Original Article

A Comparison between Modified Early Warning Score, Worthing Physiological Scoring System, National Early Warning Score, and Rapid Emergency Medicine Score in Predicting Inhospital Mortality in Multiple Trauma Patients

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Abstract

Background and Objectives: Physiological scoring systems could potentially aid emergency department (ED) trauma triage, and allowed clinicians to focus on treating the most severe patients first. This study aims to compare Modified Early Warning Score (MEWS), Worthing Physiological Scoring System (WPSS), National Early Warning Score (NEWS), and Rapid Emergency Medicine Score (REMS) in predicting inhospital mortality for multiple trauma patients. **Methods:** This prospective descriptive study was performed on adult multiple trauma patients referred to the ED of Al-Zahra and Kashani hospitals, Isfahan, Iran during 2019-2020. The primary outcome was inhospital mortality. Receiver operating characteristic (ROC) curve analysis was used to evaluate and compare the performances of four scores. **Results:** Of the 771 patients included in this study, 738 patients (95.7%) survived after 24 h of admission. The mean age of patients was 38.66 ± 18.67 years, and the majority of patients were male (79.1%). To predict inhospital mortality, the area under the ROC curve (AUC) of REMS, MEWS, NEWS, WPSS, and Injury Severity Score (ISS) were 0.944, 0.889, 0.768, 0.754, and 0.869, respectively. Results showed that REMS was more successful than other scores in predicting in-hospital mortality for multiple trauma patients. AUC of REMS was significantly better than NEWS, WPSS, and ISS in predicting inhospital mortality. **Conclusions:** The findings of this study reveal that REMS is an excellent predictor of in-hospital mortality and MEWS, NEWS, WPSS, and ISS are good predictors of in-hospital mortality.

Keywords: Emergency department, Modified Early Warning Score, mortality, National Early Warning Score, outcome, Rapid Emergency Medicine Score, trauma, Worthing Physiological Scoring System

Introduction

Trauma is the cause of death in more than 175,000 individuals in the United States every year and the main cause of death in people under the age of 45.[1] Furthermore, trauma is one of the four leading causes of death in developing countries such as Iran.[2] Trauma and injuries alone account for more than 10% of the disease burden among adults and account for more than 80% of deaths in low- and middle-income countries.[3] Likewise,

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trauma causes severe complications, disability, and financial and social costs.[4] The rate of mortality and disability due to trauma depends on the severity of the injury, the time of diagnosis, and the time of reaching an appropriate care center. Rapid evaluation, appropriate triage, and proper posttraumatic care during the 1st h after a traumatic event can reduce the rate of mortality and long-term disability.[2-5] Rapid evaluation of trauma severity is essential for early and proper triage of multiple trauma patients.[6] Using valid trauma scoring systems can assess the severity of the injury quickly and show the prognosis. Several systems have been developed to determine the prognosis of patient outcomes. As one of the oldest trauma scores, the Injury Severity Score (ISS) is an anatomy-based scoring system designed in a study to predict the outcome of car accident victims with multiple injuries.[7] Although the ISS is effective, the calculations are complex and time-consuming. Therefore, it is impractical in an emergency department (ED) and generally used for auditing and research purposes rather than for clinical decision-making.[7,8] This limitation and the recent consideration of physiological scoring systems led to a significant development in new scoring systems. Rapid Emergency Medicine Score (REMS), National Early Warning Score (NEWS), Worthing Physiological Scoring System (WPSS), and Modified Early Warning Score (MEWS) are some of the most used scoring systems. These scales differ in the included parameters and the value assigned to each of them. These scoring systems are comprised of simple physiological parameters that can be obtained rapidly, including systolic blood pressure (SBP) or mean arterial pressure (MAP), heart rate (HR), respiratory rate (RR), oxygen saturation (O2 sat), body temperature (T), supplemental oxygen uptake, and level of consciousness (LOC); the Alert Verbal Pain Unresponsiveness (AVPU); or Glasgow Coma Scale (GCS)[9-12] [Table 1].

