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Prognostic value of modified early warning score generated in a Chinese emergency department: A prospective cohort study

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Title: Prognostic value of modified early warning score generated in a Chinese emergency department: A prospective cohort study

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ABSTRACT

Objectives This study aimed to validate the performance of the Modified Early Warning Score (MEWS) in a Chinese emergency department, and to find out the best cut-off value for in-hospital mortality prediction.

Design A prospective, single-centered observational cohort study.

Setting This study was conducted at a tertiary hospital in southeast china.

Participants 383 patients, ages 18 years or older and triaged Category 1, 2 or 3 in the emergency treatment room, were enrolled, and who presented to the emergency department from May 17, 2017 until September 27, 2017.

Results A total of 383 patients were included in this study. In-hospital mortality was 13.6% (52/383), and transfer to the ICU was 21.7 % (83/383). The area under the ROC curve of MEWS for in-hospital mortality prediction was 0.83 (95% CI: 0.786, 0.881). When the cut-off point was defined as 3.5, 158 patients had MEWS>3.5, with a specificity of 66%, a sensitivity of 87%, an accuracy of 69%, a positive predictive value of 28% and a negative predictive value of 97%, respectively, when predicting in-hospital mortality.

Conclusion Our findings support the use of MEWS for in-hospital mortality prediction in patients who were triaged Category 1, 2 and 3 in a Chinese emergency department. The cut-off value for in-hospital mortality prediction defined in this study was different from many other studies.

Keywords: Modified Early Warning Score; triage; in-hospital mortality; Emergency department

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Study Strengths and limitations

- This prospective observational study was carried out according to workflow, which is a less cost effective and reduces the difficulty for data collection.
- This study evaluated the ability of the MEWS to predict in-hospital mortality in Chinese patients presenting to the emergency treatment.
- This study evaluated the MEWS on patient admission once only, so dynamic changes in the score cannot be observed during patient hospitalization.
- This prospective cohort study recruited participants at a single medical center, which could limit the generalizability of study findings.

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INTRODUCTION

Different kinds of triage systems have been developed around the world to assess the illness severity of patients presenting to emergency departments (ED) who are assigned treatment priorities.[1,2] In China, there was lacking of unified triage standard used to arrange patients when present to emergency department.[3] The triage standard used in hospitals in Shenzhen is a new four-level Chinese emergency triage criteria, published by the Public Hospital Administration of Shenzhen Municipality in August, 2013.[3] It categorizes patients as endangered (Level 1), critically ill (Level 2), acute (Level 3) and not acute (Level 4), requiring treatment immediately, in 10 minutes, in 30 minutes and in 4 hours, respectively. This is mainly decided according to patients' presenting complaints and questions about potentially aggravating factors. According to acuity, Level 1, Level 2 and Level 3 are urgent patients with a higher risk of serious adverse events, such as hospital admission and mortality, compared to Level 4, which describes non-urgent patients. [4,5]

Therefore, an excellent scoring system is urgently required for mortality predictions of patients coming to the ED. Today, there are a number of scoring systems designed to detect deteriorating patients to predict the chance of hospitalization, intensive care unit admission or in-hospital mortality in emergency department ED patients.[6,7] The VitalPac Early Warning Score (VIEWS), modified early warning score (MEWS), Rapid Emergency Medicine Score (REMS), Emergency Department Sepsis Score (MEDS) and Rapid Acute Physiology Score are the most commonly employed systems for bedside evaluation.[8-11]

MEWS was introduced in 2001 by UK professor Subbe,[12] who modified it from the early warning scores (EWS). The MEWS is a simple physiological scoring system, which includes

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five physiological parameters that can easily be collected at the moment of presentation: systolic blood pressure, pulse rate, respiratory rate, temperature and level of consciousness. The MEWS is widely used in wards, the ICU and emergency departments to detect the clinical deterioration of patients or to predict clinical outcomes.[6,7,13]

A large number of studies have reported that MEWS is an effective tool for in-hospital mortality prediction.[15-17] However, there have also been studies conducted on different populations or in different areas reporting that MEWS is not an adequate scoring system to predict in-hospital mortality.[18,19] Moreover, the cut-off value of MEWS for in-hospital mortality prediction reported in studies varied.[10 9,15,20-22] A study conducted on 518 Patients in ICU indicated that Patients with MEWS≥6 had significantly higher mortality than those with a MEWS<6.[22] However, another study about the performance of MEWS in non-traumatic critical patients in emergency department showed that the MEWS cut-off value was 3.[15] Therefore, this study hypothesizes that MEWS performance and the cut-off value may differ according to the specific population.

The MEWS is also used to evaluate patient conditions in Chinese emergency departments, including focusing on the relationship between factors and clinical outcomes, using MEWS in prehospital for identifying non-trauma patients requiring life-saving intervention, risk stratification of patients before inter-facility transport.[23-25] However, information is limited on MEWS validation for in-hospital mortality predictions in patients triaged Level 1, 2 and 3 in Chinese emergency departments. Hence, the aim of this study was to evaluate MEWS performance in predicting in-hospital mortality of population in a Chinese emergency treatment room, and find the best cut-off value.

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METHODS

Study design

A prospective, single-centered observational cohort study was conducted at the ED of a tertiary hospital, Shenzhen, China to evaluate the ability of the MEWS to predict in-hospital mortality in patients presenting to the emergency treatment room, who were categorized Levels 1, 2 and 3. The study was approved by the ethical committee of the Hospital.

Study population

The study was carried out at the tertiary hospital, which is the First Affiliated Hospital of Shenzhen University with 173,000 ED presentations in 2017. of 173,000 ED presentations, approximately 6,600 patients were admitted to the emergency treatment room. Data of patients presenting to the emergency treatment room between May 17, 2017 and September 27, 2017 were collected. Eligibility criteria: patients ages 18 years or older triaged as Category 1, 2 and 3 were included in the study. Exclusion criteria: Patients who had died prior to arrival in the ED, and patients, who needed ward admission, ICU admission or rescue according to the doctor's judgment, ignored the suggestions of doctors and left the hospital due to a variety of reasons were excluded from the study. Patients with insufficient information were also excluded.

Study procedure

Patients who presented to our ED were evaluated and triaged by the triage nurse, who had more than five years of experience. Patients were triaged to endangered (Level 1), critically ill (Level 2), acute (Level 3) and not acute (Level 4). This is decided according to the triage guidelines and judgement of triage nurse. According to acuity, patients triage to Level 1 and Level 2 were sent

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to emergency treatment room; Patients triage to Level 3 were given a priority to the consulting room or arranged to emergency treatment room if the triage nurse judge the patients as serious; Patients triage to Level 4 were arranged to waiting outside the consulting room.

Physiological parameters were measured by nurses and researchers at the time of admitted to emergency treatment room. Respiratory rate was counted manually for more than a full minute; heart rate and blood pressure were measured using an automatic electronic sphygmomanometer (HBP-9020) or multifunctional ECG monitor (PHILPS Jin Kewei, G30). Body temperature was measured using an infrared ear thermometer (Pr04000). The level of consciousness was recorded as the best response to the AVPU score (A for alert, V for reacting to vocal stimulus, P for reacting to pain and U for unresponsive).

Patient information was recorded using a questionnaire designed by the researchers. The following information was included: age, sex, nationality, educational background, 'mode of transportation' to hospital, disease types, main diagnosis, body temperature, systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate, peripheral oxygen saturation, and the AVPU (A: alert, V: voice, P: pain, and U: unresponsive) score, triage level, MEWS score (Appendix 1), and mortality.

The patients were followed up by the researcher until discharge, death or for a maximum of 90 days. The researchers calculated the MEWS using patients' recorded five physiological parameters. In-hospital mortality was the main outcome. The predictive accuracy of the MEWS was evaluated by the Receiver Operating Characteristic (ROC) curve. Sensitivity, specificity, accuracy, and positive and negative predictive value (PPV and NPV) were analyzed to indicate the predictive power of the scoring system. The patients were divided into two groups: MEWS＜

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4 and MEWS≥4. The intergroup differences in the baseline characteristic physiological parameters and the scores between the two groups were also evaluated.

Statistical analysis

First, the data distribution of each variable between the MEWS＜4 and the MEWS≥4 groups was compared. Continuous variables were given as mean with standard deviation and as median with interquartile range values when the data did not show a normal distribution; categorical data were expressed as absolute values and percentages. Inferential statistical analysis was using the t test for normal distribution data, or Kruskal-Wallis rank sum test for non-normal distribution data and chi-square tests for categorical data. Second, the area under the receiver operating characteristic curve (AUC) was measured for evaluating the predictive ability of the MEWS. Finally, sensitivity, specificity, accuracy, positive and negative predictive value (PPV and NPV) were also analyzed. P< 0.05 was regarded as statistically significant. EPidata3.1 was used for data entry, and then exported to tab-delimited text files. All analyses were performed using R (http://www.R-project.org) and EmpowerStats software (www.empowerstats.com, X&Y solutions, Inc.Boston MA).

RESULTS

A total of 516 patients met the eligibility criteria, with 133 patients excluded. Among the patients who were excluded from the study, 10 had already died when they were sent to the ED, while 46 patients ignored the suggestions of doctors and left the hospital due to a variety of reasons in the ED, and 65 patients also left the hospital after being admitted to the ward or ICU. Twelve patients were excluded due to insufficient information (Figure 1). Finally, 383 patients were in

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enrolled in the study. Of that total, 255 (66.6%) patients were male; the mean age of all patients was 59.6±18.3 years, and the ethnicity of the majority of patients was Han. Among the 383 patients, 52.5% and 21.7%were admitted to the ward and ICU from the ED, respectively. Nervous system, cardiovascular, and respiratory diseases were the three most common disease types seen in these patients, consisting of more than half of the population. In the baseline characteristics between groups MEWS＜4 and MEWS≥4, a number of baseline characteristics showed significant differences, with P＜0.05. Detailed patient baseline characteristics are shown in Table 1.

The patients were divided into two groups: MEWS ≥4 and MEWS＜4. Physiological parameters include body temperature, systolic blood pressure, diastolic blood pressure, heart rate, respiratory rate, percutaneous oxygen saturation and mental status, which were different between the two groups, and the difference was statistically significant. However, between the two groups, there were no differences in terms of blood sugar and length of stay. In addition, a total of 277 critically ill patients were triaged as Level 1 and Level 2, requiring treatment in under 10 minutes. There were more critically ill patients in the MEWS≥4 group than in the MEWS＜4 group (150/158 VS. 127/225, P <0.001). The proportion of in-hospital mortality was 13.6% (52/383), and most were in the MEWS≥4 group (7/52 VS. 45/52, P <0.001). Detailed physiological parameters of the two groups are indicated in Table 2.

The MEWS in-hospital mortality predictive ability is shown by area under the Receiver Operating Characteristic curve (AUC), at 0.83(95% CI, 0.786, 0.881) (Figure 2). When the MEWS threshold was 3.5, less than half of patients (158/383) had MEWS＞3.5, with a specificity of 66%, a sensitivity of 87%, an accuracy of 69%, a positive predictive value of 28% and a negative predictive value of 97% in predicting in-hospital mortality. Sensitivity, specificity,

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accuracy, positive and negative predictive values at different MEWS thresholds were shown in Table 3.

DISCUSSION

In this observational cohort study, the MEWS showed good performance for in-hospital mortality prediction with AUC values at 0.83. The higher the score, the higher the ratio of in-hospital mortality, indicating that MEWS was significantly correlated with patient mortality. In patients with MEWS ≥4, compared with MEWS＜4, a number of variables, such as age, triage level, vital signs, means of arrival and disease type are influencing factors of death in ED patients. When the MEWS threshold was 3.5, it showed that 87% of in-hospital mortality can be correctly predicted. The study demonstrated that MEWS is an effective tool for in-hospital mortality prediction for ED patents who triage to Levels 1, 2, and 3.

MEWS is a widely used scoring system in many countries, but differences between these studies, including study setting, population and disease types, led to different predictive ability of the MEWS. The AUC, specificity and sensitivity were the most common indexes reported in studies on MEWS performance.[17, 20, 26,27] A large proportion of studies reported that MEWS was an effective tool for mortality prediction, with AUC ranging from approximately 0.70-0.89 for the most frequently used threshold (MEWS=5), with the specificity and sensitivity reported in those studies ranging from 0.67-0.72, 0.65-0.71, respectively.[9,17,20,26] However, less information was provided on the accuracy, positive predictive value and negative predictive value of the score. In a single-center observational cohort study conducted at an urban tertiary care medical center in Chicago, adult patients who were suspected of contracting an infection in the hospital wards or

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emergency department (ED) were included.[20] Discrimination for in-hospital mortality was moderate with MEWS AUC 0.73 (95% CI, 0.71-0.74).

Furthermore, there are also studies demonstrating that MEWS is not an efficient system for mortality prediction with an approximate AUC of less than 0.6, with study populations that included septic patients admitted to medical wards, surgical patients presenting to emergency departments, and adults admitted to medical wards, respectively.[9,17,22] It showed that disease and population differences seem to strongly determine MEWS performance. However, MEWS performance in ED patients who were triaged as Level 1, 2 or 3 had not previously been validated. Our study found that mortality prediction for the MEWS is good (AUC, 0.83; 95% CI, 0.79-0.88). Moreover, our study used EmpowerStats software for data analysis, so that the AUC figure was smooth and show the 95% confidence intervals.

In our study, when the MEWS had a cut-point of 3.5, which resulted in a sensitivity of 87%, a specificity of 66%, accuracy of 69%, PPV of 28% and NPV of 97%. When combined of sensitivity and specificity, the maximum was defined as the best threshold. In order to increase the proportion of in-hospital mortality prediction and reduce missed diagnosis, sensitivity is more important than specificity in this study. When the threshold was 4.5, the specificity, accuracy and NPV improved at the cost of sensitivity and PPV, the number of death due to missed diagnosis increased from 6 to 16. Hence, this study defined the MEWS cut-point as 3.5, which was similar to a previous prospective study, whose MEWS cut-point was defined as 3.[15] However, the MEWS cut-point defined as 3 in this study was different from many other studies, whose MEWS cut-point defined as 5 or higher.[10,20-22] For the baseline characteristics of patients in this study, respiratory system diseases, digestive system diseases, circulatory system diseases and nervous system diseases consisted of 70.7% of the population and 67.3% of non-survivors,

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with the median (IQR) MEWS at 3 (3). Different kinds of diseases and populations may contribute to the difference. In general, our study provides evidence that the MEWS is an efficient system for in-hospital mortality prediction in an ED.

Limitations and implications for future research

There are several limitations in our study. First, this was a single-center observation cohort study in a tertiary hospital in Shenzhen, and the outcome of patients may be affected by the medical level of hospital, and so the performance of Modified Early Warning Score for in-hospital mortality prediction. Second, the population included in this study was selected according to triage criteria that were only published in Shenzhen. Therefore, our study results may not be generalizable to other settings. Third, we evaluated the MEWS only once, on patient admission. Dynamic changes in the score cannot be observed during patient hospitalization. Hence, we could not exclude the possibility that re-evaluation of this clinical score during hospitalization may improve or reduce the MEWS performance in this setting. In future, multicenter study should be conducted to reduce the effect that the sample size was not representative. On the contrary, due to varied performance of MEWS in different studies, research on specific disease is also needed for the use of MEWS more accurate.

CONCLUSION

This study found that MEWS was an accurate score for predicting in-hospital mortality in a Chinese emergency department. Future multi-centric prospective cohort studies are needed to validate the study findings.

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Contributions Study design: XX, WH and QL; acquisition of data: WH; data analysis and interpretation: all authors; project administration: XX and WT; manuscript first draft: XX and WH; statistical analysis: WH; manuscript revision: YZ.

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Competing interests None declared.

