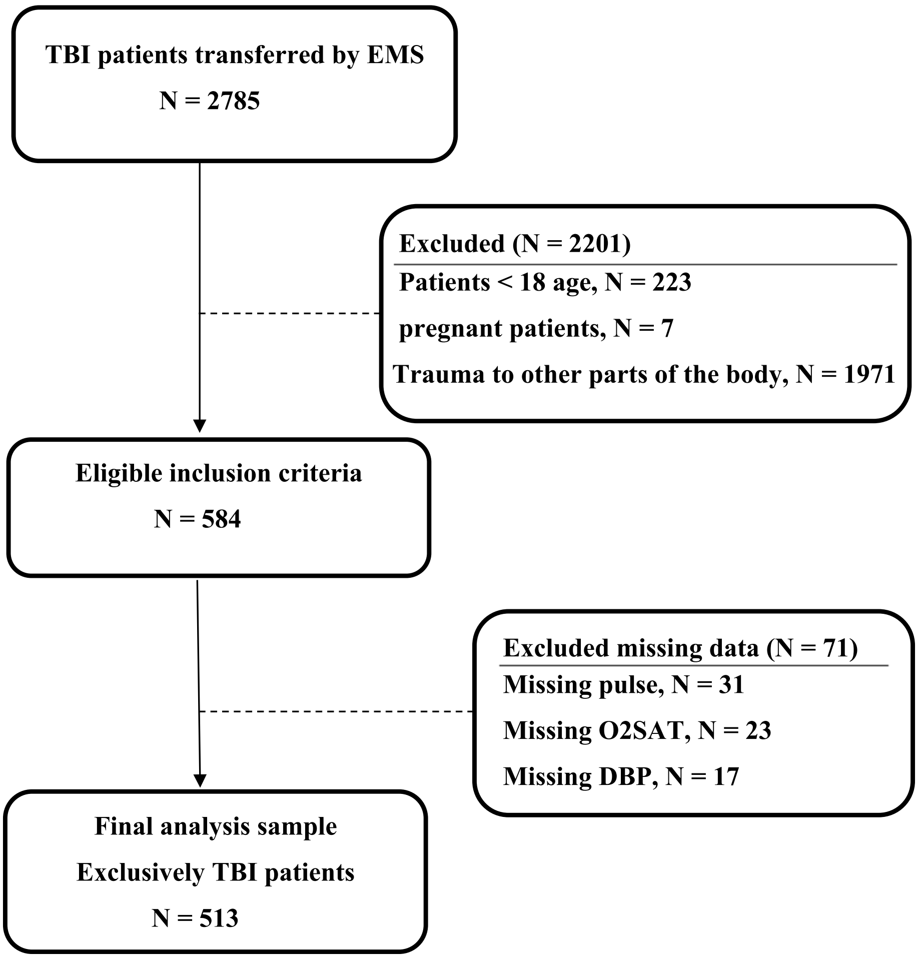


Fig. 1 Inclusion and exclusion criteria used in the study. EMS: Emergency medical system, TBI: Traumatic barin injury, O2sat: Oxygen saturation, DBP: Diastolic blood pressure

all the collected data related to any of the above symptoms were collected from prehospital patients with TBI. The collected data included information on the components of the pREMS tool routinely recorded during the transport and care of patients with TBI in the prehospital emergency system in Hamadan Province. In addition, to determine the dependent variables in the present study (the final outcome of patients in the hospital), data were retrospectively collected using the HIS system to determine the number of patients with TBI admitted to the ED of Hamedan Besat Hospital. Age and physiological components such as MAP, HR, RR, SpO2, and GCS were assessed according to the pREMS scoring scheme (Table 1).

The total pREMS score was calculated by summing the scores, with a maximum of 26. Higher scores indicate a worse prognosis. A previous study served as the basis for calculating the sample size [23]. In this study, the REMS AUC was 0.909. Using this value as a benchmark, a δ value of 0.05, and a significance level of 5%, the minimum sample size was 95 patients. However, to increase the power, we included 429 samples in the present study. The formula used is:

$$N = \frac{1 - AUC}{2}\left(\frac{Z_{\frac{\alpha}{2}}}{\delta}\right)^2$$

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee of the Asadabad School of Medical Sciences (IR.ASAUMS.REC.1402.020). Owing to the retrospective nature of the study, the absence of any intervention, and the consideration of a unique code for each participant that anonymized the statistical analysis, obtaining informed

Table 1 REMS Scoring System

Variable	Lower abnormal threshold					Higher abnormal threshold			
	+4	+3	+2	+1	0	+1	+2	+3	+4
MAP	< 50		50–69		70–109		110–129	130–159	> 159
PR (beats/min)	< 40	40–54	55–69		70–109		110–139	140–179	> 179
RR (breaths/min)	< 6		6–9	10–11	12–24	25–34		35–49	> 49
O2 Saturation (%)	< 75	75–85		76–89	> 89				
GCS	< 5	5–7	8–10	11–13	> 13				
Points to age have been assigned as follows (age, points): < 45,0; 45–54, 2; 55–64, 3; 66–74, 5; > 74, 6									

MAP Mean arterial pressure (mmHg), *PR* Pulse Rate, *RR* Respiratory Rate, *GCS* Glasgow Coma Scale Data analysis

consent was not necessary in the opinion of the Ethics Committee of the Asadabad School of Medical Sciences.