The REMS which is a prognostic tool for inhospital mortality assessment among patients admitted to the ED, was developed in 2004. It is an attenuated version of the Acute Physiology and Chronic Health Evaluation II.[13] The MEWS was developed in 2001 to identify patients at risk for catastrophic events, including death.[14] The NEWS was presented by the NEWS Development and Implementation Group on behalf of the Royal College of Physicians in 2012.[15] The WPSS was another scoring system developed in 2007.[16]

Although there have been several studies examining the usability of scoring systems, there is no study that examines MEWS, REMS, NEWS, and WPSS in multiple trauma patients together. Such scoring systems could potentially aid ED trauma triage and allowed clinicians to focus on treating the most severe patients first.[5-12]

The aim of this study was to compare the predictive performance of MEWS, REMS, NEWS, and WPSS in predicting inhospital mortality for adult multiple trauma patients presenting to the ED.

Materials and Methods

Study design and setting

This prospective cross-sectional study was performed on multiple trauma patients referred to Al-Zahra and Kashani hospitals, two university teaching hospitals, Isfahan, Iran, from June 2019 to September 2020. This study has been approved by the ethics committee of Isfahan University of Medical Sciences (IR.MUI.MED.REC.1398.340). All patients signed an informed consent form.

Participants

All adult multiple trauma patients aged 18–94 years and presented to the ED were included in the study. The exclusion criteria consisted of patients transferred from other hospitals, patients discharged, or who died before 24 h of admission, patients who suffered from a burn or drowning-related injuries, pregnant patients, and patients discharged against medical advice.

Protocol and measurements

After the patients arrived at the ED, the triage nurse evaluated the severity of the patients based on Emergency Severity Index (ESI) version 4, and then, the subject was transferred to the emergency room according to the severity. Then, the emergency medicine residents visited all the cases who presented to the ED and took over the patient's treatment and follow-up. The ESI is a five-level ED triage algorithm relied upon by nurses that provide clinically relevant stratification of patients into five groups from 1 (most urgent) to 5 (least urgent) based on acuity and resource needs.

Table 1: Rapid Emergency Medicine Score

	0	1	2	3	4	5	6
Age	<45		45-54	55-64		65-74	>74
HR (bpm)	70-109		55-69	40-54	<40		
			110-139	140-179	>179		
RR (bpm)	12-24	10-11	6-9	35-49	<6		
		25-34			>49		
MAP (mmHg)	70-109		50-69	130-159	<49		
			110-129		>159		
GCS	>13	11 -13	8-10	5-7	<5		
O_2 sat	>89	86-89		75-85	<75		

MAP: Mean arterial pressure, HR: Heart rate, RR: Respiratory rate, GCS: Glasgow Coma Scale, O_2 sat: Oxygen saturation, bpm: Beats per minute

Variables collected from each patient just after arrival at the ED included age, sex, SBP, diastolic blood pressure, RR, HR, GCS, AVPU score, temperature, oxygen saturation, mechanism of injury, and triage level based on ESI. The MAP was calculated during data analysis. All patients were followed up to determine the length of stay, and survival to hospital discharge. The AVPU scale is a simple and rapid method of assessing the LOC. The patient's LOC is reported as A (Alert), V (responds to Voice), P (responds to Pain), and U (Unresponsive).

The prognoses of the patients were compared by using REMS, MEWS, NEWS, and WPSS. These scores and ISS were calculated after data gathering and a comprehensive assessment of injuries.

The REMS consists of six parameters, 5 – physiological and 1 – age.[13] The highest score is 26 and higher scores are associated with worse prognoses [Table 1].

The MEWS consists of five physiological variables. The range of each variable is from 0 to 3.[14] The range of MEWS total score is from 0 to a maximum of 14 [Table 2].

The NEWS dataset comprises seven physiological variables.[15] The score for each of the seven parameters (0–3 points) is summed up to calculate the NEWS. The range of NEWS total score is from 0 to a maximum of 20 [Table 3].

The WPSS also evaluates six parameters.[16] The total score is between 0 and 13 [Table 4].

The ISS is an anatomical scoring system that provides an overall score for patients with multiple injuries. The ISS is useful for assessment following motor vehicle collisions. It is calculated by adding the square of each of the coded values of the three most severely injured body regions and has a range from 0 to 75.[4]

Data analysis

For this study, patients were divided into two groups, those who survived and those who died in the hospital. SPSS version 25.0 (IBM, Armonk, NY, USA) was used to analyze the variables. Categorical variables were described by frequency and percentage and continuous variables were described by mean and standard deviation or 95% confidence interval (CI). Chi-square test and Fisher's exact test were used for the comparisons between categorical variables and the *t*-test was used for the comparisons between continuous variables.