Ethical approval The study was approved by the ethical committee of the Second People's Hospital of Shenzhen.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement We are glad to share data collected in this study upon request from the corresponding author

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Table 1 Baseline characteristics between groups MEWS＜4 and MEWS≥4

Characteristics	All (n, %) n＝383	MEWS＜4 n＝225	MEWS≥4 n＝158	*P* value
Age (Mean, SD)	59.6(18.3)	57.9(16.9)	62.1(19.9)	0.008
Gender				0.43
Male	255(66.6)	159 (70.7)	96 (60.8)	
Female	128 (33.4)	66 (29.3)	62 (39.2)	
Ethnicity				0.525
Han	376 (98.2)	222 (98.7)	154 (97.5)	
Hui	1 (0.2)	0 (0.0)	1 (0.6)	
Manchu	6 (1.6)	3 (1.3)	3 (1.9)	
Means of arrival				0.009
Walking	123 (32.1)	86 (38.2)	37 (23.4)	
Wheelchair	8 (2.1)	4 (1.8)	4 (2.5)	
Ambulance	252 (66.8)	135 (60.0)	117 (74.1)	
Triage				<0.001
Discharged from ED	38 (9.9)	31 (13.8)	7 (4.4)	
Observation room	51 (13.3)	39 (17.3)	12 (7.6)	
Ward admission	201 (52.5)	126 (56.0)	75 (47.5)	
ICU admission	83 (21.7)	28 (12.4)	55 (34.8)	
Died in ED	10 (2.6)	1 (0.5)	9 (5.7)	
Disease types				0.003
Respiratory system	54 (14.1)	19 (8.4)	35 (22.2)	
Digestive system	36 (9.4)	23 (10.2)	13 (8.2)	
Cardiovascular system	82 (21.4)	50 (22.2)	32 (20.3)	
Nervous system	99 (25.8)	69 (30.7)	30 (19.0)	
Hematological system	3 (0.8)	3 (1.3)	0 (0.0)	
Endocrinologic, metabolism	3 (0.8)	3 (1.3)	0 (0.0)	
Urinary system	15 (3.9)	7 (3.1)	8 (5.1)	
Trauma	28 (7.3)	17 (7.56)	11 (7.0)	
Others	63 (16.5)	34 (15.1)	29 (18.4)	

Abbreviations: SD, standard deviation; ED, emergency department; ICU, intensive care unit.

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Table 2 Comparison of clinical parameters between patients MEWS＜4 and MEWS≥4

Parameters	All (n, %) n＝383	MEWS＜4 n＝225	MEWS≥4 n＝158	P value
Age (Mean, SD)	59.6(18.3)	57.9(16.9)	62.1(19.9)	0.008
Gender				0.430
Male	255(66.6)	159 (70.7)	96 (60.8)	
Female	128(33.4)	66(29.3)	62(39.2)	
Physiology (Mean, SD)				
Temperature (℃)	37.2 (1.0)	36.9 (0.6)	37.6 (1.2)	<0.001
SBP (mmHg)	136.6 (33.6)	140.9(29.6)	130.3 (37.9)	0.001
DBP (mmHg)	80.3 (21.1)	82.8(18.4)	76.80 (24.0)	0.002
Heart rate (bpm)	95.2 (30.8)	80.7(15.4)	116.0 (35.0)	<0.001
Respiratory rate (bpm)	23.1 (6.3)	20.7(3.0)	26.6 (7.9)	<0.001
SPO2 median (IQR)	99.0 (4)	99(2)	98 (5)	<0.001
BS median (IQR)	8.0 (3.4)	8.0(3.2)	8.2 (3.6)	0.461
LOS median (IQR)	12 (11)	11.0(9)	14 (14)	0.068
Mental status				<0.001
Alert	280 (73.1)	193 (85.8)	87 (55.1)	
Reacting to voice	39 (10.1)	21 (9.3)	18 (11.4)	
Reacting to pain	32 (8.4)	10 (4.4)	22 (13.9)	
Unresponsive	32 (8.4)	1 (0.4)	31 (19.6)	
Triage level				<0.001
Level 1	69 (18.0)	8 (3.6)	61 (38.6)	
Level 2	208 (54.3)	119 (52.9)	89 (56.3)	
Level 3	106 (27.7)	98 (43.6)	8 0(5.1)	
Survivors	331 (86.4)	218 (96.9)	113 (71.5)	<0.001
Non-survivors	52 (13.6)	7 (3.1)	45 (28.5)	<0.001

Abbreviations: SD, standard deviation; bpm, beats or breaths per minute; BS, blood sugar; DBP, diastolic blood pressure; IQR, interquartile range, LOS, length of stay, SBP, systolic blood pressure; SPO, percutaneous oxygen saturation.

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Table 3 Performance of MEWS in predicting in-hospital mortality among patients triaged to Level 1, 2 and 3 who were admitted to ED

MEWS	Threshold	Specificity (%)	Sensitivity (%)	Accuracy (%)	PPV (%)	NPV (%)
＞1.5(n. 295/383)	1.5	26	98	36	17	99
＞2.5(n.208/383)	2.5	51	90	57	23	97
＞3.5(n.158/383)	3.5	66	87	69	28	97
＞4.5(n.113/383)	4.5	77	69	76	32	94
＞5.5(n.71/383)	5.5	87	58	84	42	93
＞6.5(n.48/383)	6.5	93	50	87	54	92
＞7.5(n.25/383)	7.5	96	25	87	52	89
＞8.5(n.15/383)	8.5	98	17	87	60	88
＞9.5(n.7/383)	9.5	99	7.0	87	57	87
＞10.5(n.3/383)	10.5	99	4.0	87	67	87
＞11.5(n.1/383)	11.5	99	0.0	86	0.0	86

Abbreviations: MEWS, Modified Early Warning Score; NPV, negative predictive value; PPV, positive predictive value.

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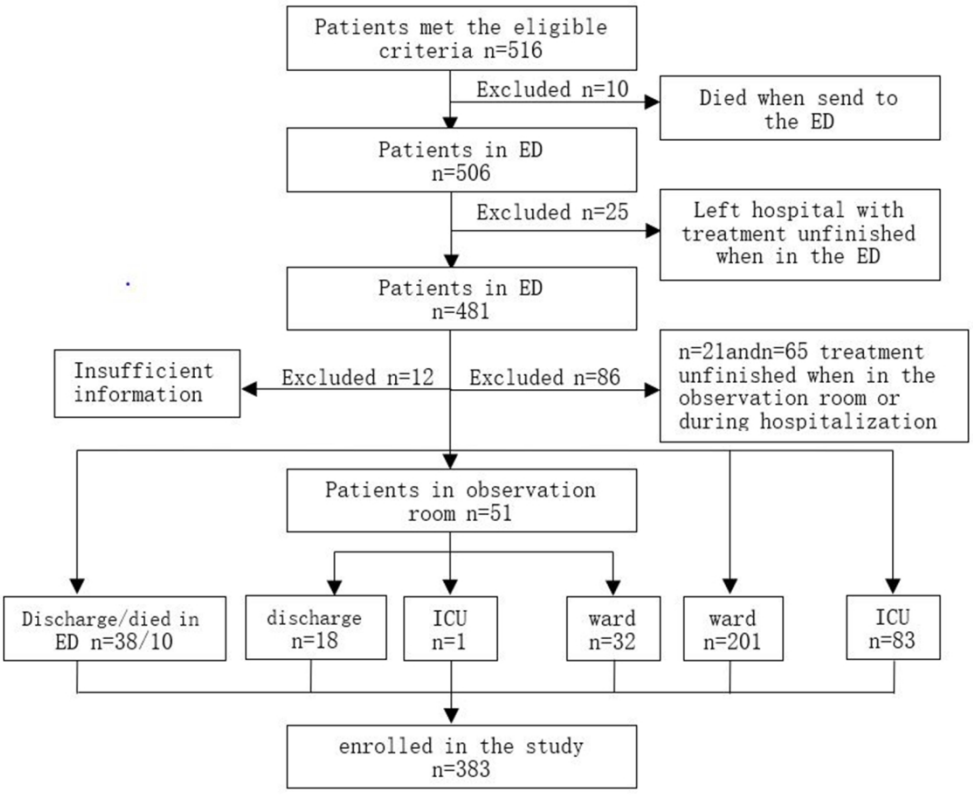

Figure 1 The flow chart of study procedure

Figure

149x137mm (300 x 300 DPI)

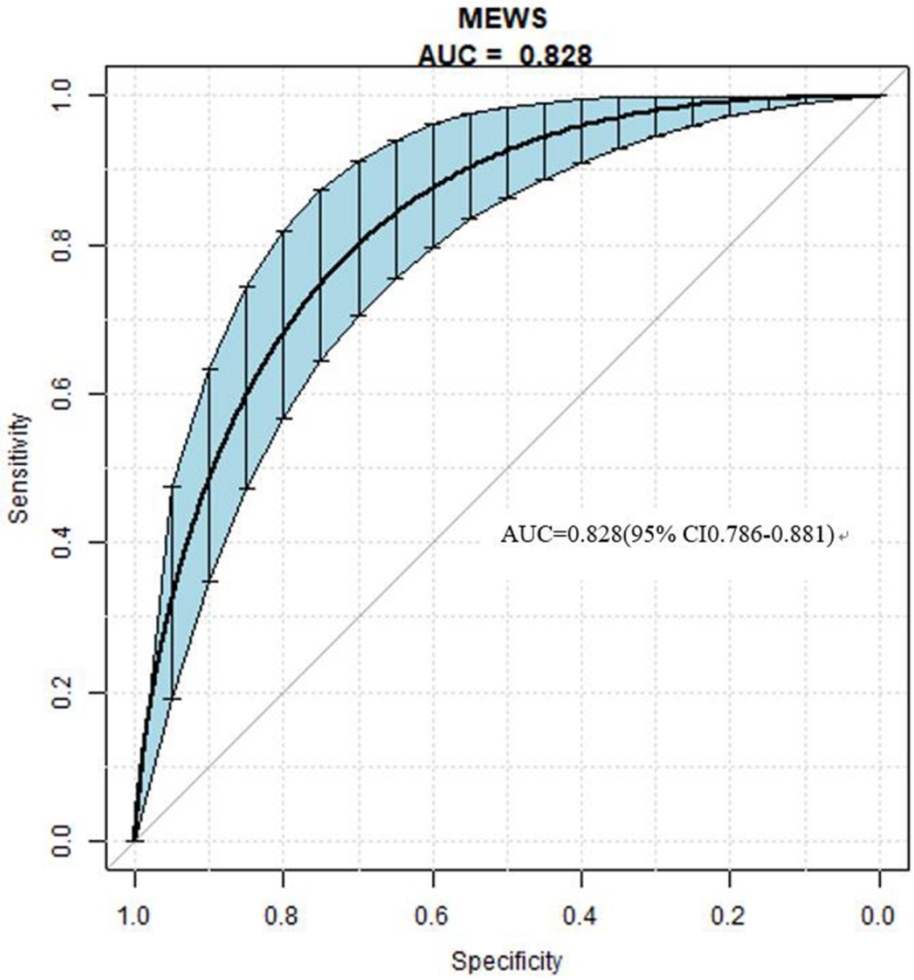

Figure 2 The AUC value of MEWS for predicting the in-hospital mortality

Blue shading shows the bootstrap estimated 95% CI with the AUC.

Figure

128x146mm (300 x 300 DPI)

Appendix 1 The Modified Early Warning Score

Parameters	3	2	1	0	1	2	3
Respiratory rate (bpm)	—	<9	—	9-14	15-20	21-29	≥30
Heart rate (bpm)	—	<40	41-50	51-100	101-111	112-129	≥130
Systolic blood pressure (mmHg)	<70	71-80	81-100	101-199	—	≥200	—
AVPU score	—	—	—	Alert	Reacting to voice	Reacting to pain	Unresponsive
Temperature (^{0}C)	—	<35.0	—	35-38.4	—	≥38.5	—

AVPU, A: alert, V: Reacting to voice, P: Reacting to pain, U: unresponsive; bpm, beats or breaths per minute.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *observational studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	P5
Methods			
Study design	4	Present key elements of study design early in the paper	P6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	P6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P6-7
Bias	9	Describe any efforts to address potential sources of bias	P6
Study size	10	Explain how the study size was arrived at	P6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P8
		(*b*) Describe any methods used to examine subgroups and interactions	P8
		(*c*) Explain how missing data were addressed	P8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	P8
		(*e*) Describe any sensitivity analyses	P8
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P8-9
		(b) Give reasons for non-participation at each stage	P8-9
		(c) Consider use of a flow diagram	P8-9
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P8-9
		(b) Indicate number of participants with missing data for each variable of interest	P8-9
Outcome data	15*	Report numbers of outcome events or summary measures	P8-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	P8-9
		(*b*) Report category boundaries when continuous variables were categorized	P8-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	P8-9
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	P8-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	P10-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12
Generalisability	21	Discuss the generalisability (external validity) of the study results	P12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Title: Prognostic value of Modified Early Warning Score generated in a Chinese emergency department: A prospective cohort study

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ABSTRACT

Objectives This study aimed to validate the performance of the Modified Early Warning Score (MEWS) in a Chinese emergency department, and to determine the best cut-off value for in-hospital mortality prediction.

Design A prospective, single-centred observational cohort study.

Setting This study was conducted at a tertiary hospital in South China.

Participants A total of 383 patients, ages 18 years or older who presented to the emergency department from May 17, 2017 until September 27, 2017, triaged as Category 1, 2, or 3, were enrolled.

Outcomes The primary outcome was a composite of in-hospital mortality and admission to the intensive care unit. The secondary outcome was using MEWS to predict hospitalised and discharged patients.

Results A total of 383 patients were included in this study. In-hospital mortality was 13.6% (52/383), and transfer to the ICU was 21.7 % (83/383). The area under the ROC curve of MEWS for in-hospital mortality prediction was 0.83 (95% CI: 0.786, 0.881). When the cut-off point was defined as 3.5, 158 patients had MEWS>3.5, with a specificity of 66%, a sensitivity of 87%, an accuracy of 69%, a positive predictive value of 28%, and a negative predictive value of 97%, respectively, when predicting in-hospital mortality.

Conclusion Our findings support the use of MEWS for in-hospital mortality prediction in patients who were triaged Category 1, 2, or 3 in a Chinese emergency department. The cut-off

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value for in-hospital mortality prediction defined in this study was different from that seen in many other studies.

Keywords: Modified Early Warning Score; triage; in-hospital mortality; Emergency department

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Study strengths and limitations

- This prospective observational study was carried out according to workflow, which is most cost-effective and reduces difficulty in data collection.
- This study used a prospective study design and provided a new cut-off point for the MEWS using ROC curve analysis to increase sensitivity in predicting in-hospital mortality.
- This study evaluated the MEWS only once, on patient admission, so dynamic changes in the score could not be observed during patient hospitalisation.
- This prospective cohort study recruited participants at a single medical centre, which could limit the generalisability of the study findings.

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INTRODUCTION

Different kinds of triage systems have been developed around the world to assess the illness severity of patients presenting to emergency departments (ED) who are assigned treatment priorities.[1,2] In China, there is a lack of a unified triage standard used to ? arrange patients when they present to the emergency department.[3] The triage standard used in hospitals in Shenzhen is a new four-level Chinese emergency triage criteria, published by the Public Hospital Administration of Shenzhen Municipality in August, 2013.[3] It categorises patients as near death (Level 1), critically ill (Level 2), acute (Level 3) and not acute (Level 4), requiring treatment immediately, in 10 minutes, in 30 minutes, and in four hours, respectively. This is mainly decided according to patients' presenting complaints and questions about potentially aggravating factors. According to acuity, Level 1, Level 2, and Level 3 are urgent patients with a higher risk of serious adverse events, such as hospital admission and mortality, compared to Level 4, which describes non-urgent patients. [4,5]

Therefore, an excellent scoring system is urgently required for mortality predictions in patients admitted to the ED. Today, there are a number of scoring systems designed to detect deteriorating patients to predict the chances of hospitalisation, intensive care unit (ICU) admission, or in-hospital mortality in emergency department ED patients.[6,7] The VitalPac Early Warning Score (VIEWS), modified early warning score (MEWS), Rapid Emergency Medicine Score (REMS), Emergency Department Sepsis Score (MEDS), and Rapid Acute Physiology Score are the most commonly employed systems for bedside evaluation.[8-11]

MEWS was introduced in 2001 by UK professor Subbe,[12] who modified it from the Early Warning Score (EWS). The MEWS is a simple physiological scoring system, which includes

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five physiological parameters that can easily be collected at the moment of presentation: systolic blood pressure, pulse rate, respiratory rate, temperature, and level of consciousness. The MEWS is widely used in wards, the ICU and emergency departments to detect the clinical deterioration of patients or to predict clinical outcomes.[6,7,13]

A large number of studies have reported that MEWS is an effective tool for in-hospital mortality prediction.[14-17] However, there have also been studies conducted on different populations or in different areas reporting that MEWS is not an adequate scoring system for predicting in-hospital mortality.[18,19] Moreover, the MEWS cut-off value (for in-hospital mortality prediction reported in studies) varied.[9,10,15,20-22] A study conducted on 518 patients in ICU indicated that patients with MEWS $\geqslant 6$ had significantly higher mortality than those with a MEWS<6.[22] However, another study on the performance of MEWS in non-traumatic critical patients in an emergency department showed the MEWS cut-off value was 3.[15] Therefore, this study hypothesises that MEWS performance and the cut-off value may differ according to the specific population.

The MEWS is also used to evaluate patient conditions in Chinese emergency departments, including focusing on the relationship between factors and clinical outcomes, using pre-hospital MEWS to identify non-trauma patients requiring life-saving intervention, and risk stratification of patients before inter-facility transport.[23-25] However, information is limited on MEWS validation for in-hospital mortality predictions in patients triaged as Level 1, 2, or 3 in Chinese emergency departments. Hence, the aim of this study was to evaluate MEWS performance in predicting in-hospital mortality of the population in a Chinese emergency treatment room, and to find the best cut-off value.

