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Original Article

Ability of Early Warning Scores to Predict In-Hospital Mortality among Elderly Patients with COVID-19: A Medical Center Study in Taiwan

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SUMMARY

Background: During the coronavirus disease 2019 (COVID-19) pandemic, early warning scores (EWS) have been used to help emergency physicians with triage. This study aimed to evaluate the three most used EWSs: Rapid Emergency Medicine Score (REMS), Modified Early Warning Score (MEWS), and National Early Warning Score (NEWS), based on the in-hospital mortality of geriatric patients with COVID-19.
Methods: This retrospective, single-center study included geriatric patients hospitalized for COVID-19 from May 2021 to July 2021 at the MacKay Memorial Hospital. Patients who (i) presented with out-of-hospital cardiac arrest (OHCA), (ii) were transferred from other hospitals, and (iii) had missing demographic data were excluded. The area under the receiver operating characteristic curve (AUC) was calculated to predict the in-hospital mortality rate associated with each EWS.
Results: The study included 135 patients, of whom 24 (17.8%) died. The median age of the included patients was 74.44 years, and 53% of them were men. Of the selected EWSs, MEWS (AUC = 0.761) exhibited the highest prognostic value, with a cutoff value of 3.5. Furthermore, NEWS (AUC = 0.758) and REMS (AUC = 0.736) exhibited good prognostic value.
Conclusion: We validated the three most used EWSs, and MEWS performed well in predicting the in-hospital mortality of geriatric patients with COVID-19 using basic parameters.

1. Introduction

The World Health Organization declared the coronavirus disease 2019 (COVID-19) a global pandemic in March 2020. As of October 2022, an estimated 640 million individuals have experienced COVID-19 infections, and > 6.6 million have died due to this disease. During the height of the pandemic, the excessive influx of patients resulted in a heavy burden on emergency departments (EDs) worldwide. The decision of whether patients should be admitted for treatment or discharged from the ED became a major issue. Moreover, geriatric patients with COVID-19 are reportedly more vulnerable than younger patients.[1] Hence, established early warning scores (EWSs) were employed to identify geriatric patients with COVID-19 who were at risk of deterioration for timely medical intervention.

The concept of EWS can be traced back to the 1990s when physicians determined that early changes in the vital signs of patients could predict clinical decline ensuing after 24 h.[2,3] These vital signs, including the Glasgow Coma Scale (GCS), body temperature, heart rate, blood pressure, respiratory rate, and oxygen saturation levels (SpO_2), are essential evaluation parameters of patients and are initially measured at ED triage at the time patients present. The Modified Early Warning Score (MEWS), which was introduced by Subbe et al., has been widely applied in the United Kingdom and United States.[4] The MEWS was further developed into the National Early Warning Score (NEWS).[5] The Rapid Emergency Medicine Score (REMS), which was revised from another EWS known as the Rapid Acute Physiology Score, was reportedly better than the previous tool.[6] Notably, there are various EWS with different degrees of utility and success; however, the aforementioned three were the most used.

MacKay Memorial Hospital is a tertiary hospital with an annual ED visit of > 130,000 patients in the populated city of Taipei. Since the COVID-19 outbreak, various infection control policies, such as screening units and quarantine wards, have been established.[7–12] The Hospital was converted to a COVID-19–designated hospital during the pandemic.

This study aimed to evaluate the performance of REMS, MEWS, and NEWS in predicting the in-hospital mortality of geriatric patients with COVID-19 admitted to the MacKay Memorial Hospital.

2. Patients and methods

2.1. Study design

We conducted a retrospective study in the ED of a COVID-19–

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designated medical center in Taiwan. This study was conducted according to the transparent reporting of a multivariable prediction model for Individual Prognosis or Diagnosis (TRIPOD) guidelines.[13]

2.2. Study population

We enrolled geriatric patients with COVID-19 who presented to the ED and were hospitalized from May 1 through July 31, 2021. Geriatric patients were defined as individuals who were aged > 65 years according to the Senior Citizens Welfare Act in Taiwan. The diagnosis of COVID-19 was confirmed via polymerase chain reaction of nasal swab specimens. We excluded patients who (i) presented with out-of-hospital cardiac arrest (OHCA), (ii) were transferred from other hospitals, and (iii) had missing demographic data.

2.3. Variables

Herein, data was collected regarding the age, sex, previous medical history, vital signs upon initial presentation at the ED, and serum laboratory tests of each enrolled patient from the electronic medical records database. The REMS, MEWS, and NEWS scores of each patient were calculated using their vital signs measured upon initial presentation during the ED triage. The parameters required to calculate the REMS, MEWS, and NEWS are presented in Table 1. The three EWSs were the main variables required to calculate receiver operating characteristics (ROCs) for performance evaluation of in-hospital mortality.

2.4. Outcome measures

The primary outcome of the study was the discriminant performance of REMS, MEWS, and NEWS for predicting in-hospital mortality of geriatric patients with COVID-19. The outcome was measured by utilizing the area under the ROCs curve (AUROC) for the REMS, MEWS, and NEWS using continuous and binary models.

2.5. Statistical analysis

Continuous data were presented using means and standard deviations for demographic analyses. The parameters were compared between the groups using independent-samplet-test for continuous data, and Pearson's chi-square test or Fisher's exact test was used for categorical variables, depending on the sample size.

The ROC curve was used to determine the overall discriminant ability of each EWS for the in-hospital mortality rate. To compare the ROC curves, an AUROC was created according to DeLong's method.[14,15] The sensitivity, specificity, positive predictive value, and negative predictive value were subsequently determined. SPSS (version 26.0; SPSS Inc., Armonk, NY, USA) was used for the statistical analyses. A *p*-value of < 0.05 was considered statistically significant.