The discriminating power of REMS, MEWS, NEWS, WPSS, and ISS to predict intrahospital mortality was compared by using the area under the receiver operating characteristic (ROC) curve (AUC) with a 95% CI. Sensitivity, specificity, positive and negative likelihood ratios, and positive and negative predictive values (NPVs) with 95% CI were plotted for each score using the ROC curve. $P < 0.05$ was considered statistically significant.

Results

Out of the 892 patients enrolled, 121 patients were excluded. Of the 771 patients included in this study, 738 patients (95.7%) survived after 24 h of admission, and the overall in-hospital mortality rate was 4.3% (n = 33 patients). The mean age of patients was 38.66 ± 18.67 years, and the majority of patients were male (79.1%). Road injuries were the main cause of trauma (69.7%), followed by falls (16.9%). Of all, 399 patients (51.8%) required surgery, and 189 patients (24.5%) were referred to the intensive care unit.

The mean of scores, the mean vital sign measures of the patients, and other baseline characteristics are reported in Table 5. Statistically significant differences between survivors and nonsurvivors were found for age, ESI triage level, SBP, MAP, HR, GCS, REMS, MEWS, NEWS, WPSS, and ISS.

Table 2: Modified Early Warning Score

	3	2	1	0	1	2	3
SBP (mm Hg)	<70	71-80	81-100	101-199		≥200	
HR (bpm)		<40	41-50	51-100	101-110	111-129	≥130
RR (bpm)		<9		9-14	15-20	21-29	≥30
Temperature (°C)		<35		35-38.4		≥38.5	
AVPU score				Alert	Reacting to voice	Reacting to pain	Unresponsive

SBP: Systolic blood pressure, HR: Heart rate, RR: Respiratory rate, AVPU: Alert Verbal Pain Unresponsive, bpm: Beats per minute

Table 3: National Early Warning Score

	3	2	1	0	1	2	3
RR (bpm)	≤8		9-11	12-20		21-24	≥25
O_2 sat (%)	≤91	92-93	94-95	≥96			
Inhaled oxygen		Yes		No			
Temperature (°C)	≤35.0		35.1-36.0	36.1-38.0	38.1-39.0	≥39.1	
SBP (mmHg)	≤90	91-100	101-110	111-219			≥220
Pulse rate (bpm)	≤40		41-50	51-90	91-110	111-130	≥131
AVPU				A			V, P, or U

RR: Respiratory rate, O_2 sat: Oxygen saturation, bpm: Beats per minute, SBP: Systolic blood pressure, AVPU: Alert Verbal Pain Unresponsive

However, there were no significant differences in other variables [Table 5].

ROC curves were used to estimate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and cutoff values of the REMS, MEWS, NEWS, WPSS, and ISS to predict inhospital mortality. The optimal cutoff values of ≥4 for the REMS, ≥3 for the MEWS, ≥5 for the NEWS, ≥3 for the WPSS score, and ≥13 for the ISS were established. The PPVs of the REMS, MEWS, NEWS, WPSS, and ISS for inhospital mortality was 18.8%, 22.0%, 11.9%, 9.3%, and 11.1%, respectively. The sensitivity and specificity of scores are shown in Table 6.

Table 4: Worthing Physiological Scoring System

	0	1	2	3
Ventilatory frequency (bpm)	≤19	20-21	≥22	
Pulse rate (bpm)	≤101	≥102		
SBP (mmHg)	≥100		≤99	
Temperature (°C)	≥35.3			<35.3
O_2 sat in air (%)	96-100	94-96	92-94	<92
AVPU	Alert			Other

O_2 sat: Oxygen saturation, bpm: Beats per minute, SBP: Systolic blood pressure, AVPU: Alert Verbal Pain Unresponsive

All scores were significantly associated with inhospital mortality, with $P < 0.001$. For inhospital mortality prediction, the AUCs of REMS, MEWS, NEWS, WPSS, and ISS were 0.944 (95% CI [0.926–0.959]), 0.889 (95% CI [0.864–0.910]), 0.768 (95% CI [0.737–0.798]), 0.754 (95% CI [0.722–0.784]), and 0.869 (95% CI [0.843–0.892]), respectively. AUC analysis demonstrated that the REMS was more successful than other scores in predicting inhospital mortality for multiple trauma patients [Figure 1].