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METHODS

Study design

A prospective, single-centred observational cohort study was conducted in the ED of a tertiary hospital in Shenzhen, China to evaluate the ability of the MEWS to predict in-hospital mortality in patients presenting to the emergency treatment room, who were categorised Levels 1, 2, or 3. The study was approved by the hospital ethics committee.

Study population

The study was carried out at the tertiary hospital, which is the First Affiliated Hospital of Shenzhen University with 173,000 ED presentations in 2017. Of 173,000 ED presentations, approximately 6,600 patients were admitted to the emergency treatment room. Data of patients presenting to the emergency treatment room between May 17, 2017 and September 27, 2017 were collected. Eligibility criteria: patients ages 18 years or older triaged as Category 1, 2, and 3 were included in the study. Exclusion criteria: Patients who had died prior to arrival in the ED, and patients who needed ward admission, ICU admission, or rescue according to the doctor's judgment, or who ignored the doctor's advice and left the hospital due to a variety of reasons, were excluded from the study. Patients with insufficient information were also excluded.

Sample size calculation

This study calculated sample size using G*Power 3.1.9.2 (http://www.softpedia.com/get/Science-CAD/G-Power.shtml). The estimated sample size was 319 with an accuracy index of 0.95, a marginal error of 0.05 with 95% confidence level and 80% power.

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Participant involvement and data collection

Patients who presented to our ED were evaluated and triaged by the triage nurse, who had more than five years of experience. Patients were triaged to near death (Level 1), critically ill (Level 2), acute (Level 3) and not acute (Level 4). This is decided according to the triage guidelines and the judgment of the triage nurse. According to acuity, patients triaged to Level 1 and Level 2 were sent to the emergency treatment room; patients triaged to Level 3 were given priority in the consulting room or sent to the emergency treatment room if the triage nurse judged the patient's condition to be serious; and patients triaged to Level 4 were sent to wait outside the consulting room.

Physiological parameters were measured by nurses and researchers at the time of admittance to the emergency treatment room. Respiratory rate was counted manually for more than a full minute; heart rate and blood pressure were measured using an automatic electronic sphygmomanometer (HBP-9020) or multifunctional ECG monitor (PHILPS Jin Kewei, G30). Body temperature was measured using an infrared ear thermometer (Pr04000). The level of consciousness was recorded as the best response to the AVPU score (A for alert, V for reacting to vocal stimulus, P for reacting to pain and U for unresponsive).

Patient information was recorded using a questionnaire designed by the researchers. The following information was included: age, gender, nationality, educational background, 'mode of transportation' to hospital, disease type, main diagnosis, body temperature, systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate, peripheral oxygen saturation, and the AVPU (A: alert, V: voice, P: pain, and U: unresponsive) score, triage level, MEWS score (Appendix 1), and mortality.

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The patients were followed up by the researcher until discharge, death, or for a maximum of 90 days. The researchers calculated the MEWS using patients' recorded five physiological parameters. In-hospital mortality was the main outcome. The predictive accuracy of the MEWS was evaluated by the Receiver Operating Characteristic (ROC) curve. Sensitivity, specificity, accuracy, and positive and negative predictive value (PPV and NPV) were analysed to indicate the predictive power of the scoring system. The patients were divided into two groups: MEWS$<$ 4 and MEWS $\geqslant$ 4. The intergroup differences in the baseline characteristic physiological parameters and the scores between the two groups were also evaluated.

Outcomes

The primary outcome was a composite of in-hospital mortality and admission to the ICU. The secondary outcome was using MEWS to predict hospitalised and discharged patients.

Ethics statement

This study was approved by the medical ethical committee of the Second People's Hospital of Shenzhen (No. 20141201005). Written informed consent was obtained from research participants or patients' legal agents.

Statistical analysis

Descriptive statistics were tabulated for the overall sample. Mean and standard deviation were calculated for continuous variables, and frequencies and percentages for all other categorical variables. Data distribution of each variable between the MEWS <4 and the MEWS≥4 groups was compared. In addition, the area under the receiver operating characteristic curve (AUC) was measured to evaluate the predictive ability of the MEWS. Finally, sensitivity, specificity,

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accuracy, positive and negative predictive values (PPV and NPV) were also analysed. Regression analysis was used to address confounding variables of age and gender. P <0.05 was regarded as statistically significant. EPidata 3.1 was used for data entry, and then exported to tab-delimited text files. All analyses were performed using R (http://www.R-project.org) and EmpowerStats software (www.empowerstats.com, X&Y solutions, Inc. Boston MA).

RESULTS

A total of 516 patients met the eligibility criteria, with 133 patients excluded. Among the patients who were excluded from the study, 10 had already died when they were sent to the ED, while 46 patients in the ED ignored the advice of doctors and left the hospital due to a variety of reasons, and 65 patients also left the hospital after being admitted to the ward or ICU. Twelve patients were excluded due to insufficient information (Figure 1). Finally, 383 patients were enrolled in the study. Of that total, 255 (66.6%) patients were male; the mean age of all patients was 59.6±18.3 years, and the ethnicity of the majority of patients was Han (98.2%). Among the 383 patients, 52.5% and 21.7% were admitted to the ward and ICU from the ED, respectively. Nervous system, cardiovascular, and respiratory diseases were the three most common disease types seen in these patients, consisting of more than half of the population. In the baseline characteristics between groups MEWS <4 and MEWS ≥4, a number of baseline characteristics showed significant differences, with P <0.05. Detailed patient baseline characteristics are shown in Table 1.

The patients were divided into two groups: MEWS ≥4 and MEWS <4. Physiological parameters include body temperature, systolic blood pressure, diastolic blood pressure, heart rate, respiratory

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rate, percutaneous oxygen saturation and mental status, which were different between the two groups, and the difference was statistically significant. However, between the two groups, there were no differences in terms of blood sugar and length of stay. In addition, a total of 277 critically ill patients were triaged as Level 1 and Level 2, requiring treatment within 10 minutes. There were more critically ill patients in the MEWS ≥4 group than in the MEWS <4 group (150/158 VS. 127/225, P <0.001). The proportion of in-hospital mortality was 13.6% (52/383), and most were in the MEWS ≥4 group (7/52 versus 45/52, P <0.001). Detailed physiological parameters of the two groups are indicated in Table 2.

The MEWS in-hospital mortality predictive ability is shown by area under the Receiver Operating Characteristic curve (AUC), at 0.83 (95% CI, 0.786-0.881) (Figure 2). When the MEWS threshold was 3.5, less than half of patients (158/383) had MEWS >3.5, with a specificity of 66%, a sensitivity of 87%, an accuracy of 69%, a positive predictive value of 28%, and a negative predictive value of 97% in predicting in-hospital mortality. Sensitivity, specificity, accuracy, positive and negative predictive values at different MEWS thresholds are shown in Table 3.

Logistic regression analysis was used to examine the association between MEWS and the primary and secondary outcome measures. As seen in Table 4, the MEWS was significantly associated with in-hospital mortality (odds ratios-OR, 1.65; 95% CI, 1.44-1.89; P < 0.001), admission to ICU (OR, 1.54; 95% CI, 1.39-1.72, P < 0.001), and predicting hospitalised and discharged patients (OR, 1.55; 95% CI, 1.28-1.89, P < 0.001) (Table 4). The MEWS in-hospital mortality, admission to ICU predictive ability and predicting ability of hospitalised and discharged patients are shown in Figure 2, Figure 3, and Figure 4, respectively.

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DISCUSSION

In this observational cohort study, the MEWS showed good performance for in-hospital mortality prediction with AUC values at 0.83. The higher the score, the higher the ratio of in-hospital mortality, indicating that MEWS was significantly correlated with patient mortality. In patients with MEWS ≥4, compared with MEWS <4, a number of variables, such as age, triage level, vital signs, means of arrival and disease type are influencing factors of death in ED patients. When the MEWS threshold was 3.5, it showed that 87% of in-hospital mortality can be correctly predicted. The study demonstrated that MEWS is an effective tool for in-hospital mortality prediction for ED patients who triage to Levels 1, 2, and 3.

MEWS is a widely used scoring system in many countries, but differences between these studies, including study setting, population and disease types, has led to different predictive ability of the MEWS. The AUC, specificity and sensitivity were the most common indexes reported in studies on MEWS performance.[17,20,26,27] A large proportion of studies reported that MEWS was an effective tool for mortality prediction, with AUC ranging from approximately 0.70-0.89 for the most frequently used threshold (MEWS=5), with the specificity and sensitivity reported in those studies ranging from 0.67-0.72, 0.65-0.71, respectively.[9,17,20,26] However, less information was provided on the accuracy, positive predictive value and negative predictive value of the score. In a single-centre observational cohort study conducted at an urban tertiary care medical centre in Chicago, adult patients who were suspected of contracting an infection in a hospital ward or emergency department (ED) were included.[20] Discrimination for in-hospital mortality was moderate with MEWS AUC 0.73 (95% CI, 0.71-0.74).

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Furthermore, there are also studies demonstrating that MEWS is not an efficient system for mortality prediction with an approximate AUC of less than 0.6, with study populations that included septic patients admitted to medical wards, surgical patients presenting to emergency departments, and adults admitted to medical wards, respectively.[9,17,22] It showed that disease and population differences seem to strongly determine MEWS performance. However, MEWS performance in ED patients who were triaged as Level 1, 2, or 3 had not previously been validated. Our study found that mortality prediction for the MEWS is good (AUC, 0.83; 95% CI, 0.79-0.88).

In this study, when the MEWS had a cut-off point of 3.5, it resulted in a sensitivity of 87%, a specificity of 66%, accuracy of 69%, PPV of 28% and NPV of 97%. When combined with sensitivity and specificity, the maximum was defined as the best threshold. In order to increase the proportion of in-hospital mortality prediction and reduce missed diagnoses, sensitivity is more important than specificity in this study. When the threshold was 4.5, the specificity, accuracy, and NPV improved at the cost of sensitivity and PPV, and the number of deaths due to missed diagnosis increased from 6 to 16. Hence, this study defined the MEWS cut-off point as 3.5, which was similar to a previous prospective study, whose MEWS cut-off point was defined as 3.[15] However, the MEWS cut-off point defined as 3 in this study was different from that of many other studies, whose MEWS cut-off point was defined as 5 or higher.[10,20-22] For the baseline characteristics of patients in this study, respiratory system diseases, digestive system diseases, circulatory system diseases, and nervous system diseases were found in 70.7% of the population and 67.3% of non-survivors, with the median (IQR) MEWS at 3 (3). Different kinds of diseases and populations may have contributed to the difference. In general, our study

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provides evidence that the MEWS is an efficient system for in-hospital mortality prediction in an ED.

Limitations and implications for future research

There are several limitations in our study. First, this was a single-centre observational cohort study at a tertiary hospital in Shenzhen. Patient outcomes may have been affected by the level of care provided by the hospital, and may therefore have also affected the performance of the Modified Early Warning Score for in-hospital mortality prediction. Second, the population included in this study was selected according to triage criteria that were only published in Shenzhen. Therefore, our study results may not be generalisable to other settings. Third, we evaluated the MEWS only once, on patient admission. Dynamic changes in the score could not be observed during patient hospitalisation. Hence, we could not exclude the possibility that re-evaluation of this clinical score during hospitalisation may have improved or reduced the MEWS performance in this setting. In future, a multicentre study should be conducted to reduce the effect of the sample size not being representative. On the contrary, due to the varied performance of MEWS in different studies, research on specific diseases is also required, in order for the use of MEWS to be more accurate. While the actual number of enrolled subjects was 383 (higher than the required sample size of 319), there were 133 patients excluded in the analysis due to missing data resulting in potential selection bias. Thus, future research should implement strategies to minimise missing data on patient report forms.

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CONCLUSION

This study found that MEWS was an accurate score for predicting in-hospital mortality and admission to ICU in a Chinese emergency department. Future multi-centric prospective cohort studies are needed to validate the study findings.

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Competing interests None declared.

Ethical approval The study was approved by the ethical committee of the Second People's Hospital of Shenzhen.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement We are glad to share data collected in this study upon request from the corresponding author.

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Table 1 Baseline characteristics between groups MEWS<4 and MEWS≥4

Characteristics	All (n, %) n=383	MEWS<4 n=225	MEWS≥4 n=158	*P* value
Age (Mean, SD)	59.6(18.3)	57.9(16.9)	62.1(19.9)	0.008
Gender				0.43
Male	255(66.6)	159 (70.7)	96 (60.8)	
Female	128 (33.4)	66 (29.3)	62 (39.2)	
Ethnicity				0.525
Han	376 (98.2)	222 (98.7)	154 (97.5)	
Hui	1 (0.2)	0 (0.0)	1 (0.6)	
Manchu	6 (1.6)	3 (1.3)	3 (1.9)	
Means of arrival				0.009
Walking	123 (32.1)	86 (38.2)	37 (23.4)	
Wheelchair	8 (2.1)	4 (1.8)	4 (2.5)	
Ambulance	252 (66.8)	135 (60.0)	117 (74.1)	
Triage				<0.001
Discharged from ED	38 (9.9)	31 (13.8)	7 (4.4)	
Observation room	51 (13.3)	39 (17.3)	12 (7.6)	
Ward admission	201 (52.5)	126 (56.0)	75 (47.5)	
ICU admission	83 (21.7)	28 (12.4)	55 (34.8)	
Died in ED	10 (2.6)	1 (0.5)	9 (5.7)	
Disease types				0.003
Respiratory system	54 (14.1)	19 (8.4)	35 (22.2)	
Digestive system	36 (9.4)	23 (10.2)	13 (8.2)	
Cardiovascular system	82 (21.4)	50 (22.2)	32 (20.3)	
Nervous system	99 (25.8)	69 (30.7)	30 (19.0)	
Hematological system	3 (0.8)	3 (1.3)	0 (0.0)	
Endocrinologic, metabolism	3 (0.8)	3 (1.3)	0 (0.0)	
Urinary system	15 (3.9)	7 (3.1)	8 (5.1)	
Trauma	28 (7.3)	17 (7.56)	11 (7.0)	
Others	63 (16.5)	34 (15.1)	29 (18.4)	

Abbreviations: SD, standard deviation; ED, emergency department; ICU, intensive care unit.

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Table 2 Comparison of clinical parameters between patients MEWS <4 and MEWS≥4

Parameters	All (n, %) n=383	MEWS<4 n=225	MEWS≥4 n=158	P value
Age (Mean, SD)	59.6(18.3)	57.9(16.9)	62.1(19.9)	0.008
Gender				0.430
Male	255(66.6)	159 (70.7)	96 (60.8)	
Female	128(33.4)	66(29.3)	62(39.2)	
Physiology (Mean, SD)				
Temperature (℃)	37.2 (1.0)	36.9 (0.6)	37.6 (1.2)	<0.001
SBP (mmHg)	136.6 (33.6)	140.9(29.6)	130.3 (37.9)	0.001
DBP (mmHg)	80.3 (21.1)	82.8(18.4)	76.80 (24.0)	0.002
Heart rate (bpm)	95.2 (30.8)	80.7(15.4)	116.0 (35.0)	<0.001
Respiratory rate (bpm)	23.1 (6.3)	20.7(3.0)	26.6 (7.9)	<0.001
SPO2 median (IQR)	99.0 (4)	99(2)	98 (5)	<0.001
BS median (IQR)	8.0 (3.4)	8.0(3.2)	8.2 (3.6)	0.461
LOS median (IQR)	12 (11)	11.0(9)	14 (14)	0.068
Mental status				<0.001
Alert	280 (73.1)	193 (85.8)	87 (55.1)	
Reacting to voice	39 (10.1)	21 (9.3)	18 (11.4)	
Reacting to pain	32 (8.4)	10 (4.4)	22 (13.9)	
Unresponsive	32 (8.4)	1 (0.4)	31 (19.6)	
Triage level				<0.001
Level 1	69 (18.0)	8 (3.6)	61 (38.6)	
Level 2	208 (54.3)	119 (52.9)	89 (56.3)	
Level 3	106 (27.7)	98 (43.6)	8 0(5.1)	
Survivors	331 (86.4)	218 (96.9)	113 (71.5)	<0.001
Non-survivors	52 (13.6)	7 (3.1)	45 (28.5)	<0.001

Abbreviations: SD, standard deviation; bpm, beats or breaths per minute; BS, blood sugar; DBP, diastolic blood pressure; IQR, interquartile range, LOS, length of stay, SBP, systolic blood pressure; SPO, percutaneous oxygen saturation.