Data analysis

Continuous variables are described using means and standard deviations (SDs), whereas categorical variables are described using frequencies and percentages. Based on previous research, we assumed that hospital discharge or death would occur three days after the event [18, 24]. The primary objective of this study was to create a dichotomous variable for the outcomes of hospitalized TBI patients who died compared with those discharged from the hospital within 72 h. For the secondary objective, we created a dichotomous variable that included patients admitted to the ICU or OR. Parametric tests, such as the $\chi2$ test for categorical variables and t test for continuous variables, were used. Spearman's test was used to assess correlations. Univariate and multivariate logistic regression analyses were conducted to estimate the odds ratio, adjusted odds ratio, and 95% confidence interval for the pREMS scores in relation to the primary and secondary in-hospital TBI outcomes (hospital discharge or death within 72 h and ICU or OR admission, which allowed for the calculation of the odds ratio). The overall predictive power of the pREMS for each outcome was assessed using the area under the receiver operating characteristic curve (AUROC). The primary and secondary endpoints had corresponding sensitivity and specificity curves, respectively. The Youden test was used to determine the optimal pREMS cutoff point. Calibration and Hosmer–Lemshaw tests were also used to assess calibration. Nagelkerke's R-squared value was also used to evaluate the overall performance of the model. Statistical significance was defined as $P < 0.05$. All analyses were performed using SPSS 21 and XLSTAT 2018.

Results

In this study, TBIs were caused by motorcycle accidents (38.2%, 196 cases), car accidents (38.12%, 140 cases), falls (16.00%, 82 cases), pedestrians (16.8%, 86 cases), and conflicts (1.08%, 9 cases). Among the patients, 87.91% (451) were discharged from the hospital within 72 h (mean age 48.37 ± 20.28 years, 45.3% of whom were men), while 7.21% (37) died within 72 h (mean age 54.57 ± 20.38 years, 57% of whom were men). Among the 4.9% (25) of patients discharged from the ED, 3.11% (16) and 1.75% (9) were admitted to the ICU and OR, respectively (Fig. 2).

In summary, Table 2 provides a comprehensive overview of the demographic and clinical characteristics of the TBI patients, including the distribution of TBI causes, age, sex, and their associations with various clinical outcomes. According to the REMS vital signs criteria (REMS components), the median PRs at hospital discharge and death were 92 and 130 beats/minute, respectively. The median RRs were 21 and 30 breaths per minute, and the MAPs were 70 and 91 mm Hg at hospital discharge and death, respectively. In addition, the median GCS score was lower in patients who were discharged from the hospital than in those who were discharged (9 vs. 12).

Table 3 shows the results of the analyses performed using multivariate logistic regression, focusing on pREMS and patient outcomes. Consistent with the primary objectives, pREMS was found to have an impact on hospital discharge and death (AOR = 1.62, $P < 0.001$). Conversely, pREMS was not a good predictor of admission to the ICU for patients with TBI, nor was it a predictor of OR (AOR = 1.085, $P = 0.603$). The initial pREMS overall AUROC was 0.877 (95% CI: 0.829–0.927) for hospital discharge and death within 72 h (Fig. 4) and 0.618 (95% CI: 0.395–0.841) for admission to the ICU and admission to the OR as indicators for predicting hospital outcomes of patients with TBI (Fig. 5). Based on sensitivity and specificity curve analyses, a mean pREMS of 9.5 was identified as the optimal statistical cutoff point for predicting hospital discharge (OR, 1.602; 95% CI: 2.79–2.87) (Table 4). For predicting admission of patients to the ICU and OR, the Rock curve showed a value of 7 as the best cutoff value for