The results showed that REMS was an excellent predictor of in-hospital mortality and MEWS, NEWS, WPSS, and ISS were good predictors of in-hospital mortality. The REMS was significantly better than NEWS, WPSS, and ISS in predicting in-hospital mortality.

Discussion

Despite advances in injury prevention and medical care, trauma

Table 5: Comparison of demographic and clinical characteristics of multiple trauma patients according to inhospital mortality

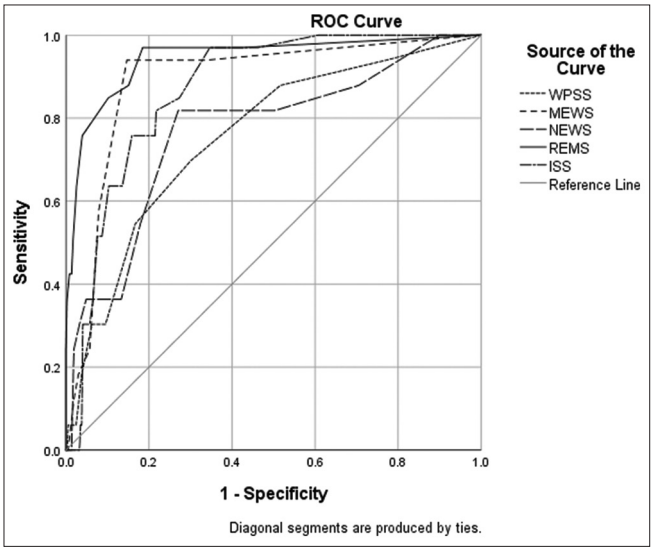
Characteristics	Total ($n=771$)	Survived ($n=738$)	Nonsurvived ($n=33$)	*P*
Age; year	38.66±18.67	38.10±18.24	51.09±23.60	0.004
Gender (%)				
Female	161 (20.9)	157 (21.3)	4 (12.1)	0.206
Male	610 (79.1)	581 (78.7)	29 (87.9)	
Mechanism (%)				
Road injuries	537 (69.7)	515 (69.8)	22 (66.7)	0.063
Fall	130 (16.9)	119 (16.1)	11 (33.3)	
Assault	98 (12.7)	98 (13.3)	0	
Others	6 (0.7)	6 (0.8)	0	
Triage level (%)				
1	162 (21.0)	134 (18.2)	28 (84.8)	<0.001
2	408 (52.5)	403 (54.6)	5 (15.2)	
3	201 (26.5)	201 (27.2)	0	
GCS (%)				
3-8	40 (5.2)	20 (2.7)	20 (60.7)	<0.001
9-12	31 (4.0)	27 (3.7)	4 (12.1)	
13-14	27 (3.5)	26 (3.5)	1 (3.0)	
15	673 (87.3)	665 (90.1)	8 (24.2)	
Length of stay; day	6.25±5.74	6.22±5.74	6.88±5.82	0.625
HR; bpm	87.35±14.08	87.03±13.74	96.24±20.45	0.001
SBP; mmHg	129.95±19.24	130.44±16.56	119.21±16.67	<0.001
MAP; mmHg	90.34±14.22	91.15±32.66	76.05±12.26	<0.001
RR; bpm	19.18±3.64	19.31±3.46	20.10±6.50	0.062
Temperature; °C	36.97±0.30	36.97±0.31	36.93±0.16	0.403
O_2 sat; %	94.59±3.10	94.57±2.99	95.03±5.03	0.404
ISS	11.77±10.30	11.29±10.17	22.42±6.67	<0.001
REMS	1.98±2.88	1.66±2.41	9.03±3.57	<0.001
MEWS	1.77±1.40	1.67±1.31	4.00±1.54	<0.001
NEWS	3.40±2.85	3.26±2.74	6.52±3.46	<0.001
WPSS	2.08±1.98	2.00±1.92	3.97±2.38	<0.001