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Table 3 Performance of MEWS in predicting in-hospital mortality among patients triaged to Level 1, 2, and 3 who were admitted to ED

MEWS	Threshold	Specificity (%)	Sensitivity (%)	Accuracy (%)	PPV (%)	NPV (%)
>1.5(n. 295/383)	1.5	26	98	36	17	99
>2.5(n.208/383)	2.5	51	90	57	23	97
>3.5(n.158/383)	3.5	66	87	69	28	97
>4.5(n.113/383)	4.5	77	69	76	32	94
>5.5(n.71/383)	5.5	87	58	84	42	93
>6.5(n.48/383)	6.5	93	50	87	54	92
>7.5(n.25/383)	7.5	96	25	87	52	89
>8.5(n.15/383)	8.5	98	17	87	60	88
>9.5(n.7/383)	9.5	99	7.0	87	57	87
>10.5(n.3/383)	10.5	99	4.0	87	67	87
>11.5(n.1/383)	11.5	99	0.0	86	0.0	86

Abbreviations: MEWS, Modified Early Warning Score; NPV, negative predictive value; PPV, positive predictive value.

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Table 4 Association of MEWS with in-hospital mortality, admission to ICU, and predicting hospitalised and discharged patients

MEWS	Model 1 OR (95% CI) *P*	Model 2 OR (95% CI) *P*
In-hospital mortality	1.66 (1.45, 1.90) <0.001	1.65 (1.44, 1.89) <0.001
Admission to ICU	1.52 (1.37, 1.69) <0.001	1.54 (1.39, 1.72) <0.001
Predicting hospitalised and discharged patients	1.54 (1.27, 1.86) <0.001	1.55 (1.28, 1.89) <0.001

Model 1, original model; Model 2 with adjustment for age and gender.
Presented as OR with 95% CI (MEWS≥4, and MEWS <4 as reference).
Abbreviation: CI, confidence intervals; ICU, intensive care unit; OR, odds ratios.

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Figure 1 The flow chart of study procedure

Figure 2 The AUC value of MEWS for predicting the in-hospital mortality

Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 3 The AUC value of MEWS for predicting admission to Intensive Care Unit

Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 4 The AUC value of MEWS for predicting hospitalised and discharged patients

Blue shading shows the bootstrap estimated 95% CI with AUC.

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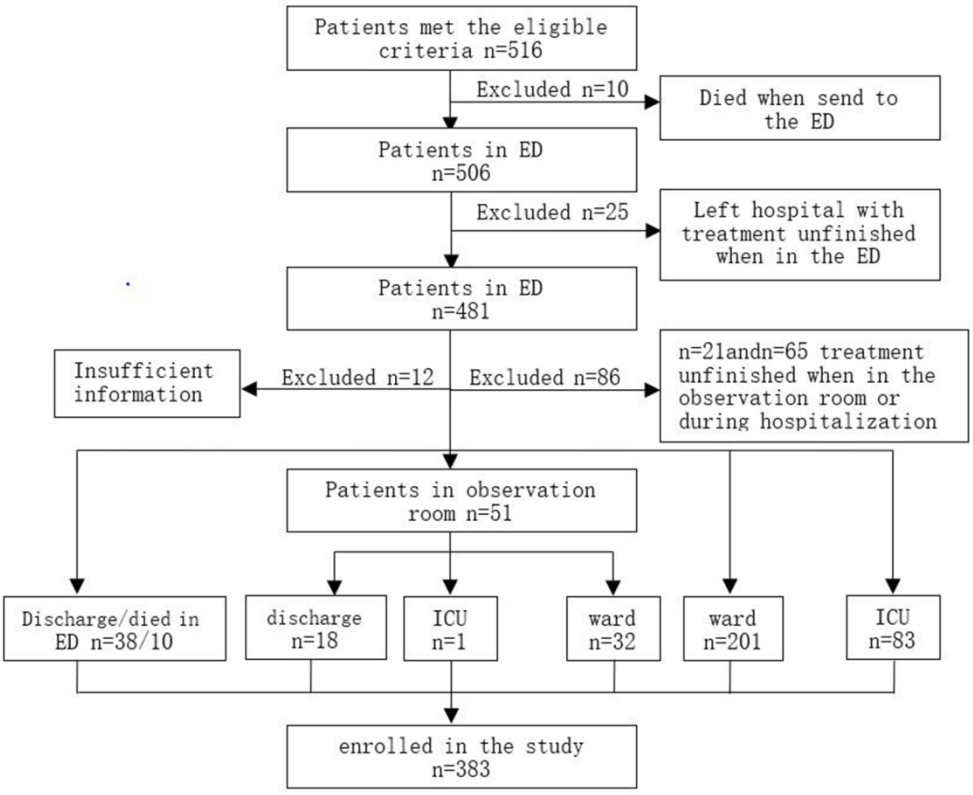

Figure 1 The flow chart of study procedure

Figure

149x137mm (300 x 300 DPI)

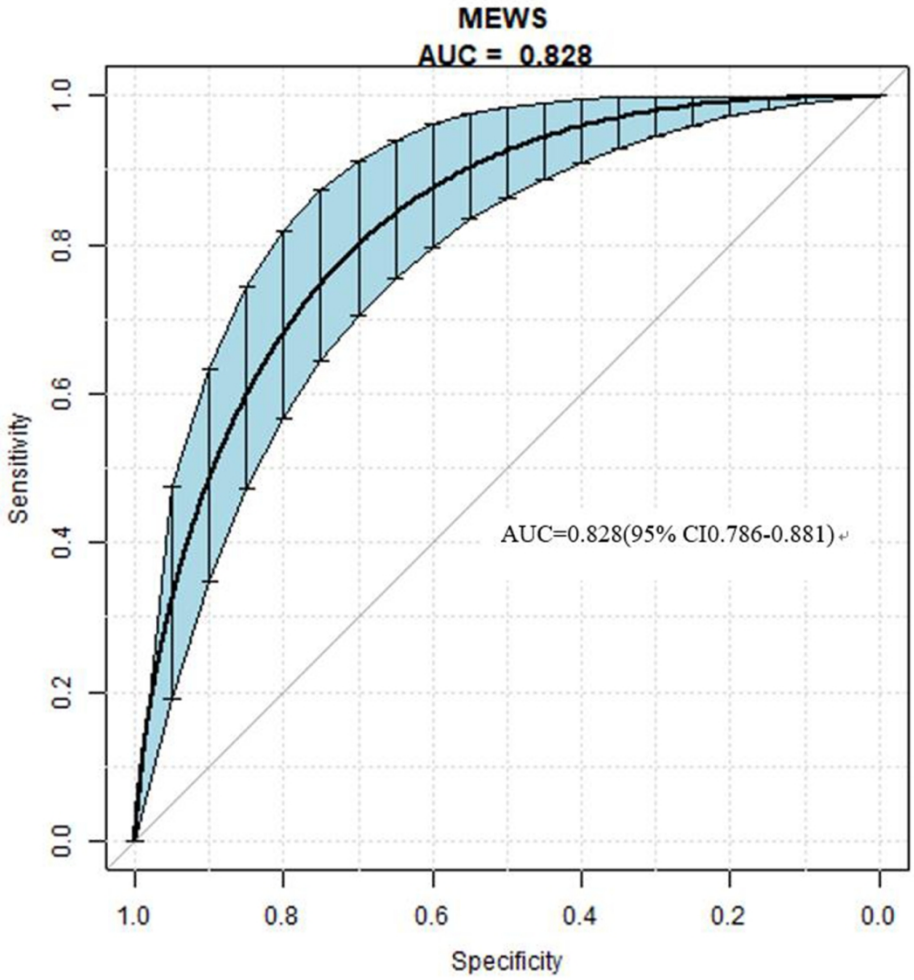

Figure 2 The AUC value of MEWS for predicting the in-hospital mortality

Blue shading shows the bootstrap estimated 95% CI with the AUC.

Figure

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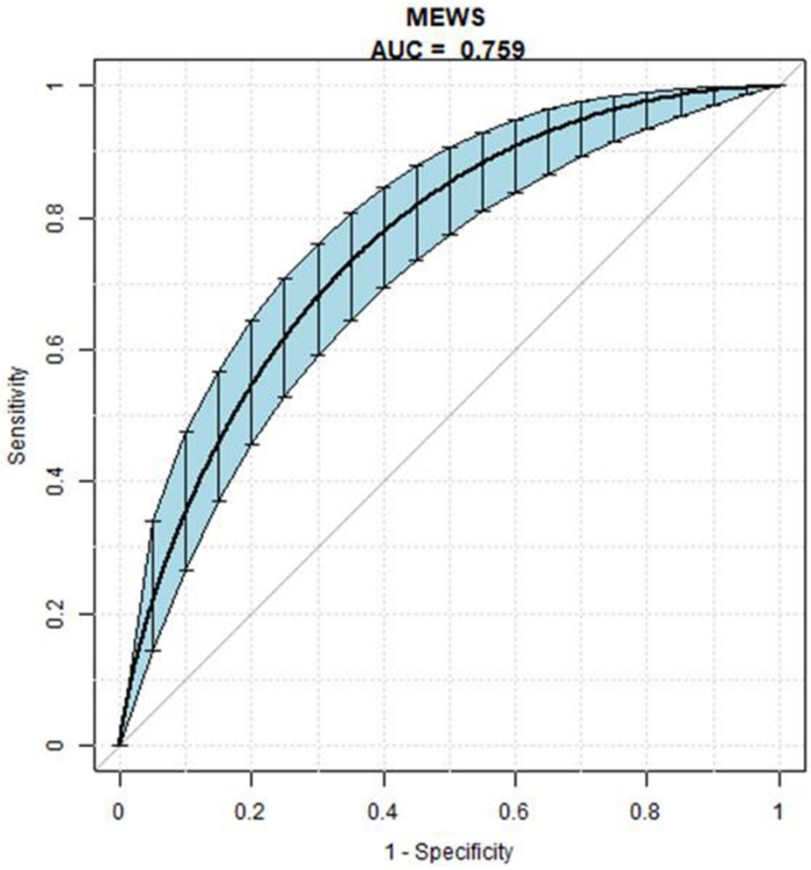

Figure 3 The AUC value of MEWS for predicting admission to Intensive Care Unit
Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 3

181x178mm (300 x 300 DPI)

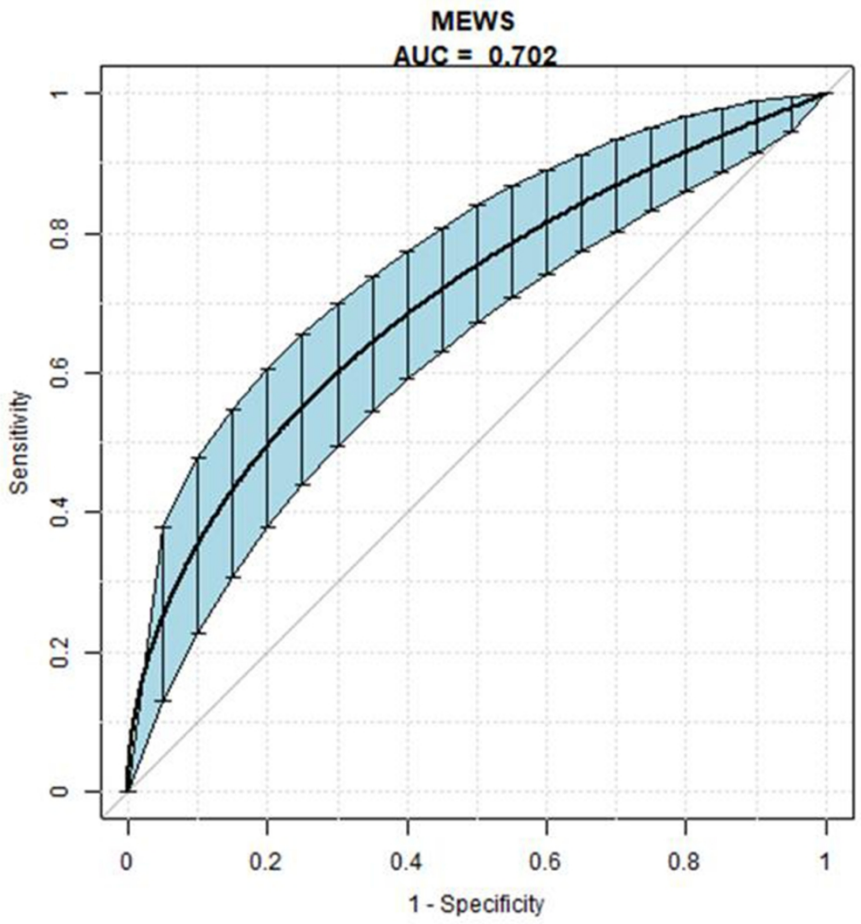

Figure 4 The AUC value of MEWS for predicting hospitalised and discharged patients Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 4

171x178mm (300 x 300 DPI)

Appendix 1 The Modified Early Warning Score

Parameters	3	2	1	0	1	2	3
Respiratory rate (bpm)	—	<9	—	9-14	15-20	21-29	≥30
Heart rate (bpm)	—	<40	41-50	51-100	101-111	112-129	≥130
Systolic blood pressure (mmHg)	<70	71-80	81-100	101-199	—	≥200	—
AVPU score	—	—	—	Alert	Reacting to voice	Reacting to pain	Unresponsive
Temperature (^{0}C)	—	<35.0	—	35-38.4	—	≥38.5	—

AVPU, A: alert, V: Reacting to voice, P: Reacting to pain, U: unresponsive; bpm, beats or breaths per minute.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *observational studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	P6
Methods			
Study design	4	Present key elements of study design early in the paper	P7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	P7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P8-9
Bias	9	Describe any efforts to address potential sources of bias	P10
Study size	10	Explain how the study size was arrived at	P7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P8-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P9-10
		(*b*) Describe any methods used to examine subgroups and interactions	P9-10
		(*c*) Explain how missing data were addressed	P9-10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	P9-10
		(*e*) Describe any sensitivity analyses	P9-10
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P7
		(b) Give reasons for non-participation at each stage	P25-Figure1
		(c) Consider use of a flow diagram	P25-Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P21-Table 1
		(b) Indicate number of participants with missing data for each variable of interest	P10
Outcome data	15*	Report numbers of outcome events or summary measures	P10-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	P10-11
		(*b*) Report category boundaries when continuous variables were categorized	P10-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	P10-11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	P10-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	P12-13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	P12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Prognostic value of Modified Early Warning Score generated in a Chinese emergency department: A prospective cohort study

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Title: Prognostic value of Modified Early Warning Score generated in a Chinese emergency department: A prospective cohort study

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ABSTRACT

Objectives This study aimed to validate the performance of the Modified Early Warning Score (MEWS) in a Chinese emergency department, and to determine the best cut-off value for in-hospital mortality prediction.

Design A prospective, single-centred observational cohort study.

Setting This study was conducted at a tertiary hospital in South China.

Participants A total of 383 patients, ages 18 years or older who presented to the emergency department from May 17, 2017 until September 27, 2017, triaged as Category 1, 2, or 3, were enrolled.

Outcomes The primary outcome was a composite of in-hospital mortality and admission to the intensive care unit. The secondary outcome was using MEWS to predict hospitalised and discharged patients.

Results A total of 383 patients were included in this study. In-hospital mortality was 13.6% (52/383), and transfer to the ICU was 21.7 % (83/383). The area under the ROC curve of MEWS for in-hospital mortality prediction was 0.83 (95% CI: 0.786, 0.881). When the cut-off point was defined as 3.5, 158 patients had MEWS>3.5, with a specificity of 66%, a sensitivity of 87%, an accuracy of 69%, a positive predictive value of 28%, and a negative predictive value of 97%, respectively, when predicting in-hospital mortality.

Conclusion Our findings support the use of MEWS for in-hospital mortality prediction in patients who were triaged Category 1, 2, or 3 in a Chinese emergency department. The cut-off

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value for in-hospital mortality prediction defined in this study was different from that seen in many other studies.

Keywords: Modified Early Warning Score; triage; in-hospital mortality; Emergency department

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Study strengths and limitations

- This prospective observational study was carried out according to workflow, which is most cost-effective and reduces difficulty in data collection.
- This study used a prospective study design and provided a new cut-off point for the MEWS using ROC curve analysis to increase sensitivity in predicting in-hospital mortality.
- This study evaluated the MEWS only once, on patient admission, so dynamic changes in the score could not be observed during patient hospitalisation.
- This prospective cohort study recruited participants at a single medical centre, which could limit the generalisability of the study findings.