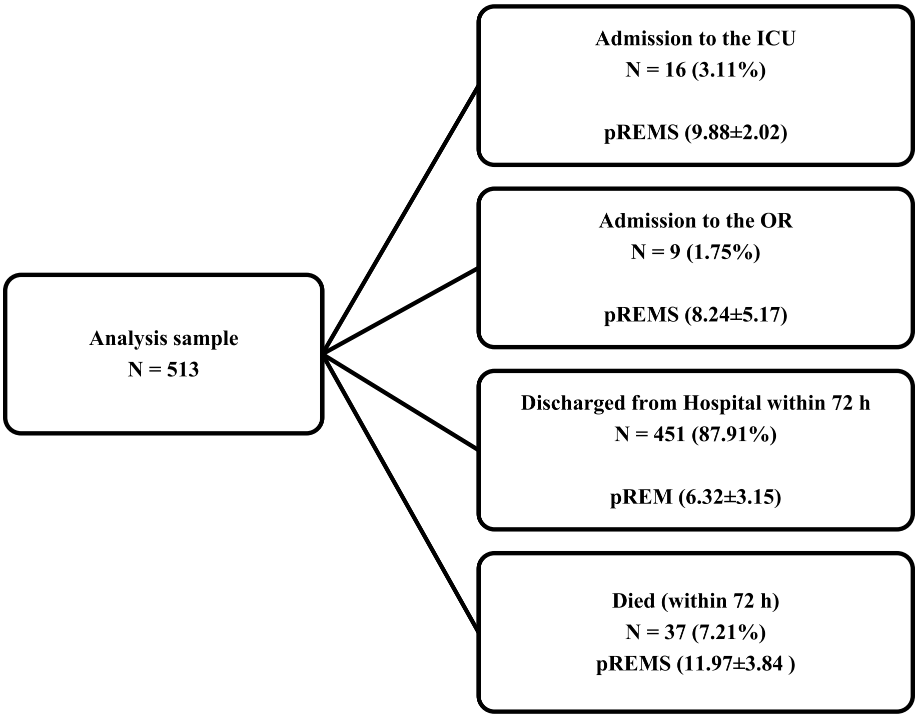


Fig. 2 ED dispersion of the TBI patient sample (mean ± SD). ICU: intensive care unit, OR: operating room, REMS: Rapid Emergency Medicine Score. Prehospital REMS are presented as the mean ± SD

Table 2 Demographics of prehospital Rapid Emergency Medicine Score (pREMS) and TBI patient outcomes (*N* = 513) (classification according to the REMS scoring system)

Characteristic			ICU admitted *N* = 16 (3.11%)	OR admitted *N* = 9 (1.75%)	Discharge from the hospital 72 h *N* = 451 (87.91%)	Died within 72 h *N* = 37 (7.21%)
pREMS (Mean ± SD)	**TBI Cause**	Car accident	7.12 ± 2.10	5.40 ± 4.27	6.76 ± 3.6	6.11 ± 3.14
		Motorcycle	7.60 ± 6.18	10.00 ± 0.00	6.85 ± 3.62	7.25 ± 3.130
		Falling	3.5 ± 0.70	6.00 ± 0.00	6.67 ± 3.17	7.33 ± 3.07
		Pedestrians	6.00 ± 0.00	6.00 ± 0.00	7.37 ± 3.95	8.83 ± 3.31
		Conflict	-	6.55 ± 1.66	7.00 ± 1.06	-
	Age (years)	< 45	7.50 ± 4.65	4.714 ± 2.92	6.90 ± 3.53	7.41 ± 3.62
		45 – 54	7.00 ± 3.39	7.00 ± 0.00	7.49 ± 4.08	7.5 ± 3.39
		55 – 64	6.00 ± 1.41	12.00 ± 0.00	6.53 ± 3.30	6.83 ± 1.60
		65 – 74	5.50 ± 0.70	-	6.46 ± 2.96	7.50 ± 3.11
		> 74	5.50 ± 3.53	-	6.75 ± 3.87	6.60 ± 4.09
	Sex	Female	5.66 ± 1.86	5.83 ± 3.43	7.05 ± 3.16	7.38 ± 3.16
		Male	7.40 ± 4.50	5.66 ± 4.50	6.80 ± 3.50	7.062 ± 3.19
Total pREMS (Mean ± SD)			9.88 ± 2.02	8.24 ± 5.17	6.32 ± 3.15	11.97 ± 3.84

TBI Traumatic brain injury, *MAP* Mean arterial pressure, *HR* Heart rate, *RR* Respiratory rate, *GCS* Glasgow Coma Scale, *O2 Sat* Oxygen saturation, *BPM* Beats per minute, *pREMS* Prehospital Rapid Emergency Score

the pREMS for predicting admission of TBI patients to the ICU or OR (AUROC = 0.618, OR = 1.264).

Additionally, univariable logistic regression analysis revealed that age, O2SAT (oxygen saturation) at hospital discharge and death within 72 h were not statistically significant (p values of 0.36 and 0.48, respectively).

Table 3 Multivariate logistic regression for prehospital rapid emergency medicine score (pREMS) in the outcome of TBI patients

Outcomes	Dependent Variable	Adjusted[1,2]				
		B	Wald	p value	Exp (B)	CI for Exp (B)
Primary	OR admitted[a]					
	ICU admitted	0.082	0.271	$p=0.603$	1.085	0.798–1.477
Secondary	Discharge from the hospital 72 ha					
	Died within 72 h	-0.480	52.366	$p<0.001$	0.619	0.543–0.705

ICU Intensive Care Unit, *OR* Operation Room, *CI* Confidence Interval, *OR* Odds ratio, *AOR* Adjusted odds ratio (adjusted[1] for ICU admitted, OR admitted, adjusted[2] for discharge from hospital 72 h, died within 72 h), [a]; referenc

Table 4 Prehospital Rapid Emergency Medicine Score (pREMS) cutoff point for TBI patient outcomes

pREMS Scores	Primary Objective Hospital discharge (72 h) VS Died (72 h)	Secondary Objective Operation room Versus (72 h) ICU Admission (72 h)
Optimal Cutoff	9.5	7
AUROC	0.877	0.618
Sensitivity	0.944 (0.807, 0.993)	0.889 (0.540, 0.998)
Specificity	0.658 (0.612, 0.700)	0.375 (0.185, 0.615)
NPV	0.184	0.857
PPV	0.993	0.444
Likelihood ratio +	11.837	1.422
Likelihood ratio -	0.363	0.296
Odd Ratio	1.602	1.264
Accuracy	0.679	0.560
Hosmer–Lemeshow Test	0.560	0.73
Nagelkerke's R-Square (%)	0.015	0.377

The confidence intervals for the CI and AUROC, which represent the area under the receiver operating characteristic curve (PPV), are also known as the positive predictive value (NPV) or negative predictive value (NPV), the positive likelihood ratio is referred to as the likelihood ratio +, and the negative likelihood ratio is known as the likelihood ratio –

However, the comparisons of heart rate (HR), respiratory rate (RR), mean arterial pressure (MAP) and Glasgow Coma Scale (GCS) score with pREMS at hospital discharge and death within 72 h were statistically significant ($p=0.037$, 0.039, 0.047 and 0.002, respectively). Furthermore, after adjusting for multiple factors, the GCS score proved to have the strongest predictive power for hospital discharge (odds ratio, 0.52; 95% CI, 0.48–0.56; $P<0.001$).