GCS: Glasgow Coma Scale, SBP: Systolic blood pressure, HR: Heart rate, RR: Respiratory rate, O_2 sat: Oxygen saturation, bpm: Beats per minute, MAP: Mean arterial pressure, REMS: Rapid Emergency Medicine Score, MEWS: Modified Early Warning Score, NEWS: National Early Warning Score, WPSS: Worthing Physiological Scoring System, ISS: Injury Severity Score

Table 6: The receiver operating characteristics analysis results of physiologic scoring systems and Glasgow Coma Scale in prediction of inhospital mortality

Variables	REMS	MEWS	NEWS	WPSS	ISS
Cutoff	≥4	≥3	≥5	≥3	≥13
Sensitivity (95% CI)	96.97 (84.2-99.9)	93.94 (79.8-99.3)	81.82 (64.5-93.0)	69.70 (51.3-84.4)	96.96 (84.2-99.9)
Specificity (95% CI)	81.30 (78.3-84.1)	85.09 (82.3-87.6)	72.96 (69.6-76.1)	69.78 (66.3-73.1)	65.18 (61.6-68.6)
PPV (95% CI)	18.8 (16.5-21.4)	22.0 (18.9-25.5)	11.9 (10.0-14.2)	9.3 (7.4-11.7)	11.1 (10.0-12.3)
NPV (95% CI)	98.9 (98.9-100.0)	99.7 (98.8-99.9)	98.9 (97.7-99.5)	98.1 (96.8-98.9)	99.8 (98.6-100.0)
PLR (95% CI)	5.19 (4.4-6.1)	6.30 (5.2-7.6)	3.03 (2.5-3.7)	2.31 (1.8-3.0)	2.78 (2.5-3.1)
NLR (95% CI)	0.04 (0.01-0.3)	0.07 (0.02-0.3)	0.25 (0.1-0.5)	0.43 (0.3-0.7)	0.05 (0.01-0.3)
AUC (95% CI)	0.944 (0.926-0.959)	0.889 (0.864-0.910)	0.768 (0.737-0.798)	0.754 (0.722-0.784)	0.869 (0.843-0.892)
P	<0.001	<0.001	<0.001	<0.001	<0.001

REMS: Rapid Emergency Medicine Score, MEWS: Modified Early Warning Score, NEWS: National Early Warning Score, WPSS: Worthing Physiological Scoring System, ISS: Injury Severity Score, CI: Confidence interval, NPV: Negative predictive value, PPV: Positive predictive value, NLR: Negative likelihood ratio, CI: Confidence interval, AUC: Area under the curve



Area under the curve

Test result variable(s)	Area
WPSS	0.754
MEWS	0.889
NEWS	0.768
REMS	0.944
ISS	0.869

Figure 1: Receiver operating curves for predicting inhospital mortality according to Rapid Emergency Medicine Score, Modified Early Warning Score, National Early Warning Score, Worthing Physiological Scoring System, and Injury Severity Score

deaths remain a major public health problem worldwide. To improve overall survival and treatment outcomes, it is important to quickly and accurately determine the severity of trauma patients in the ED. Various scoring systems are shown to objectively assess the initial condition of a trauma patient, which include physiologic and anatomic systems.[17]

This study aimed to compare the utilities of MEWS, REMS, NEWS, and WPSS in predicting inhospital mortality in adult multiple trauma patients presenting to the ED and found that they were significantly associated with inhospital mortality (AUCs of REMS, MEWS, NEWS, and WPSS were 0.944, 0.889, 0.768, and 0.754, respectively). REMS was an excellent predictor of inhospital mortality and MEWS, NEWS, WPSS, and ISS were good predictors of inhospital mortality. AUC of REMS in the prediction of inhospital mortality was significantly better than NEWS, WPSS, and ISS.

The reason for the increase in the predictive value of REMS may be the addition of age to the variables in other scores. Because these scores include vital signs (e.g. MAP and PR) and neurological variables (GCS and AVPU) that were strongly associated with mortality risk, they were excellent and good predictors of inhospital mortality. Out of the parameters measured by these scores, four were independent predictors of inhospital mortality: age, RR, SBP (or MAP), and LOC.