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INTRODUCTION

Different kinds of triage systems have been developed around the world to assess the illness severity of patients presenting to emergency departments (ED) who are assigned treatment priorities.[1,2] In China, there is a lack of a unified triage standard used to ? arrange patients when they present to the emergency department.[3] The triage standard used in hospitals in Shenzhen is a new four-level Chinese emergency triage criteria, published by the Public Hospital Administration of Shenzhen Municipality in August, 2013.[3] It categorises patients as near death (Level 1), critically ill (Level 2), acute (Level 3) and not acute (Level 4), requiring treatment immediately, in 10 minutes, in 30 minutes, and in four hours, respectively. This is mainly decided according to patients' presenting complaints and questions about potentially aggravating factors. According to acuity, Level 1, Level 2, and Level 3 are urgent patients with a higher risk of serious adverse events, such as hospital admission and mortality, compared to Level 4, which describes non-urgent patients. [4,5]

Therefore, an excellent scoring system is urgently required for mortality predictions in patients admitted to the ED. Today, there are a number of scoring systems designed to detect deteriorating patients to predict the chances of hospitalisation, intensive care unit (ICU) admission, or in-hospital mortality in emergency department ED patients.[6,7] The VitalPac Early Warning Score (VIEWS), modified early warning score (MEWS), Rapid Emergency Medicine Score (REMS), Emergency Department Sepsis Score (MEDS), and Rapid Acute Physiology Score are the most commonly employed systems for bedside evaluation.[8-11]

MEWS was introduced in 2001 by UK professor Subbe,[12] who modified it from the Early Warning Score (EWS). The MEWS is a simple physiological scoring system, which includes

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five physiological parameters that can easily be collected at the moment of presentation: systolic blood pressure, pulse rate, respiratory rate, temperature, and level of consciousness. The MEWS is widely used in wards, the ICU and emergency departments to detect the clinical deterioration of patients or to predict clinical outcomes.[6,7,13]

A large number of studies have reported that MEWS is an effective tool for in-hospital mortality prediction.[14-17] However, there have also been studies conducted on different populations or in different areas reporting that MEWS is not an adequate scoring system for predicting in-hospital mortality.[18,19] Moreover, the MEWS cut-off value (for in-hospital mortality prediction reported in studies) varied.[9,10,15,20-22] A study conducted on 518 patients in ICU indicated that patients with MEWS $\geqslant 6$ had significantly higher mortality than those with a MEWS<6.[22] However, another study on the performance of MEWS in non-traumatic critical patients in an emergency department showed the MEWS cut-off value was 3.[15] Therefore, this study hypothesises that MEWS performance and the cut-off value may differ according to the specific population.

The MEWS is also used to evaluate patient conditions in Chinese emergency departments, including focusing on the relationship between factors and clinical outcomes, using pre-hospital MEWS to identify non-trauma patients requiring life-saving intervention, and risk stratification of patients before inter-facility transport.[23-25] However, information is limited on MEWS validation for in-hospital mortality predictions in patients triaged as Level 1, 2, or 3 in Chinese emergency departments. Hence, the aim of this study was to evaluate MEWS performance in predicting in-hospital mortality of the population in a Chinese emergency treatment room, and to find the best cut-off value.

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METHODS

Study design

A prospective, single-centred observational cohort study was conducted in the ED of a tertiary hospital in Shenzhen, China to evaluate the ability of the MEWS to predict in-hospital mortality in patients presenting to the emergency treatment room, who were categorised Levels 1, 2, or 3. The study was approved by the hospital ethics committee.

Study population

The study was carried out at the tertiary hospital, which is the First Affiliated Hospital of Shenzhen University with 173,000 ED presentations in 2017. Of 173,000 ED presentations, approximately 6,600 patients were admitted to the emergency treatment room. Data of patients presenting to the emergency treatment room between May 17, 2017 and September 27, 2017 were collected. Eligibility criteria: patients ages 18 years or older triaged as Category 1, 2, and 3 were included in the study. Exclusion criteria: Patients who had died prior to arrival in the ED, and patients who needed ward admission, ICU admission, or rescue according to the doctor's judgment, or who ignored the doctor's advice and left the hospital due to a variety of reasons, were excluded from the study. Patients with insufficient information were also excluded.

Sample size calculation

This study calculated sample size using G*Power 3.1.9.2 (http://www.softpedia.com/get/Science-CAD/G-Power.shtml). The estimated sample size was 319 with an accuracy index of 0.95, a marginal error of 0.05 with 95% confidence level and 80% power.

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Participant involvement and data collection

Patients who presented to our ED were evaluated and triaged by the triage nurse, who had more than five years of experience. Patients were triaged to near death (Level 1), critically ill (Level 2), acute (Level 3) and not acute (Level 4). This is decided according to the triage guidelines and the judgment of the triage nurse. According to acuity, patients triaged to Level 1 and Level 2 were sent to the emergency treatment room; patients triaged to Level 3 were given priority in the consulting room or sent to the emergency treatment room if the triage nurse judged the patient's condition to be serious; and patients triaged to Level 4 were sent to wait outside the consulting room.

Physiological parameters were measured by nurses and researchers at the time of admittance to the emergency treatment room. Respiratory rate was counted manually for more than a full minute; heart rate and blood pressure were measured using an automatic electronic sphygmomanometer (HBP-9020) or multifunctional ECG monitor (PHILPS Jin Kewei, G30). Body temperature was measured using an infrared ear thermometer (Pr04000). The level of consciousness was recorded as the best response to the AVPU score (A for alert, V for reacting to vocal stimulus, P for reacting to pain and U for unresponsive).

Patient information was recorded using a questionnaire designed by the researchers. The following information was included: age, gender, nationality, educational background, 'mode of transportation' to hospital, disease type, main diagnosis, body temperature, systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate, peripheral oxygen saturation, and the AVPU (A: alert, V: voice, P: pain, and U: unresponsive) score, triage level, MEWS score (Appendix 1), and mortality.

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The patients were followed up by the researcher until discharge, death, or for a maximum of 90 days. The researchers calculated the MEWS using patients' recorded five physiological parameters. In-hospital mortality was the main outcome. The predictive accuracy of the MEWS was evaluated by the Receiver Operating Characteristic (ROC) curve. Sensitivity, specificity, accuracy, and positive and negative predictive value (PPV and NPV) were analysed to indicate the predictive power of the scoring system. The patients were divided into two groups: MEWS$<$ 4 and MEWS $\geqslant$ 4. The intergroup differences in the baseline characteristic physiological parameters and the scores between the two groups were also evaluated.

Outcomes

The primary outcome was a composite of in-hospital mortality and admission to the ICU. The secondary outcome of this study was using MEWS for prediction whether admitted to general ward unit or discharged from hospital.

Ethics statement

This study was approved by the medical ethical committee of the Second People's Hospital of Shenzhen (No. 20141201005). Written informed consent was obtained from research participants or patients' legal agents.

Statistical analysis

Descriptive statistics were tabulated for the overall sample. Mean and standard deviation were calculated for continuous variables, and frequencies and percentages for all other categorical variables. Data distribution of each variable between the MEWS <4 and the MEWS≥4 groups was compared. In addition, the area under the receiver operating characteristic curve (AUC) was

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measured to evaluate the predictive ability of the MEWS. Finally, sensitivity, specificity, accuracy, positive and negative predictive values (PPV and NPV) were also analysed. Regression analysis was used to address confounding variables of age and gender. $P < 0.05$ was regarded as statistically significant. EPidata 3.1 was used for data entry, and then exported to tab-delimited text files. All analyses were performed using R (http://www.R-project.org) and EmpowerStats software (www.empowerstats.com, X&Y solutions, Inc. Boston MA).

RESULTS

A total of 516 patients met the eligibility criteria, with 133 patients excluded. Among the patients who were excluded from the study, 10 had already died when they were sent to the ED, while 46 patients in the ED ignored the advice of doctors and left the hospital due to a variety of reasons, and 65 patients also left the hospital after being admitted to the ward or ICU. Twelve patients were excluded due to insufficient information (Figure 1). Finally, 383 patients were enrolled in the study. Of that total, 255 (66.6%) patients were male; the mean age of all patients was 59.6±18.3 years, and the ethnicity of the majority of patients was Han (98.2%). Among the 383 patients, 52.5% and 21.7% were admitted to the ward and ICU from the ED, respectively. Nervous system, cardiovascular, and respiratory diseases were the three most common disease types seen in these patients, consisting of more than half of the population. In the baseline characteristics between groups MEWS <4 and MEWS ≥ 4, a number of baseline characteristics showed significant differences, with $P < 0.05$. Detailed patient baseline characteristics are shown in Table 1.

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The patients were divided into two groups: MEWS ≥4 and MEWS <4. Physiological parameters include body temperature, systolic blood pressure, diastolic blood pressure, heart rate, respiratory rate, percutaneous oxygen saturation and mental status, which were different between the two groups, and the difference was statistically significant. However, between the two groups, there were no differences in terms of blood sugar and length of stay. In addition, a total of 277 critically ill patients were triaged as Level 1 and Level 2, requiring treatment within 10 minutes. There were more critically ill patients in the MEWS ≥4 group than in the MEWS <4 group (150/158 VS. 127/225, P <0.001). The proportion of in-hospital mortality was 13.6% (52/383), and most were in the MEWS ≥4 group (7/52 versus 45/52, P <0.001). Detailed physiological parameters of the two groups are indicated in Table 2.

The MEWS in-hospital mortality predictive ability is shown by area under the Receiver Operating Characteristic curve (AUC), at 0.83 (95% CI, 0.786-0.881) (Figure 2). Logistic regression analysis was used to examine the association between MEWS and the primary and secondary outcome measures. As seen in Table 3, the MEWS was significantly associated with in-hospital mortality (odds ratios-OR, 1.65; 95% CI, 1.44-1.89; P < 0.001), admission to ICU (OR, 1.54; 95% CI, 1.39-1.72, P < 0.001), and predicting admission to general ward unit or discharge from hospital (OR, 1.55; 95% CI, 1.28-1.89, P < 0.001) (Table 3). The MEWS in-hospital mortality, admission to ICU predictive ability and predicting ability of admission to general ward unit or discharge from hospital are shown in Figure 2, Figure 3, and Figure 4, respectively.

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DISCUSSION

In this observational cohort study, the MEWS showed good performance for in-hospital mortality prediction with AUC values at 0.83. The higher the score, the higher the ratio of in-hospital mortality, indicating that MEWS was significantly correlated with patient mortality. In patients with MEWS ≥4, compared with MEWS <4, a number of variables, such as age, triage level, vital signs, means of arrival and disease type are influencing factors of death in ED patients. The study demonstrated that MEWS is an effective tool for in-hospital mortality prediction for ED patients who triage to Levels 1, 2, and 3.

MEWS is a widely used scoring system in many countries, but differences between these studies, including study setting, population and disease types, has led to different predictive ability of the MEWS. The AUC, specificity and sensitivity were the most common indexes reported in studies on MEWS performance.[17,20,26,27] A large proportion of studies reported that MEWS was an effective tool for mortality prediction, with AUC ranging from approximately 0.70-0.89 for the most frequently used threshold (MEWS=5), with the specificity and sensitivity reported in those studies ranging from 0.67-0.72, 0.65-0.71, respectively.[9,17,20,26] However, less information was provided on the accuracy, positive predictive value and negative predictive value of the score. In a single-centre observational cohort study conducted at an urban tertiary care medical centre in Chicago, adult patients who were suspected of contracting an infection in a hospital ward or emergency department (ED) were included.[20] Discrimination for in-hospital mortality was moderate with MEWS AUC 0.73 (95% CI, 0.71-0.74).

Furthermore, there are also studies demonstrating that MEWS is not an efficient system for mortality prediction with an approximate AUC of less than 0.6, with study populations that

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included septic patients admitted to medical wards, surgical patients presenting to emergency departments, and adults admitted to medical wards, respectively.[9,17,22] It showed that disease and population differences seem to strongly determine MEWS performance. However, MEWS performance in ED patients who were triaged as Level 1, 2, or 3 had not previously been validated. Our study found that mortality prediction for the MEWS is good (AUC, 0.83; 95% CI, 0.79-0.88).

When combined with sensitivity and specificity, the maximum was defined as the best threshold. In order to increase the proportion of in-hospital mortality prediction and reduce missed diagnoses, sensitivity is more important than specificity in this study. When the threshold was 4, the specificity, accuracy, and NPV improved at the cost of sensitivity and PPV, and the number of deaths due to missed diagnosis increased from 6 to 16. Hence, this study defined the MEWS cut-off point as 4, which was different from a previous prospective study, whose MEWS cut-off point was defined as 3.[15] However, the MEWS cut-off point defined as 3 in this study was different from that of many other studies, whose MEWS cut-off point was defined as 5 or higher.[10,20-22] For the baseline characteristics of patients in this study, respiratory system diseases, digestive system diseases, circulatory system diseases, and nervous system diseases were found in 70.7% of the population and 67.3% of non-survivors, with the median (IQR) MEWS at 3 (3). Different kinds of diseases and populations may have contributed to the difference. In general, our study provides evidence that the MEWS is an efficient system for in-hospital mortality prediction in an ED.

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Limitations and implications for future research

There are several limitations in our study. First, this was a single-centre observational cohort study at a tertiary hospital in Shenzhen. Patient outcomes may have been affected by the level of care provided by the hospital, and may therefore have also affected the performance of the Modified Early Warning Score for in-hospital mortality prediction. Second, the population included in this study was selected according to triage criteria that were only published in Shenzhen. Therefore, our study results may not be generalisable to other settings. Third, we evaluated the MEWS only once, on patient admission. Dynamic changes in the score could not be observed during patient hospitalisation. Hence, we could not exclude the possibility that re-evaluation of this clinical score during hospitalisation may have improved or reduced the MEWS performance in this setting. In future, a multicentre study should be conducted to reduce the effect of the sample size not being representative. On the contrary, due to the varied performance of MEWS in different studies, research on specific diseases is also required, in order for the use of MEWS to be more accurate. While the actual number of enrolled subjects was 383 (higher than the required sample size of 319), there were 133 patients excluded in the analysis due to missing data resulting in potential selection bias. Thus, future research should implement strategies to minimise missing data on patient report forms.

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CONCLUSION

This study found that MEWS was an accurate score for predicting in-hospital mortality and admission to ICU in a Chinese emergency department. Future multi-centric prospective cohort studies are needed to validate the study findings. As patients with MEWS equal or higher than 4 had higher rates of in-hospital mortality and admission to ICU, calculating MEWS may be an important indicator for closely monitoring patients, requesting immediately contacting doctor-in-charge, and establishing a rapid response intervention team. In this studied hospital, the triage system in the ED has already added MEWS as one of vital parameter monitors, and designed an algorithm in the triage system which can calculate MEWS automatically.

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Competing interests None declared.

Ethical approval The study was approved by the ethical committee of the Second People's Hospital of Shenzhen.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement We are glad to share data collected in this study upon request from the corresponding author.

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Table 1 Baseline characteristics between groups MEWS<4 and MEWS≥4

Characteristics	All (n, %) n=383	MEWS<4 n=225	MEWS≥4 n=158	*P* value
Age (Mean, SD)	59.6(18.3)	57.9(16.9)	62.1(19.9)	0.008
Gender				0.43
Male	255(66.6)	159 (70.7)	96 (60.8)	
Female	128 (33.4)	66 (29.3)	62 (39.2)	
Ethnicity				0.525
Han	376 (98.2)	222 (98.7)	154 (97.5)	
Hui	1 (0.2)	0 (0.0)	1 (0.6)	
Manchu	6 (1.6)	3 (1.3)	3 (1.9)	
Means of arrival				0.009
Walking	123 (32.1)	86 (38.2)	37 (23.4)	
Wheelchair	8 (2.1)	4 (1.8)	4 (2.5)	
Ambulance	252 (66.8)	135 (60.0)	117 (74.1)	
Triage				<0.001
Discharged from ED	38 (9.9)	31 (13.8)	7 (4.4)	
Observation room	51 (13.3)	39 (17.3)	12 (7.6)	
Ward admission	201 (52.5)	126 (56.0)	75 (47.5)	
ICU admission	83 (21.7)	28 (12.4)	55 (34.8)	
Died in ED	10 (2.6)	1 (0.5)	9 (5.7)	
Disease types				0.003
Respiratory system	54 (14.1)	19 (8.4)	35 (22.2)	
Digestive system	36 (9.4)	23 (10.2)	13 (8.2)	
Cardiovascular system	82 (21.4)	50 (22.2)	32 (20.3)	
Nervous system	99 (25.8)	69 (30.7)	30 (19.0)	
Hematological system	3 (0.8)	3 (1.3)	0 (0.0)	
Endocrinologic, metabolism	3 (0.8)	3 (1.3)	0 (0.0)	
Urinary system	15 (3.9)	7 (3.1)	8 (5.1)	
Trauma	28 (7.3)	17 (7.56)	11 (7.0)	
Others	63 (16.5)	34 (15.1)	29 (18.4)	

Abbreviations: SD, standard deviation; ED, emergency department; ICU, intensive care unit.