Therefore, we observed a clear pattern of increased mortality rates with increasing pREMS scores (Fig. 3). Specifically, the mortality rate was 1.5-fold greater for those with a pREMS score above 5, while the mortality rate was 7.5-fold greater for those with a score above 10. Overall, however, people with a pREMS > 15 had a significantly greater mortality rate (66.66-fold).

Discussion

Our study revealed that patients who arrived at the ED with lower pREMS were more likely to survive and be discharged from the hospital within 72 h. Approximately 3.3% (17) of the EMS TBI patients in our study started with a pREMS of zero. Interestingly, nearly 69% of patients had a lower pREMS than other TBI patients when they were discharged from the hospital after less than 72 h (Table 2). In contrast, only a very small proportion of patients (less than 0.4%, especially two patients) had initial pREMS values of 20 and 21; none of them were discharged from the hospital within 72 h, and they eventually died. Therefore, we observed a clear pattern of increased mortality rates with increasing pREMS scores (Fig. 3). Specifically, the mortality rate was 1.5-fold greater for those with a pREMS score above 5, while the

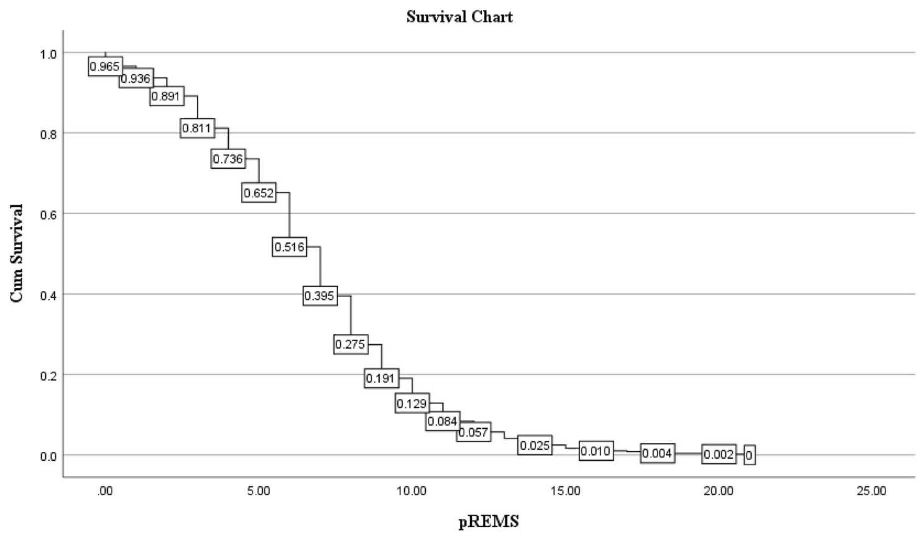


Fig. 3 The mortality survival rate of hospitalized patients who sustained trauma within 72 h decreased as the use of the code tool increased

mortality rate was 7.5-fold greater for those with a score above 10. Overall, however, people with a pREMS > 15 had a significantly greater mortality rate (66.66-fold).

In accordance with the main objective of our study, the results showed that the mean pREMS was significantly different between patients who were discharged from the hospital (6.32 ± 3.15) and those who died (11.97 ± 3.84). These results showed a correlation between increased mortality and a greater pREMS, such that for every one-degree increase in pREMS, the probability of dying in the hospital within 72 h increased 1.62-fold (pREMS of 26 points) (Table 3). This emphasizes the importance of early risk stratification and the potential of pREMS to support clinical decision making and resource allocation in prehospital settings.