The REMS can be quickly computed in 20 min and has been shown to correlate with mortality in patients with trauma in previous studies.[4,8,11,13] In the study conducted by Imholff *et al*. REMS was found to be a strong predictor of inhospital mortality for trauma patients (AUC = 0.91). REMS performed similarly to Revised Trauma Score (RTS) and outperformed several other traditionally used trauma scales including ISS and shock index.[4] Nakhjavan-Shahraki *et al*. showed that the prognostic values of REMS could be excellent for mortality (AUC = 0.93) and poor outcome (*P* = 0.92) in patients with trauma in emergency settings.[18] The findings of the current study are consistent with those of these previous studies, which show that REMS is a simple and accurate predictor of in-hospital mortality for multiple trauma patients.

The MEWS was used to determine the risk of mortality and the severity of trauma. It has been previously reported that MEWS is a good predictor of inhospital mortality in the trauma population because MEWS achieves a high AUC (0.83–0.90).[10,19] Consistently, our results reported that the MEWS is a good predictor (AUC = 0.89) of inhospital mortality. Salottolo *et al*. demonstrated that the MEWS is more associated with mortality than injury severity in trauma patients.[20] Jiang also

showed that the MEWS has a lower AUC value of identifying trauma severity.[10]

The NEWS was used widely to detect deteriorating patients in a range of clinical situations. Lee *et al*. showed that the NEWS was effective in predicting inhospital mortality (AUC: 0.765).[21] Smith *et al*.[22] and Kovacs *et al*.[23] showed that the NEWS for inhospital mortality had a very high predictive value (AUC = 0.894–0.902). Of course, none of these studies have been performed on trauma patients. In the study conducted by Suh *et al*., the NEWS showed better performance in predicting inhospital mortality of patients with trauma compared to the RTS (AUC = 0.88 vs. 0.83).[24]

Few studies have assessed the prognostic value of WPSS for inhospital mortality. Ha *et al*. showed that both REMS and WPSS had a good prognostic value for the mortality of patients in the ED.[25] A multicenter study reported a higher prognostic value for WPSS score compared to the RTS score in predicting mortality and severe disabilities in patients with trauma. The AUC of RTS and WPSS for prediction of inhospital mortality was 0.86 and 0.91, respectively.[26] In contrast, the current study showed a lower prognostic value for the WPSS score in predicting inhospital mortality in trauma patients compared to the REMS, MEWS, and NEWS.

In the optimal cutoff values of scores, the PPV of the REMS, MEWS, NEWS, WPSS, and ISS for inhospital mortality was 18.8%, 22.0.0%, 11.9%, 9.3%, and 11.1%, respectively. Furthermore, the NPV of the REMS, MEWS, NEWS, WPSS, and ISS for inhospital mortality was 98.9%, 99.7%, 98.9%, 98.1%, and 99.8%, respectively. Consistent with the present study, scoring in previous studies also had high NPV and low PPV.[8,11,21] For example, when the REMS was 4 or more, the PPV was 18.8% and NPV was 98.9. That is one out of every five patients who triggered the REMS had inhospital mortality, and among multiple trauma patients who had a negative score (REMS <4), the probability of inhospital mortality was 98.9%.

In the present study, the PPV was low and the NPV was high. This could be due to the low prevalence of inhospital mortality. In this study, intrahospital mortality was 4.3%. PPV and NPV are directly related to prevalence. For any given score (i.e., sensitivity and specificity remain the same) as prevalence decreases, the PPV decreases and the NPV increases. To increase the PPV of scores, we could use the scores for patients at high risk of inhospital mortality, for example, in patients with severe multiple trauma (ISS >5) because that is patients with a higher prevalence of mortality.

Limitations

The present study has some limitations. One of the limitations of the study was the lack of information about patients who were admitted to the ED and who died before 24 h; hence, they were not included in the study. Second, many multiple trauma patients in the study presented with head-and-neck injuries, which may cause bias in the results.

Conclusions

The ability to predict inhospital mortality quickly and accurately could lead to improved patient outcomes. This study found that the REMS is an excellent predictor of inhospital mortality and MEWS, NEWS, WPSS, and ISS are good predictors of inhospital mortality in patients with multiple trauma. The scores are simple and rapid tools for application and can be used for the timely triage of multiple trauma patients in the ED. The AUC of REMS in predicting inhospital mortality was significantly better than NEWS, WPSS, and ISS. We hope that the REMS and MEWS will be a more useful tool for triage in trauma patients and will lead to an improvement in trauma management.

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Conflicts of interest

There are no conflicts of interest.

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