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Table 2 Comparison of clinical parameters between patients MEWS <4 and MEWS≥4

Parameters	All (n, %) n=383	MEWS<4 n=225	MEWS≥4 n=158	P value
Age (Mean, SD)	59.6 (18.3)	57.9 (16.9)	62.1 (19.9)	0.008
Gender				0.430
Male	255 (66.6)	159 (70.7)	96 (60.8)	
Female	128 (33.4)	66 (29.3)	62 (39.2)	
Physiology (Mean, SD)				
Temperature (℃)	37.2 (1.0)	36.9 (0.6)	37.6 (1.2)	<0.001
SBP (mmHg)	136.6 (33.6)	140.9 (29.6)	130.3 (37.9)	0.001
DBP (mmHg)	80.3 (21.1)	82.8 (18.4)	76.80 (24.0)	0.002
Heart rate (bpm)	95.2 (30.8)	80.7 (15.4)	116.0 (35.0)	<0.001
Respiratory rate (bpm)	23.1 (6.3)	20.7 (3.0)	26.6 (7.9)	<0.001
SPO2 median (IQR)	99.0 (4)	99 (2)	98 (5)	<0.001
BS median (IQR)	8.0 (3.4)	8.0 (3.2)	8.2 (3.6)	0.461
LOS median (IQR)	12 (11)	11 (9)	14 (14)	0.068
Mental status				<0.001
Alert	280 (73.1)	193 (85.8)	87 (55.1)	
Reacting to voice	39 (10.1)	21 (9.3)	18 (11.4)	
Reacting to pain	32 (8.4)	10 (4.4)	22 (13.9)	
Unresponsive	32 (8.4)	1 (0.4)	31 (19.6)	
Triage level				<0.001
Level 1	69 (18.0)	8 (3.6)	61 (38.6)	
Level 2	208 (54.3)	119 (52.9)	89 (56.3)	
Level 3	106 (27.7)	98 (43.6)	80 (5.1)	
Survivors	331 (86.4)	218 (96.9)	113 (71.5)	<0.001
Non-survivors	52 (13.6)	7 (3.1)	45 (28.5)	<0.001

Abbreviations: SD, standard deviation; bpm, beats or breaths per minute; BS, blood sugar; DBP, diastolic blood pressure; IQR, interquartile range, LOS, length of stay, SBP, systolic blood pressure; SPO, percutaneous oxygen saturation.

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Table 3 Association of MEWS with in-hospital mortality, admission to ICU, and predicting admission to general ward unit or discharge from hospital

MEWS	Model 1 OR (95% CI) *P*	Model 2 OR (95% CI) *P*
In-hospital mortality	1.66 (1.45, 1.90) <0.001	1.65 (1.44, 1.89) <0.001
Admission to ICU	1.52 (1.37, 1.69) <0.001	1.54 (1.39, 1.72) <0.001
Predicting admission to general ward unit or discharge from hospital	1.54 (1.27, 1.86) <0.001	1.55 (1.28, 1.89) <0.001

Abbreviation: CI, confidence intervals; ICU, intensive care unit; OR, odds ratios.
Model 1, original model; Model 2 with adjustment for age and gender. Presented as OR with 95% CI (MEWS≥4, and MEWS <4 as reference).

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Figure 1 The flow chart of study procedure.

Figure 2 The AUC value of MEWS for predicting the in-hospital mortality.

Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 3 The AUC value of MEWS for predicting admission to Intensive Care Unit.

Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 4 The AUC value of MEWS for predicting admission to general ward unit or discharge from hospital. Blue shading shows the bootstrap estimated 95% CI with AUC.

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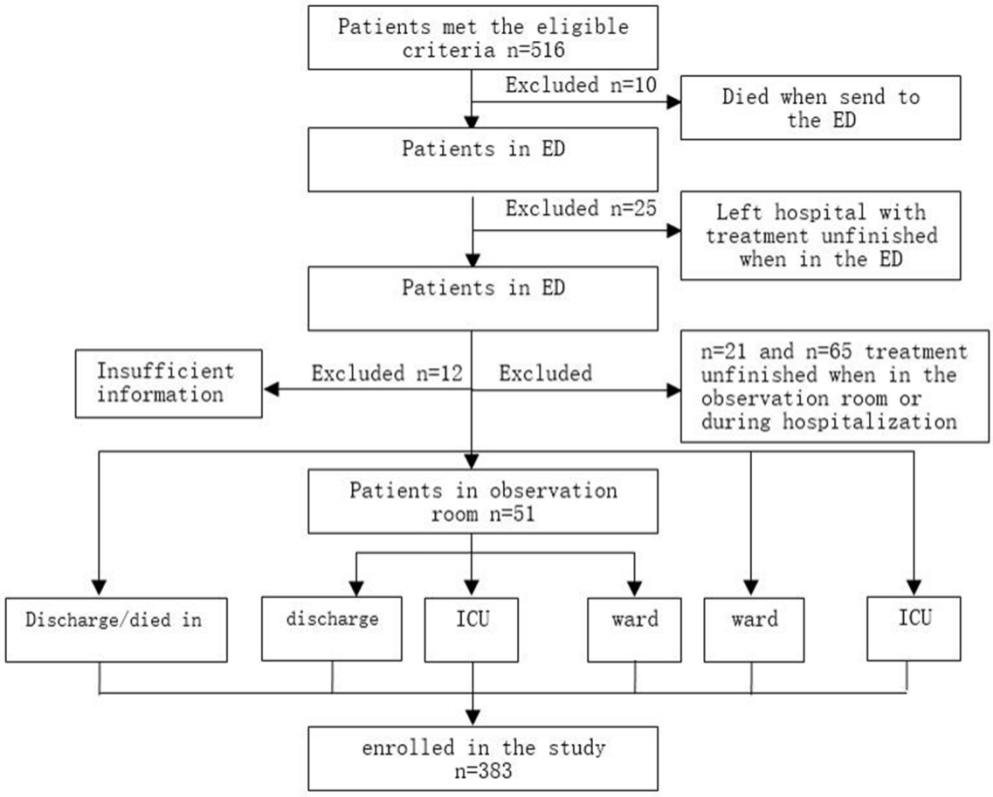

Figure 1 The flow chart of study procedure

Figure 1

204x177mm (300 x 300 DPI)

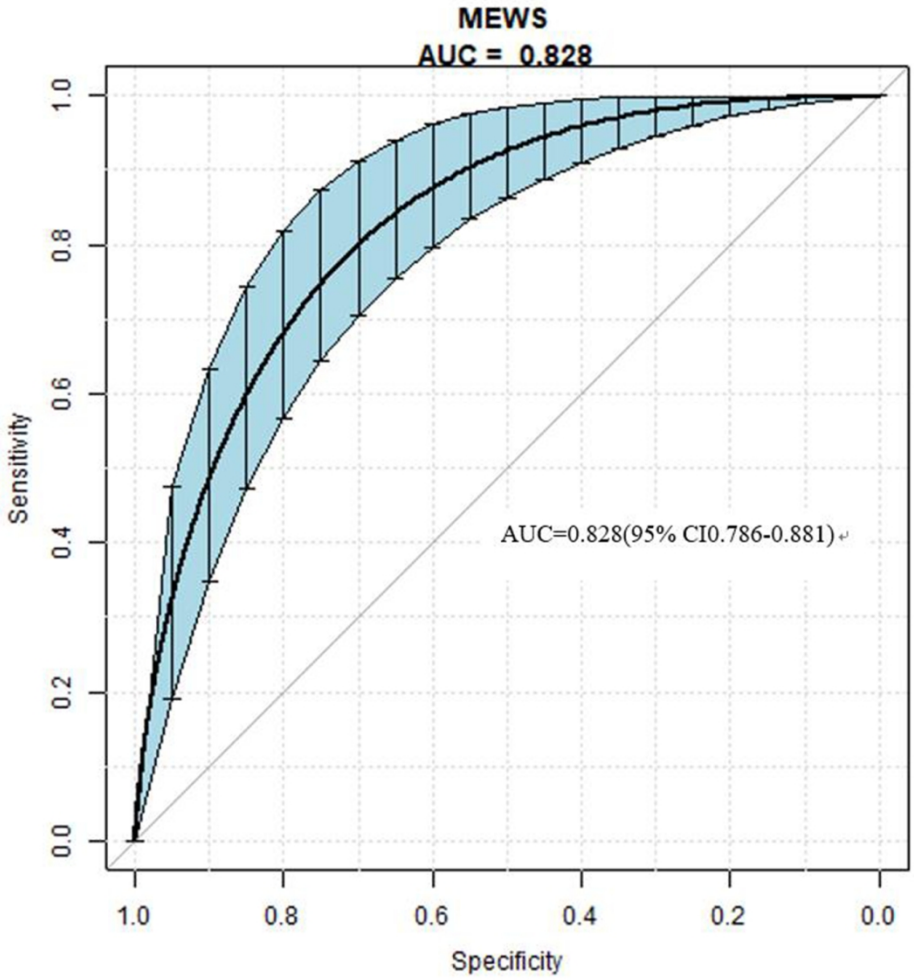

Figure 2 The AUC value of MEWS for predicting the in-hospital mortality

Blue shading shows the bootstrap estimated 95% CI with the AUC.

Figure

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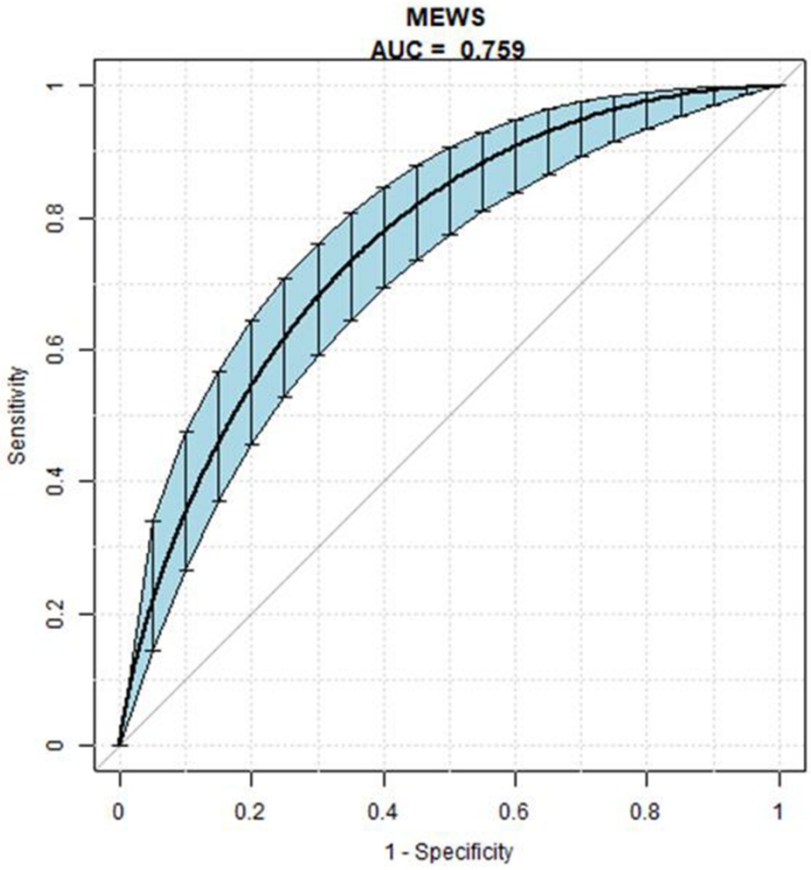

Figure 3 The AUC value of MEWS for predicting admission to Intensive Care Unit
Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 3

181x178mm (300 x 300 DPI)

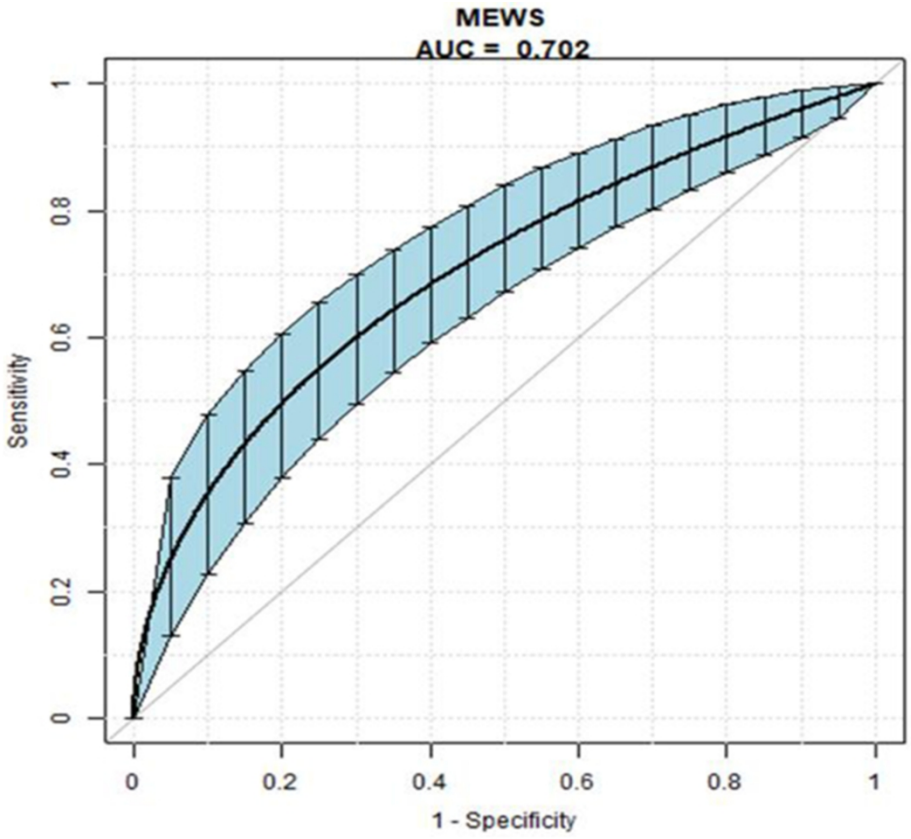

Figure 4 The AUC value of MEWS for predicting admission to general ward unit or discharged from hospital
Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 4

268x244mm (300 x 300 DPI)

Appendix 1 The Modified Early Warning Score

Parameters	3	2	1	0	1	2	3
Respiratory rate (bpm)	—	<9	—	9-14	15-20	21-29	≥30
Heart rate (bpm)	—	<40	41-50	51-100	101-111	112-129	≥130
Systolic blood pressure (mmHg)	<70	71-80	81-100	101-199	—	≥200	—
AVPU score	—	—	—	Alert	Reacting to voice	Reacting to pain	Unresponsive
Temperature (^{0}C)	—	<35.0	—	35-38.4	—	≥38.5	—

AVPU, A: alert, V: Reacting to voice, P: Reacting to pain, U: unresponsive; bpm, beats or breaths per minute.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *observational studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	P6
Methods			
Study design	4	Present key elements of study design early in the paper	P7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	P7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P8-9
Bias	9	Describe any efforts to address potential sources of bias	P10
Study size	10	Explain how the study size was arrived at	P7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P8-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P9-10
		(*b*) Describe any methods used to examine subgroups and interactions	P9-10
		(*c*) Explain how missing data were addressed	P9-10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	P9-10
		(*e*) Describe any sensitivity analyses	P9-10
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P7
		(b) Give reasons for non-participation at each stage	P25-Figure1
		(c) Consider use of a flow diagram	P25-Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P21-Table 1
		(b) Indicate number of participants with missing data for each variable of interest	P10
Outcome data	15*	Report numbers of outcome events or summary measures	P10-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	P10-11
		(*b*) Report category boundaries when continuous variables were categorized	P10-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	P10-11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	P10-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	P12-13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	P12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Keywords:	("Modified Early Warning Score") OR "MEWS", ("Emergency") AND "triage", Emergency department

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Title: Prognostic value of Modified Early Warning Score generated in a Chinese emergency department: A prospective cohort study

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ABSTRACT

Objectives This study aimed to validate the performance of the Modified Early Warning Score (MEWS) in a Chinese emergency department, and to determine the best cut-off value for in-hospital mortality prediction.

Design A prospective, single-centred observational cohort study.

Setting This study was conducted at a tertiary hospital in South China.

Participants A total of 383 patients, ages 18 years or older who presented to the emergency department from May 17, 2017 through September 27, 2017, triaged as Category 1, 2, or 3, were enrolled.

Outcomes The primary outcome was a composite of in-hospital mortality and admission to the intensive care unit. The secondary outcome was using MEWS to predict hospitalised and discharged patients.

Results A total of 383 patients were included in this study. In-hospital mortality was 13.6% (52/383), and transfer to the ICU was 21.7% (83/383). The area under the ROC curve of MEWS for in-hospital mortality prediction was 0.83 (95% CI: 0.786, 0.881). When predicting in-hospital mortality with the cut-off point defined as 3.5, 158 patients had MEWS>3.5, with a specificity of 66%, a sensitivity of 87%, accuracy of 69%, a positive predictive value of 28%, and a negative predictive value of 97%, respectively.