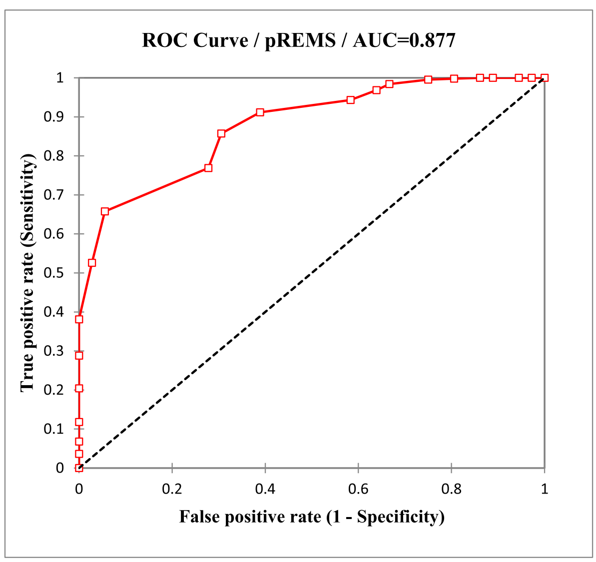
Unfortunately, few studies have examined the impact of pREMS tools on hospital outcomes in patients with prehospital TBI. According to Olsson et al., who also supported our results, a one-point increase in the 26-point REMS was associated with an OR of 1.40 for in-hospital death in all age groups and in both main patient groups of sex (dyspnea, diabetes, coma, chest pain and stroke) [25]. Crowe et al. showed that the overall patient death rate can be predicted based on the early prehospital risk of early REMS [26]. In a study conducted at multiple centers, Ruangsomboon et al. assessed the efficacy of the REMS, along with three other EWSs, in predicting the probability of mortality among COVID-19 patients in the ED [27]. The findings demonstrated that the REMS displayed superior prognostic accuracy, surpassing the ability of the quick Sequential Organ Failure Assessment (QSOFA), Modified Early Warning Score (MEWS), and National Early Warning Score (NEWS) to predict in-hospital mortality among COVID-19 patients in the ED. In addition, a study evaluating the accuracy of the REMS and simple clinical score (SCS) in predicting sepsis severity and ED mortality rates revealed that the REMS was more accurate (88.6%) than the SCS tool (76.7%) [28]. Therefore, the above results, together with those of our study, suggest that the REMS could be useful as a risk stratification tool in the prehospital setting to identify patients who may require closer monitoring or more intensive care, thereby affecting outcomes and resource allocation.

Our study's second goal revealed that the pREMS tool could not differentiate between patients admitted to the OR and those admitted to the ICU. Furthermore, multivariate logistic regression revealed a 0.08% probability of being admitted to the ICU or OR for each increase in the pREMS score compared to other TBI patients (Table 2). After reviewing the relevant literature, no study has examined the effects of pREMS on the admission of patients with TBI to the ICU or OR. However, Pandey et al. reported a substantial correlation between the NEWS and ICU admission. They found that as the NEWS increased, the likelihood of ICU admission increased significantly [29]. In addition, these studies examined the ability of the Quick Sepsis-Related Organ Failure Assessment (QSOFA) to predict ICU admission. The NEWS showed a slightly greater accuracy (AUROC, 0.67) than the qSOFA (AUROC, 0.61) [30, 31]. Additionally, Innocenti et al. reported a significant association between ICU admission and various EWSs (MEWS, qSOFA, CCI, SOFA, APACHE II and MEDS), all of which strongly correlated with ICU admission in this patient population ($p < 0.05$) [32].

In terms of the main objective of the present study, the initial pREMS demonstrated an overall area under the receiver operating characteristic curve (AUROC) of 0.877 (0.829–0.927) (Fig. 4), indicating that it is a reliable tool for predicting in-hospital outcomes for TBI patients. In contrast, the AUROC was not suitable for predicting the pRMES when patients were admitted to the ICU or the OR was 0.618 (Fig. 5). Similar to our study, the research conducted by Olsson divided patients into three main groups: high risk of mortality (REMS > 13), moderate risk of mortality (6 < REMS < 13), and low risk of mortality (REMS < 6) [17, 25]. Each increase in the REMS score beyond 13 led to a corresponding increase in the patient mortality rate, ranging from 7.8% to 17.1%. Overall, the results of this study support the effectiveness of the REMS in accurately predicting mortality outcomes and hospitalization duration in nonsurgical patients in the ED.

The significance of monitoring vital signs with high accuracy, especially in patients with TBI, was emphasized in this study. Oxygen saturation (O2SAT) was the least reliable predictor of mortality (OR: 0.48, 95% CI: 0.44, 0.52), whereas the Glasgow Coma Scale (GCS) score was the most reliable (odds ratio [OR] 0.52, 95% confidence interval [CI] 0.48–0.56). The predictive value of the GCS is derived from its capacity to provide insightful data on a patient's neurological condition [33]. Our findings revealed the following differences in median GCS scores: patients with pREMS scores of 3–5 who died had a median GCS score 1.9 points lower than that of patients who were discharged within 72 h ($p < 0.0001$). Patients with a mean pREMS of 11.97 who died had a median GCS score of 9.

points lower than those who were discharged within 72 h ($p < 0.0001$). A lower GCS score indicates more severe brain injury and a greater likelihood of poor outcomes such as death or prolonged hospitalization. The adjusted odds ratio of 0.32 suggested that for every one-point increase in the GCS score, the odds of hospital discharge than death within 72 h decreased by 1.92-fold. This indicates that a higher GCS score is associated with a better prognosis. This result is in line with those of other studies [34–36].

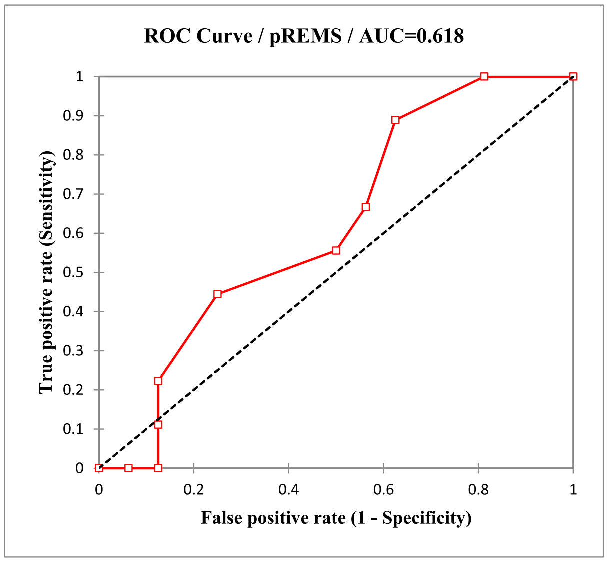


Area Under the ROC Curve

Area	Std. Errora	Asymptotic Sig.b	Asymptotic 95% Confidence Interval Lower Bound	Asymptotic 95% Confidence Interval Upper Bound
.878	.025	.000	.829	.927

a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

Fig. 4 The area under the ROC curve (AUROC) shows how well the first prehospital REMS predicts whether a patient will die within 72 h or be discharged from the emergency department (ED)



Area Under the ROC Curve

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval: Lower Bound	Asymptotic 95% Confidence Interval: Upper Bound
.618	.114	.300	.395	.841

a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

Fig. 5 The area under the ROC curve (AUROC), which shows how well the first prehospital REMS can forecast a patient's likelihood of being admitted to the ICU or OR

Understanding the relationship between pREMS and in-hospital TBI outcomes empowers EMTs to make informed decisions regarding patient care, resource utilization, and long-term care planning, fostering a comprehensive approach to TBI management that prioritizes personalized evidence-based interventions [37]. By integrating pREMS into clinical practice guidelines and decision support systems, EMTs can leverage their predictive insights to optimize TBI patient care pathways, improve resource allocation, and enhance the quality of life of TBI survivors. The transformative impact of pREMS on in-hospital TBI outcomes heralds a new era of personalized, data-driven care for patients with TBI, setting the stage for continued advancements in emergency medicine and prehospital care. Moreover, the potential applications of pREMS in prehospital settings extend to the realm of telemedicine and mobile health technologies, where the incorporation of pREMS into digital platforms and decision support algorithms can enhance the remote assessment and triage of TBI patients in resource-limited or austere environments. Furthermore, by using pREMS as a prognostic tool in telemedicine initiatives, healthcare providers can extend their critical care expertise to remote locations, enabling timely interventions and optimized transfer protocols for TBI patients in rural or underserved areas. As future research efforts continues to refine the predictive algorithms and applications of pREMS in preclinical settings, the potential for a transformative impact on TBI care and patient outcomes remains promising. The acceptance of pREMS as a useful tool for predicting TBI outcomes opens up the possibility for future research to enhance its prediction algorithms. This could involve assessing the usefulness of incorporating the mechanism of injury into the score and exploring its potential integration into cutting-edge technologies and decision-making systems.

Our study has several limitations. First, we excluded the records of patients from our study who lacked the data required to calculate trauma scores. Second, the pREMS scores were unable to distinguish between mortality directly attributable to the trauma and mortality indirectly attributable to subsequent inpatient treatment during the corresponding hospitalization. Therefore, these results cannot be used to control for differences in treatment with different modalities. Third, the present study focused exclusively on patients with traumatic brain injury, and the results may not be generalizable to other patients with traumatic brain injury and concomitant injuries in other parts of the body. Therefore, future studies should be conducted to determine the predictive effect of pREMS scores in patients with traumatic brain injury and multiple injuries. Therefore, relevant factors must be considered when applying the study results.

Additional research is required to properly evaluate the effectiveness of pREMS in predicting outcomes in patients with traumatic brain injury (TBI). Moreover, considering that the components of the pREMS score were not specifically developed for pediatric patients, and that individuals below 18 years of age were not included in the study, the findings cannot be extrapolated to this particular population. Additionally, the study sample was limited to patients from a single hospital, potentially introducing bias in the selection process, which restricts the applicability of the findings to other trauma patients. Hence, it is of the utmost importance to conduct precise prospective studies to validate our findings. On the other hand, the present study only examined the mortality of patients with head trauma within 72 h, so the results of the present study may be different in the above period and other periods.

Conclusions

The results indicate that the pREMS, a new preclinical trauma score for traumatic brain injury, is a useful tool for prehospital risk stratification (RST) in TBI patients. The pREMS showed good discriminatory power for predicting in-hospital mortality within 72 h in patients with traumatic brain injury.

Abbreviations

TBI	Traumatic Brain Injury
pREMS	Prehospital Rapid Emergency Medicine Score
ICU	Intensive Care Unit
OR	Operating Room
ED	Emergency Room
EWS	Early Warning Scores
RST	Risk Stratification Tool
DSM-5	Diagnostic and Statistical Manual of Mental Disorders

Acknowledgements
We extend our heartfelt appreciation to Dr. Majid Barati, Assistant for Educational, Cultural, and Student Affairs, at the Asadabad School of Medical Sciences. We are sincerely grateful for his generous support and valuable assistance in facilitating this research.

Authors' contributions
AKh obtained ethical approval and prepared the manuscript. AA, AKh, SN, MA,VM, and MT collaborated in the design, analysis, and interpretation of the study results. The authors have also contributed to the writing of this manuscript. AA specifically helped to analyze and interpret the data. All authors thoroughly reviewed and edited the manuscript and endorsed the final version. The reason for selecting the mentioned referees for the review of the article is their expertise and experience in the field of refereeing articles, especially qualitative articles.