Conclusion Our findings support the use of MEWS for in-hospital mortality prediction in patients who were triaged Category 1, 2, or 3 in a Chinese emergency department. The cut-off value for

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in-hospital mortality prediction defined in this study was different from that seen in many other studies.

Keywords: Modified Early Warning Score; Triage; In-hospital mortality; Emergency department

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Study strengths and limitations

- This prospective observational study was carried out according to workflow, which is the most cost-effective option, and reduces difficulty in data collection.
- This study used a prospective study design and provided a new cut-off point for the MEWS using ROC curve analysis to increase sensitivity in predicting in-hospital mortality.
- This study evaluated the MEWS only once, on patient admission, which means that dynamic changes in the score could not be observed during patient hospitalisation.
- This prospective cohort study recruited participants at a single medical centre, which could limit the generalisability of the study findings.

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INTRODUCTION

Different kinds of triage systems have been developed worldwide to assess the illness severity of patients presenting to emergency departments (ED) who are assigned treatment priorities.[1,2] In China, there is a lack of a unified triage standard to manage patients when they present to the emergency department.[3] The triage standard used in hospitals in Shenzhen is a new four-level Chinese emergency triage criteria, published by the Public Hospital Administration of Shenzhen Municipality in August, 2013.[3] It categorises patients as near death (Level 1), critically ill (Level 2), acute (Level 3), and not acute (Level 4), requiring treatment immediately, in 10 minutes, in 30 minutes, and in four hours, respectively. This is mainly decided according to patients' presenting complaints and questions about potentially aggravating factors. According to acuity, Level 1, Level 2, and Level 3 are urgent patients with a higher risk of serious adverse events, such as hospital admission and mortality, compared to Level 4, which describes non-urgent patients. [4,5]

Therefore, an excellent scoring system is urgently required for mortality predictions in patients admitted to the ED. Today, there are a number of scoring systems designed to predict the chances of hospitalisation, intensive care unit (ICU) admission, or in-hospital mortality in emergency department ED patients.[6,7] The VitalPac Early Warning Score (VIEWS), Modified Early Warning Score (MEWS), Rapid Emergency Medicine Score (REMS), Emergency Department Sepsis Score (MEDS), and Rapid Acute Physiology Score are the most commonly employed systems for bedside evaluation.[8-12]

MEWS was introduced in 2001 by Subbe and colleagues,[13] who modified it from the Early Warning Score (EWS). The MEWS is a simple physiological scoring system, which includes five physiological parameters - systolic blood pressure, pulse rate, respiratory rate, temperature, and

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level of consciousness - that can easily be collected at the moment of presentation. The MEWS is widely used in wards, the ICU, and emergency departments to detect the clinical deterioration of patients or to predict clinical outcomes.[6,7,13]

A large number of studies have reported that MEWS is an effective tool for in-hospital mortality prediction.[14-17] However, there have also been studies conducted on different populations or in different areas reporting that MEWS is not an adequate scoring system for predicting in-hospital mortality.[18,19] Moreover, the MEWS cut-off value (for in-hospital mortality prediction reported in studies) varies.[9,10,15,20-22] A study conducted on 518 patients in ICU indicated that patients with MEWS≥6 had significantly higher mortality than those with a MEWS<6.[22] However, another study, which examined the performance of MEWS in assessing non-traumatic critical patients in an emergency department, showed the MEWS cut-off value was 3.[15] Therefore, this study hypothesises that MEWS performance and cut-off value may differ according to the specific population.

The MEWS is also used to evaluate patient conditions in Chinese emergency departments, including focusing on the relationship between factors and clinical outcomes, using pre-hospital MEWS to identify non-trauma patients requiring life-saving intervention, and risk stratification of patients before inter-facility transport.[23-25] However, information on MEWS validation is limited to in-hospital mortality predictions in patients triaged as Level 1, 2, or 3 in Chinese emergency departments. Hence, the aim of this study was to evaluate MEWS performance in predicting in-hospital mortality of the population in a Chinese emergency treatment room, and to find the best cut-off value.

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METHODS

Study design

A prospective, single-centred observational cohort study was conducted in the ED of a tertiary hospital in Shenzhen, China to evaluate the ability of the MEWS to predict in-hospital mortality in patients presenting to the emergency treatment room who were categorised Level 1, 2, or 3. The study was approved by the hospital ethics committee.

Study population

The study was carried out at the tertiary hospital, the First Affiliated Hospital of Shenzhen University, which saw 173,000 ED presentations in 2017. Of the 173,000 ED presentations, approximately 6,600 patients were admitted to the emergency treatment room. Data of patients presenting to the emergency treatment room between May 17, 2017 and September 27, 2017 were collected. Eligibility criteria: patients ages 18 years or older triaged as Category 1, 2, and 3 were included in the study. Exclusion criteria: Patients who had died prior to arrival in the ED, and patients who needed ward admission, ICU admission, or rescue according to the doctor's judgment, or who ignored the doctor’s advice and left the hospital due to a variety of reasons, were excluded from the study. Patients with insufficient information were also excluded.

Sample size calculation

This study calculated sample size using G*Power 3.1.9.2 (http://www.softpedia.com/get/Science-CAD/G-Power.shtml). The estimated sample size was 319 with an accuracy index of 0.95, a marginal error of 0.05 with 95% confidence level and 80% power.

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Participant involvement and data collection

Patients who presented to our ED were evaluated and triaged by the triage nurse, who had more than five years of experience. Patients were triaged to near death (Level 1), critically ill (Level 2), acute (Level 3) and not acute (Level 4). This is decided according to the triage guidelines and the judgment of the triage nurse. According to acuity, patients triaged to Levels 1 and 2 were sent to the emergency treatment room; patients triaged to Level 3 were given priority in the consulting room or sent to the emergency treatment room if the triage nurse judged the patient's condition to be serious; and patients triaged to Level 4 were sent to wait outside the consulting room.

Physiological parameters were measured by nurses and researchers at the time of admittance to the emergency treatment room. Respiratory rate was counted manually for more than a full minute; heart rate and blood pressure were measured using an automatic electronic sphygmomanometer (HBP-9020) or multifunctional ECG monitor (PHILPS Jin Kewei, G30). Body temperature was measured using an infrared ear thermometer (Pr04000). The level of consciousness was recorded as the best response to the AVPU score (A for alert, V for reacting to vocal stimulus, P for reacting to pain and U for unresponsive). Patient information was recorded using a questionnaire designed by the researchers. The following information was included: age, gender, nationality, educational background, mode of transportation to hospital, disease type, main diagnosis, body temperature, systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate, peripheral oxygen saturation, and the AVPU (A: alert, V: voice, P: pain, and U: unresponsive) score, triage level, MEWS score (Appendix 1), and mortality.

The patients were followed up by the researcher until discharge, death, or for a maximum of 90 days. The researchers calculated the MEWS using patients' five recorded physiological parameters.

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In-hospital mortality was the main outcome. The predictive accuracy of the MEWS was evaluated by the Receiver Operating Characteristic (ROC) curve. Sensitivity, specificity, accuracy, and positive and negative predictive value (PPV and NPV) were analysed to indicate the predictive power of the scoring system. The patients were divided into two groups: MEWS＜4 and MEWS≥4. The intergroup differences in the baseline characteristic physiological parameters and the scores between the two groups were also evaluated.

Outcomes

The primary outcome was a composite of in-hospital mortality and admission to the ICU. The secondary outcome of this study was using MEWS to predict admission to the general ward unit or discharge from hospital.

Ethics statement

This study was approved by the medical ethical committee of the Second People's Hospital of Shenzhen (No. 20141201005). Written informed consent was obtained from research participants or patients' legal agents.

Statistical analysis

Descriptive statistics were tabulated for the overall sample. Mean and standard deviation were calculated for continuous variables, and frequencies and percentages for all other categorical variables. Data distribution of each variable between the MEWS <4 and the MEWS≥4 groups was compared. In addition, the area under the receiver operating characteristic curve (AUC) was measured to evaluate the predictive ability of the MEWS. Finally, sensitivity, specificity, accuracy, positive and negative predictive values (PPV and NPV) were also analysed. Regression analysis

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was used to address confounding variables of age and gender. P <0.05 was regarded as statistically significant. EPidata 3.1 was used for data entry, and then exported to tab-delimited text files. All analyses were performed using R (http://www.R-project.org) and EmpowerStats software (www.empowerstats.com, X&Y Solutions, Inc. Boston MA).

RESULTS

A total of 516 patients met the eligibility criteria, with 133 patients excluded. Among the patients who were excluded from the study, 10 had already died when they were sent to the ED, while 46 patients in the ED ignored the advice of doctors and left the hospital, due to a variety of reasons. Another 65 patients left the hospital after being admitted to the ward or ICU. Twelve patients were excluded due to insufficient information (Figure 1). Ultimately, 383 patients were enrolled in the study. Of that total, 255 (66.6%) patients were male; the mean age of all patients was 59.6±18.3 years, and the ethnicity of the majority of patients was Han Chinese (98.2%). Among the 383 patients, 52.5% and 21.7% were admitted to the ward and ICU from the ED, respectively. Nervous system, cardiovascular, and respiratory diseases were the three most common disease types seen in these patients, consisting of more than half of the population. In the baseline characteristics between groups MEWS <4 and MEWS ≥4, a number of baseline characteristics showed significant differences, with P <0.05. Detailed patient baseline characteristics are shown in Table 1.

The patients were divided into two groups: MEWS ≥4 and MEWS <4. Physiological parameters include body temperature, systolic blood pressure, diastolic blood pressure, heart rate, respiratory rate, percutaneous oxygen saturation and mental status, which were different between the two groups, and the difference was statistically significant. However, between the two groups, there

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were no differences in terms of blood sugar and length of stay. In addition, a total of 277 critically ill patients were triaged as Level 1 and Level 2, requiring treatment within 10 minutes. There were more critically ill patients in the MEWS ≥4 group than in the MEWS <4 group (150/158 VS. 127/225, P <0.001). The proportion of in-hospital mortality was 13.6% (52/383), with most of these patients in the MEWS ≥4 group (7/52 versus 45/52, P <0.001). Detailed physiological parameters of the two groups are outlined in Table 2.

The MEWS in-hospital mortality predictive ability is shown by area under the Receiver Operating Characteristic curve (AUC), at 0.83 (95% CI, 0.786-0.881) (Figure 2). Logistic regression analysis was used to examine the association between MEWS and the primary and secondary outcome measures. As seen in Table 3, the MEWS was significantly associated with in-hospital mortality (odds ratios-OR, 1.65; 95% CI, 1.44-1.89; P < 0.001), admission to ICU (OR, 1.54; 95% CI, 1.39-1.72, P < 0.001), and predicting admission to a general ward unit or discharge from hospital (OR, 1.55; 95% CI, 1.28-1.89, P < 0.001) (Table 3). The MEWS in-hospital mortality, predictive ability of admission to ICU, and predictive ability of admission to a general ward unit or discharge from hospital are shown in Figure 2, Figure 3, and Figure 4, respectively.

DISCUSSION

In this observational cohort study, the MEWS showed good performance for in-hospital mortality prediction with AUC values at 0.83. The higher the score, the higher the ratio of in-hospital mortality, indicating that MEWS was significantly correlated with patient mortality. In patients with MEWS ≥4, compared with MEWS <4, a number of variables, such as age, triage level, vital signs, means of arrival, and disease type, are influencing factors of death in ED patients. The study

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demonstrated that MEWS is an effective tool for in-hospital mortality prediction for ED patients who triage to Levels 1, 2, and 3.

MEWS is a widely used scoring system in many countries, but differences between these studies, including study setting, population, and disease type, has led to differences in the predictive ability of the MEWS. The AUC, specificity, and sensitivity were the most common indexes reported in studies on MEWS performance.[17,20,26,27] A large proportion of studies have reported that MEWS is an effective tool for mortality prediction, with AUC ranging from approximately 0.70-0.89 for the most frequently used threshold (MEWS=5), and specificity and sensitivity ranging from 0.67-0.72, 0.65-0.71, respectively.[9,17,20,26] However, less information was provided on the accuracy, positive predictive value, and negative predictive value of the score. In a single-centre observational cohort study conducted at an urban tertiary care medical centre in Chicago, adult patients who were suspected of contracting an infection in a hospital ward or emergency department (ED) were included.[20] Discrimination for in-hospital mortality was moderate with MEWS AUC 0.73 (95% CI, 0.71-0.74).

Furthermore, there are also studies demonstrating that MEWS is not an efficient system for mortality prediction with an approximate AUC of less than 0.6, with study populations that included septic patients admitted to medical wards, surgical patients presenting to emergency departments, and adults admitted to medical wards, respectively.[9,17,22] This study showed that disease and population differences seem to strongly determine MEWS performance. However, MEWS performance in ED patients who were triaged as Level 1, 2, or 3 had previously not been validated. Our study found that mortality prediction for the MEWS is good (AUC, 0.83; 95% CI, 0.79-0.88).

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When combined with sensitivity and specificity, the maximum was defined as the best threshold. In this study, in order to increase the proportion of in-hospital mortality prediction and reduce missed diagnoses, sensitivity is more important than specificity. When the threshold was 4, the specificity, accuracy, and NPV improved at the cost of sensitivity and PPV, and the number of deaths due to missed diagnosis increased from 6 to 16. Hence, this study defined the MEWS cut-off point as 4, which was different from a previous prospective study, whose MEWS cut-off point was defined as 3.[15] However, the MEWS cut-off point defined as 3 in this study was different from that of many other studies, whose MEWS cut-off point was defined as 5 or higher.[10,20-22] For the baseline characteristics of patients in this study, respiratory system diseases, digestive system diseases, circulatory system diseases, and nervous system diseases were found in 70.7% of the population and 67.3% of non-survivors, with the median (IQR) MEWS at 3 (3). Different kinds of diseases and populations may have contributed to the difference. In general, our study provides evidence that the MEWS is an efficient system for in-hospital mortality prediction in an ED.

Limitations and implications for future research

There are several limitations in our study. First, this was a single-centre observational cohort study at a tertiary hospital in Shenzhen. Patient outcomes may have been affected by the level of care provided by the hospital, and may therefore have also affected the performance of the Modified Early Warning Score for in-hospital mortality prediction. Second, the population included in this study was selected according to triage criteria that were only published in Shenzhen. Therefore, our study results may not be generalisable to other settings. Third, we evaluated the MEWS only once, on patient admission. Dynamic changes in the score could not be observed during patient

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hospitalisation. Hence, we could not exclude the possibility that re-evaluation of this clinical score during hospitalisation may have improved or reduced the MEWS performance in this setting. In future, a multicentre study should be conducted, to reduce the effect of the sample size not being representative. In addition, due to the varied performance of MEWS in other studies, research on specific diseases is also required, in order for the use of MEWS to be more accurate. While the actual number of enrolled subjects was 383 (higher than the required sample size of 319), we excluded 133 patients in the analysis due to missing data, resulting in potential selection bias. Thus, future research should implement strategies to minimise missing data in patient report forms.

CONCLUSION

This study found that MEWS was an accurate score for predicting in-hospital mortality and admission to ICU in a Chinese emergency department. Future multicentric prospective cohort studies are needed to validate the study findings. As patients with MEWS equal to or higher than 4 had higher rates of in-hospital mortality and ICU admission, calculating MEWS may be an important indicator for closely monitoring patients, making an immediate request to contact the doctor-in-charge, and establishing a rapid response intervention team. In this hospital, the ED triage system has already added MEWS as one of the vital parameter monitors, and designed an algorithm in the triage system that can automatically calculate MEWS.

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Competing interests None declared.

Ethical approval The study was approved by the ethical committee of the Second People's Hospital of Shenzhen.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement We are glad to share data collected in this study upon request from the corresponding author.