Funding
This study was conducted as a research project with the approval of the Research Council of Asadabad School of Medical Sciences (No: 139).

Availability of data and materials
In case of a justified request and permission from the Ethics Committee of Asadabad Faculty of Medical Sciences, the corresponding author will make the dataset used and/or analyzed for this study available and accessible.

Declarations

Ethics approval and consent to participate
For this study was obtained from the Research Ethics Committee of the Asadabad School of Medical Sciences (IR.ASAUMS.REC.1402.020).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Medical Surgical Nursing, School of Nursing and Midwifery, Chronic Diseases (Home Care) Research Center, Hamadan University of Medical Sciences, Hamadan, Iran. [2]Department of Nursing, Malayer School of Nursing, Hamadan University of Medical Sciences, Hamadan, Iran. [3]Department of Prehospital Emergency Medicine, Asadabad School of Medical Sciences, Asadabad, Iran. [4]Department of Nursing, Asadabad School of Medical Sciences, Asadabad, Iran.

Received: 1 May 2024 Accepted: 29 July 2024
Published online: 02 August 2024

References
1. Mortality Data on CDC WONDER. Centers for Disease Control and Prevention National Center for Health Statistics. April 2023. https://wonder.cdc.gov/mcd.html.
2. Monsef Kasmaei V, Asadi P, Zohrevandi B, Raouf MT. An Epidemiologic Study of Traumatic Brain Injuries in Emergency Department. Emerg (Tehran). 2015;3(4):141–5.
3. Lulla A, Lumba-Brown A, Totten AM, Maher PJ, Badjatia N, Bell R, et al. Prehospital Guidelines for the Management of Traumatic Brain Injury - 3rd Edition. Prehosp Emerg Care. 2023;27(5):507–38.
4. Navab E, Esmaeili M, Poorkhorshidi N, Salimi R, Khazaei A, Moghimbeigi A. Predictors of Out of Hospital Cardiac Arrest Outcomes in Pre-Hospital Settings; a Retrospective Cross-sectional Study. Arch Acad Emerg Med. 2019;7(1):36.
5. Afshari A, Torabi M, Navkhasi S, Aslani M, Khazaei A. Navigating into the unknown: exploring the experience of exposure to prehospital emergency stressors: a sequential explanatory mixed-methods. BMC Emerg Med. 2023;23(1):136.
6. Ghiyasvandian S, Khazaei A, Zakerimoghadam M, Salimi R, Afshari A, Mogimbeigi A. Evaluation of Airway Management Proficiency in Pre-Hospital Emergency Setting; a Simulation Study. Emerg (Tehran). 2018;6(1):e58.
7. Khazaei A, Afshari A, Salimi R, Fattahi A, Imani B, Torabi M. Exploring stress management strategies among emergency medical service providers in Iran: a qualitative content analysis. BMC Emerg Med. 2024;24(1):106.
8. Alqurashi N, Alotaibi A, Bell S, Lecky F, Body R. The diagnostic accuracy of prehospital triage tools in identifying patients with traumatic brain injury: A systematic review. Injury. 2022;53(6):2060–8.
9. Khazaei A, Esmaeili M, Navab E. The Most and Least Stressful Prehospital Emergencies from Emergency Medical Technicians' View Point; a Cross-Sectional Study. Arch Acad Emerg Med. 2019;7(1):e20.

10. Choi Y, Park Jh, Hong K, Ro Y, Song K, Shin S. Development and validation of a prehospital-stage prediction tool for traumatic brain injury: a multicentre retrospective cohort study in Korea. BMJ Open. 2022;12:e055918.
11. Bagnato C, Ranzato K, Giarraca A, Restelli P, Saronni S, Gadda G, et al. A prospective study comparing two methods of pre-hospital triage for trauma. Updates Surg. 2022;74(5):1739–47.
12. Behnke S, Schlechtriemen T, Binder A, Bachhuber M, Becker M, Trauth B, et al. Effects of state-wide implementation of the Los Angeles Motor Scale for triage of stroke patients in clinical practice. Neurol Res Pract. 2021;3(1):31.
13. Pélieu I, Kull C, Walder B. Prehospital and Emergency Care in Adult Patients with Acute Traumatic Brain Injury. Med Sci (Basel). 2019;7(1):12. https://doi.org/10.3390/medsci7010012.
14. Eslami-Panah M, Torabi M, Borhani F, Abbaszadeh A. Relationship of Moral Climate and Moral Distress with Job Involvement among Nurses Working in Hospitals Affiliated with Hamadan University of Medical Sciences in 2020. Avicenna Journal of Nursing and Midwifery Care. 2022;30(4):259–69.
15. Tenovuo O, Diaz-Arrastia R, Goldstein LE, Sharp DJ, van der Naalt J, Zasler ND. Assessing the Severity of Traumatic Brain Injury-Time for a Change? J Clin Med. 2021;10(1):148. https://doi.org/10.3390/jcm10010148.
16. Mehmood A, Hung YW, He H, Ali S, Bachani AM. Performance of injury severity measures in trauma research: a literature review and validation analysis of studies from low-income and middle-income countries. BMJ Open. 2019;9(1):e023161.
17. Olsson T, Lind L. Comparison of the rapid emergency medicine score and APACHE II in nonsurgical emergency department patients. Acad Emerg Med. 2003;10(10):1040–8.
18. Adhiyaman V, Chattopadhyay I. Unexpected deaths following discharge of medical patients from hospital. Clin Med (Lond). 2019;19(6):531.
19. Ruangsomboon O, Boonmee P, Limsuwat C, Chakorn T, Monsomboon A. The utility of the rapid emergency medicine score (REMS) compared with SIRS, qSOFA and NEWS for Predicting in-hospital Mortality among Patients with suspicion of Sepsis in an emergency department. BMC Emerg Med. 2021;21(1):2.
20. Bajan K. Rapid Emergency Medicine Score-Reinventing Prognostication in Emergency Care. Indian J Crit Care Med. 2020;24(6):378–9.
21. Nolan B, Tien H, Haas B, Saskin R, Nathens A. The Rapid Emergency Medicine Score: A Critical Appraisal of Its Measurement Properties and Applicability to the Air Retrieval Environment. Air Med J. 2019;38(3):154–60.
22. American Psychiatric Association. Diagnostic and statistical manual of mental disorders (5th ed.). Washington, DC: American Psychiatric Publishing; 2013. https://doi.org/10.1176/appi.books.9780890425596.
23. Phunghassaporn N, Sukhvibul P, Techapongsatorn S, Tansawet A. Accuracy and external validation of the modified rapid emergency medicine score in road traffic injuries in a Bangkok level I trauma center. Heliyon. 2022;8(12):e12225.
24. Yang S, Wang Z, Liu Z, Wang J, Ma L. Association between time of discharge from ICU and hospital mortality: a systematic review and meta-analysis. Crit Care. 2016;20(1):390.
25. Olsson T, Terent A, Lind L. Rapid Emergency Medicine score: a new prognostic tool for in-hospital mortality in nonsurgical emergency department patients. J Intern Med. 2004;255(5):579–87.
26. Crowe RP, Bourn SS, Fernandez AR, Myers JB. Initial Prehospital Rapid Emergency Medicine Score (REMS) as a Predictor of Patient Outcomes. Prehosp Emerg Care. 2021;1–11. https://doi.org/10.1080/10903127.2020.1862944.
27. Ruangsomboon O, Phanprasert N, Jirathanavichai S, Puchongmart C, Boonmee P, Thirawattanasoot N, et al. The utility of the Rapid Emergency Medicine Score (REMS) compared with three other early warning scores in predicting in-hospital mortality among COVID-19 patients in the emergency department: a multicenter validation study. BMC Emerg Med. 2023;23(1):45.
28. Chatchumni M, Maneesri S, Yongsiriwit K. Performance of the Simple Clinical Score (SCS) and the Rapid Emergency Medicine Score (REMS) to predict severity level and mortality rate among patients with sepsis in the emergency department. Australas Emerg Care. 2022;25(2):121–5.
29. Alam N, Vegting IL, Houben E, van Berkel B, Vaughan L, Kramer MHH, et al. Exploring the performance of the National Early Warning Score (NEWS) in a European emergency department. Resuscitation. 2015;90:111–5.
30. Abbott TEF, Vaid N, Ip D, Cron N, Wells M, Torrance HDT, et al. A single-centre observational cohort study of admission National Early Warning Score (NEWS). Resuscitation. 2015;92:89–93.
31. Corfield AR, Lees F, Zealley I, Houston G, Dickie S, Ward K, et al. Utility of a single early warning score in patients with sepsis in the emergency department. Emerg Med J. 2014;31(6):482–7.
32. Innocenti F, Tozzi C, Donnini C, De Villa E, Conti A, Zanobetti M, et al. SOFA score in septic patients: incremental prognostic value over age, comorbidities, and parameters of sepsis severity. Intern Emerg Med. 2018;13:405–12.
33. Chen H, Chen R, Wu X, Qian J, Shi X, Wan L, et al. Glasgow Coma Scale as an Indicator of Patient Prognosis: A Retrospective Study of 257 Patients with Heatstroke from 3 Medical Centers in Guangdong. China Med Sci Monit. 2023;29:e939118.
34. Ghaffarzad A, Vahed N, Shams Vahdati S, Ala A, Jalali M. The Accuracy of Rapid Emergency Medicine Score in Predicting Mortality in Non-Surgical Patients: A Systematic Review and Meta-Analysis. Iran J Med Sci. 2022;47(2):83–94.
35. Imhoff BF, Thompson NJ, Hastings MA, Nazir N, Moncure M, Cannon CM. Rapid Emergency Medicine Score (REMS) in the trauma population: a retrospective study. BMJ Open. 2014;4(5):e004738.
36. Ahmadi S, Sarveazad A, Babahajian A, Ahmadzadeh K, Yousefifard M. Comparison of Glasgow Coma Scale and Full Outline of UnResponsiveness score for prediction of in-hospital mortality in traumatic brain injury patients: a systematic review and meta-analysis. Eur J Trauma Emerg Surg. 2023;49(4):1693–706.
37. Kumar G, Kaur R, Yadav R, kachru N. Comparison of Emergency Trauma Score (EMTRAS) with Rapid Emergency Medicine Score (REMS) for Prediction of Early Mortality in Adult Trauma Patients. Arch Anesth & Crit Care. 2022;8(3):193–200.

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