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Table 1 Baseline characteristics between groups MEWS<4 and MEWS≥4

Characteristics	All (n, %) n=383	MEWS<4 n=225	MEWS≥4 n=158	*P* value
Age (Mean, SD)	59.6(18.3)	57.9(16.9)	62.1(19.9)	0.008
Gender				0.43
Male	255(66.6)	159 (70.7)	96 (60.8)	
Female	128 (33.4)	66 (29.3)	62 (39.2)	
Ethnicity				0.525
Han	376 (98.2)	222 (98.7)	154 (97.5)	
Hui	1 (0.2)	0 (0.0)	1 (0.6)	
Manchu	6 (1.6)	3 (1.3)	3 (1.9)	
Means of arrival				0.009
Walking	123 (32.1)	86 (38.2)	37 (23.4)	
Wheelchair	8 (2.1)	4 (1.8)	4 (2.5)	
Ambulance	252 (66.8)	135 (60.0)	117 (74.1)	
Triage				<0.001
Discharged from ED	38 (9.9)	31 (13.8)	7 (4.4)	
Observation room	51 (13.3)	39 (17.3)	12 (7.6)	
Ward admission	201 (52.5)	126 (56.0)	75 (47.5)	
ICU admission	83 (21.7)	28 (12.4)	55 (34.8)	
Died in ED	10 (2.6)	1 (0.5)	9 (5.7)	
Disease types				0.003
Respiratory system	54 (14.1)	19 (8.4)	35 (22.2)	
Digestive system	36 (9.4)	23 (10.2)	13 (8.2)	
Cardiovascular system	82 (21.4)	50 (22.2)	32 (20.3)	
Nervous system	99 (25.8)	69 (30.7)	30 (19.0)	
Hematological system	3 (0.8)	3 (1.3)	0 (0.0)	
Endocrinologic, metabolism	3 (0.8)	3 (1.3)	0 (0.0)	
Urinary system	15 (3.9)	7 (3.1)	8 (5.1)	
Trauma	28 (7.3)	17 (7.56)	11 (7.0)	
Others	63 (16.5)	34 (15.1)	29 (18.4)	

Abbreviations: SD, standard deviation; ED, emergency department; ICU, intensive care unit.

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Table 2 Comparison of clinical parameters between patients MEWS <4 and MEWS≥4

Parameters	All (n, %) n=383	MEWS<4 n=225	MEWS≥4 n=158	P value
Age (Mean, SD)	59.6 (18.3)	57.9 (16.9)	62.1 (19.9)	0.008
Gender				0.430
Male	255 (66.6)	159 (70.7)	96 (60.8)	
Female	128 (33.4)	66 (29.3)	62 (39.2)	
Physiology (Mean, SD)				
Temperature (℃)	37.2 (1.0)	36.9 (0.6)	37.6 (1.2)	<0.001
SBP (mmHg)	136.6 (33.6)	140.9 (29.6)	130.3 (37.9)	0.001
DBP (mmHg)	80.3 (21.1)	82.8 (18.4)	76.80 (24.0)	0.002
Heart rate (bpm)	95.2 (30.8)	80.7 (15.4)	116.0 (35.0)	<0.001
Respiratory rate (bpm)	23.1 (6.3)	20.7 (3.0)	26.6 (7.9)	<0.001
SPO2 median (IQR)	99.0 (4)	99 (2)	98 (5)	<0.001
BS median (IQR)	8.0 (3.4)	8.0 (3.2)	8.2 (3.6)	0.461
LOS median (IQR)	12 (11)	11 (9)	14 (14)	0.068
Mental status				<0.001
Alert	280 (73.1)	193 (85.8)	87 (55.1)	
Reacting to voice	39 (10.1)	21 (9.3)	18 (11.4)	
Reacting to pain	32 (8.4)	10 (4.4)	22 (13.9)	
Unresponsive	32 (8.4)	1 (0.4)	31 (19.6)	
Triage level				<0.001
Level 1	69 (18.0)	8 (3.6)	61 (38.6)	
Level 2	208 (54.3)	119 (52.9)	89 (56.3)	
Level 3	106 (27.7)	98 (43.6)	80 (5.1)	
Survivors	331 (86.4)	218 (96.9)	113 (71.5)	<0.001
Non-survivors	52 (13.6)	7 (3.1)	45 (28.5)	<0.001

Abbreviations: SD, standard deviation; bpm, beats or breaths per minute; BS, blood sugar; DBP, diastolic blood pressure; IQR, interquartile range, LOS, length of stay, SBP, systolic blood pressure; SPO, percutaneous oxygen saturation.

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Table 3 Association of MEWS with in-hospital mortality, admission to ICU, and predicting admission to general ward unit or discharge from hospital

MEWS	Model 1 OR (95% CI) *P*	Model 2 OR (95% CI) *P*
In-hospital mortality	1.66 (1.45, 1.90) <0.001	1.65 (1.44, 1.89) <0.001
Admission to ICU	1.52 (1.37, 1.69) <0.001	1.54 (1.39, 1.72) <0.001
Predicting admission to general ward unit or discharge from hospital	1.54 (1.27, 1.86) <0.001	1.55 (1.28, 1.89) <0.001

Abbreviation: CI, confidence intervals; ICU, intensive care unit; OR, odds ratios.
Model 1, original model; Model 2 with adjustment for age and gender. Presented as OR with 95% CI (MEWS≥4, and MEWS <4 as reference).

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Figure 1 The flow chart of study procedure.

Figure 2 The AUC value of MEWS for predicting the in-hospital mortality. Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 3 The AUC value of MEWS for predicting admission to Intensive Care Unit. Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 4 The AUC value of MEWS for predicting admission to general ward unit or discharge from hospital. Blue shading shows the bootstrap estimated 95% CI with AUC.

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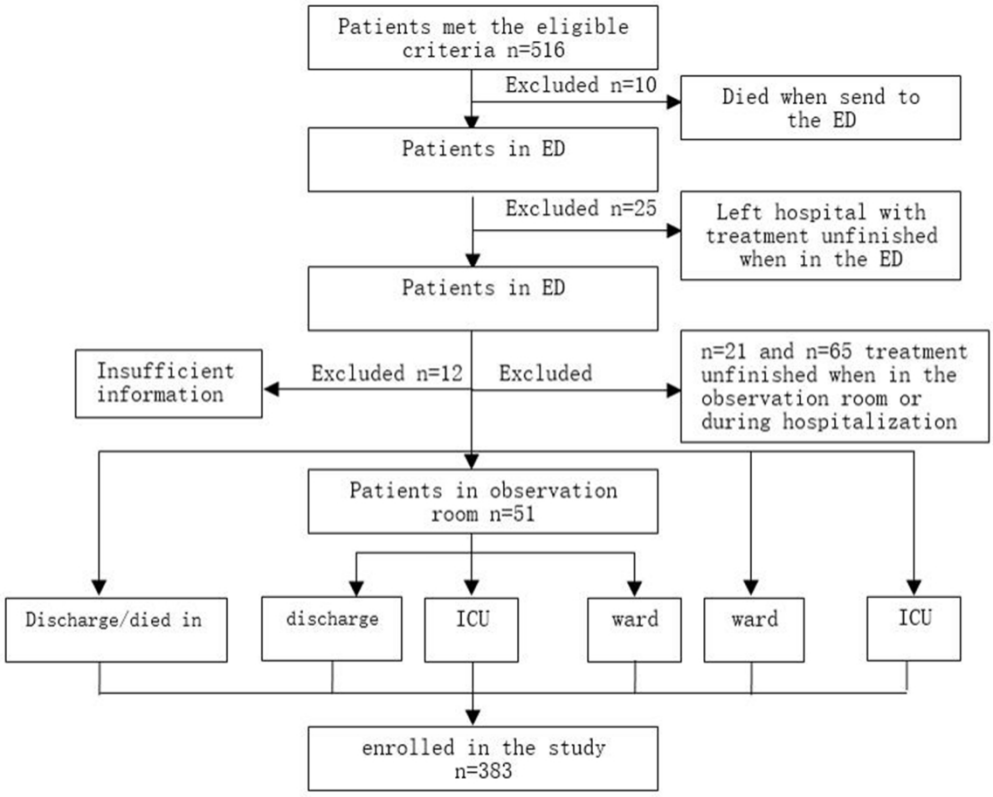

Figure 1 The flow chart of study procedure

Figure 1

204x177mm (300 x 300 DPI)

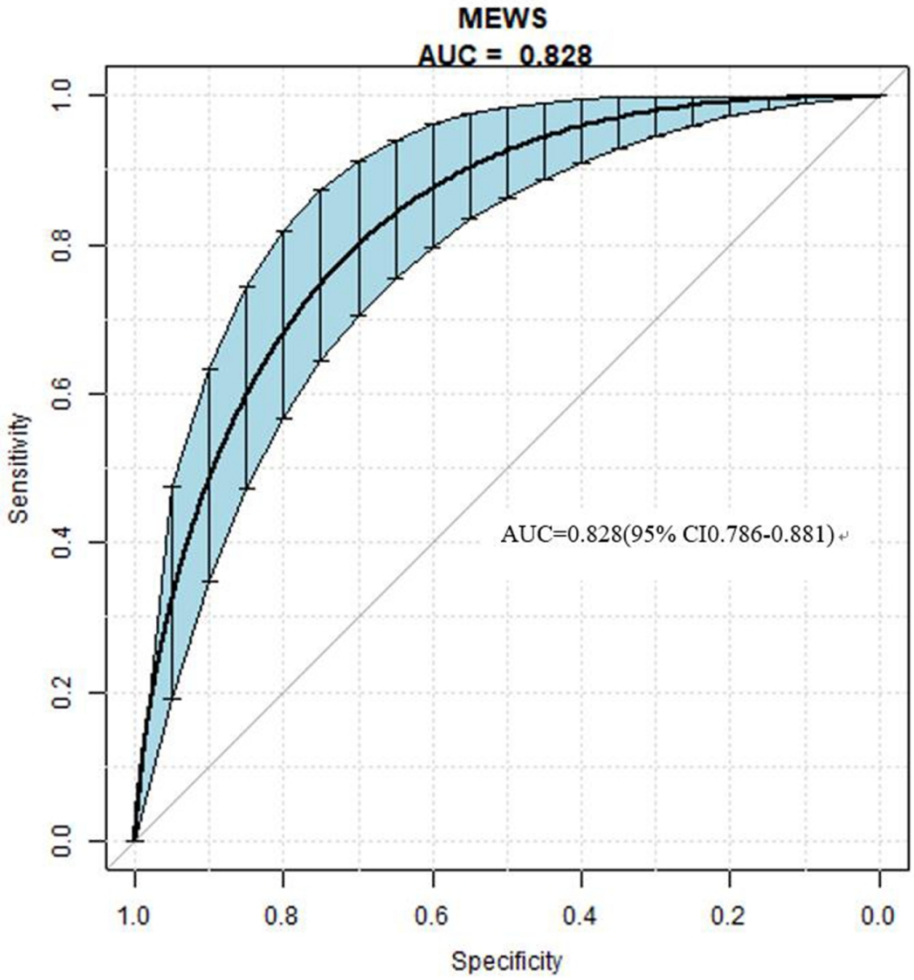

Figure 2 The AUC value of MEWS for predicting the in-hospital mortality

Blue shading shows the bootstrap estimated 95% CI with the AUC.

Figure

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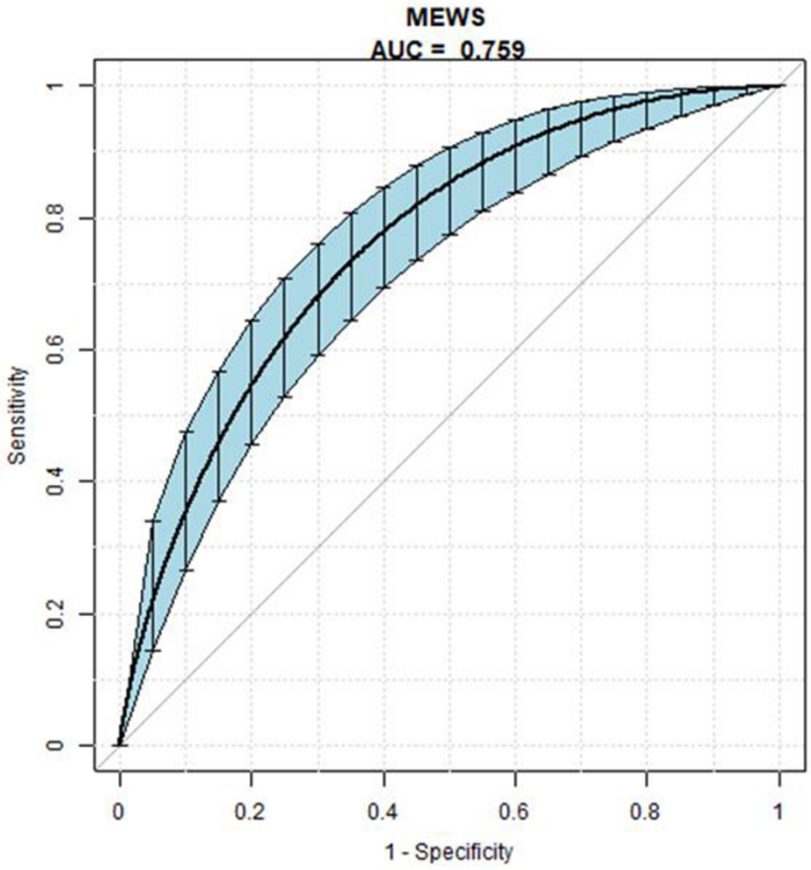

Figure 3 The AUC value of MEWS for predicting admission to Intensive Care Unit
Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 3

181x178mm (300 x 300 DPI)

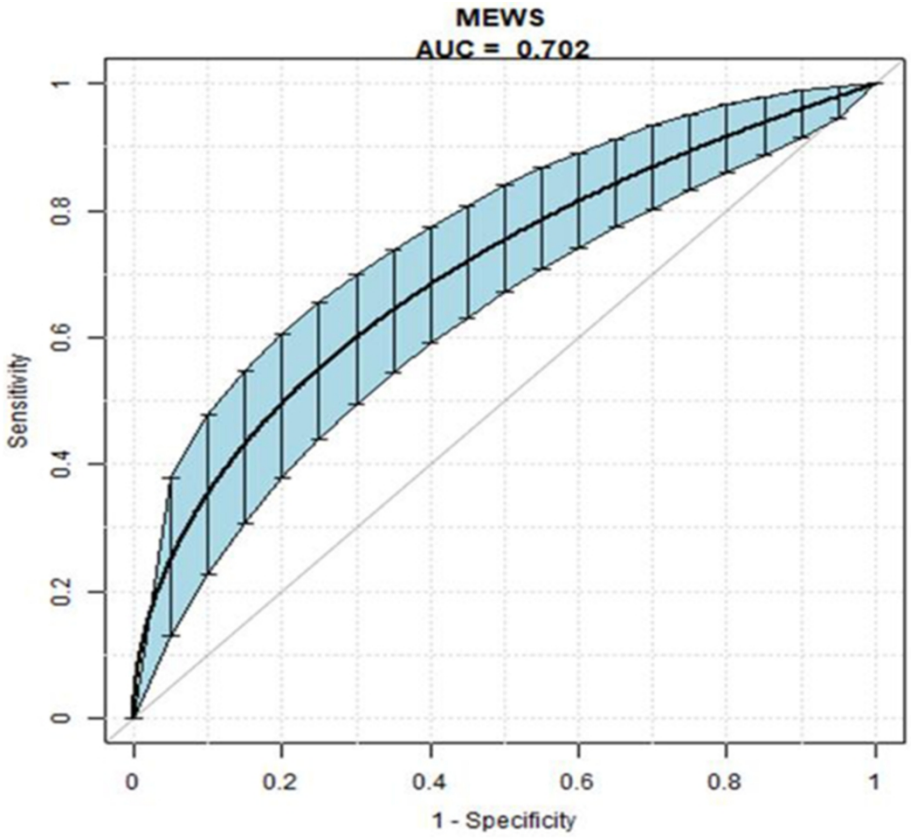

Figure 4 The AUC value of MEWS for predicting admission to general ward unit or discharged from hospital
Blue shading shows the bootstrap estimated 95% CI with AUC.

Figure 4

268x244mm (300 x 300 DPI)

Appendix 1 The Modified Early Warning Score

Parameters	3	2	1	0	1	2	3
Respiratory rate (bpm)	—	<9	—	9-14	15-20	21-29	≥30
Heart rate (bpm)	—	<40	41-50	51-100	101-111	112-129	≥130
Systolic blood pressure (mmHg)	<70	71-80	81-100	101-199	—	≥200	—
AVPU score	—	—	—	Alert	Reacting to voice	Reacting to pain	Unresponsive
Temperature (^{0}C)	—	<35.0	—	35-38.4	—	≥38.5	—

AVPU, A: alert, V: Reacting to voice, P: Reacting to pain, U: unresponsive; bpm, beats or breaths per minute.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *observational studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	P6
Methods			
Study design	4	Present key elements of study design early in the paper	P7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	P7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P8-9
Bias	9	Describe any efforts to address potential sources of bias	P10
Study size	10	Explain how the study size was arrived at	P7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P8-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P9-10
		(*b*) Describe any methods used to examine subgroups and interactions	P9-10
		(*c*) Explain how missing data were addressed	P9-10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	P9-10
		(*e*) Describe any sensitivity analyses	P9-10
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P7
		(b) Give reasons for non-participation at each stage	P25-Figure1
		(c) Consider use of a flow diagram	P25-Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P21-Table 1
		(b) Indicate number of participants with missing data for each variable of interest	P10
Outcome data	15*	Report numbers of outcome events or summary measures	P10-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	P10-11
		(*b*) Report category boundaries when continuous variables were categorized	P10-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	P10-11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	P10-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	P12-13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	P12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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