2.6. Ethics statement

The study was approved by the Institutional Review Board of MacKay Memorial Hospital (21MMHIS377e). Informed consent was waived by the board owing to the retrospective design of the study and the fact that all study data were analyzed anonymously.

3. Results

In total, 139 geriatric patients with COVID-19 hospitalized from May 1 to July 31, 2021 were eligible for this study. After excluding patients with OHCA (n = 1), those who were transferred from other hospitals (n = 2), and those with missing data (n = 1), 135 patients were finally enrolled in the study. The flow chart of the patient enrollment process is presented in Figure 1.

The demographic characteristics of the enrolled patients are shown in Table 2. The mean age was 74.44 ± 6.69 years, and 53.3% of the patients were men. In-hospital mortality occurred in 24 (17.8%) patients after admission. Comparisons between the mortality and survival groups revealed no significant age differences. However, the

Table 1
Parameters required to calculate REMS, MEWS, and NEWS.

Early Warning Score	Parameters	Range
Rapid Emergency Medicine Score (REMS)	Age; Heart rate; Respiratory rate; Blood pressure; SpO_2; GCS	0–26
National Early Warning Score (NEWS)	Heart rate; Respiratory rate; Blood pressure; SpO_2; GCS, Oxygen supplement	0–20
Modified Early Warning Score (MEWS)	Heart rate; Respiratory rate; Blood pressure; Body temperature; Level of consciousness	0–14

Abbreviation: GCS: Glasgow Coma Scale.

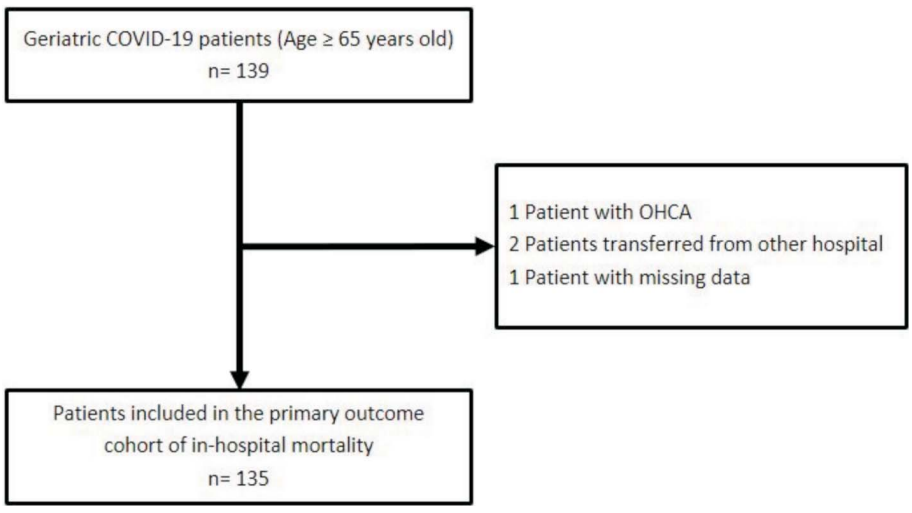

Figure 1. Flow chart of the patient enrollment process of the study.

Table 2
Demographic characteristics and initial vital signs at triage of patients with COVID-19 in the study cohort.

	All patients (n = 135)	Mortality (n = 24)	Survival (n = 111)	*p*-value
Basic characteristics				
Age	74.44 ± 6.69	75.17 ± 6.90	74.29 ± 6.66	0.93
Sex	53.30%	62.71%	51.15%	< 0.05
Medical history				
HTN	52%	67%	48%	< 0.05
DM	30%	42%	27%	< 0.05
CAD	15%	14%	21%	0.11
HF	5%	17%	2%	< 0.05
CKD	13%	38%	7%	< 0.05
Vital signs (mean ± SD)				
GCS	14.31 ± 2.19	13.63 ± 3.40	14.46 ± 1.82	< 0.05
BT	37.55 ± 0.96	37.83 ± 1.09	37.49 ± 0.93	0.32
HR	92.81 ± 21.17	106.17 ± 24.19	89.93 ± 19.40	0.09
RR	20.76 ± 9.10	22.74 ± 5.96	20.28 ± 9.62	0.57
SBP	130.19 ± 28.55	135.67 ± 27.97	129.01 ± 27.97	0.34
DBP	73.58 ± 13.72	76.00 ± 15.80	73.05 ± 13.25	0.42
MAP	92.45 ± 16.22	95.89 ± 19.57	91.71 ± 15.41	0.21
SpO_2	93.36 ± 8.49	86.71 ± 15.22	94.83 ± 5.17	< 0.05
Emergency warning scores (mean ± SD)				
REMS	7.93 ± 3.43	9.88 ± 3.58	7.50 ± 3.26	0.22
NEWS	4.21 ± 3.49	7.04 ± 3.85	3.59 ± 3.09	< 0.05
MEWS	2.50 ± 1.75	3.96 ± 2.01	2.19 ± 1.52	< 0.05

Abbreviation: HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; HF, heart failure; CKD, chronic kidney disease; SD, standard deviation; GCS, Glasgow Coma Scale; BT, body temperature; HR, heart rate; RR, respiratory rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; SpO_2, pulse oximetry; REMS, Rapid Emergency Medicine Score; NEWS, National Early Warning Score; MEWS, Modified Early Warning Score.

mortality group had significantly more men (61.7% vs. 51.2%, $p < 0.05$). Further, this group demonstrated higher proportions of patients with hypertension (67% vs. 48%, $p < 0.05$), diabetes mellitus (42% vs. 27%, $p < 0.05$), heart failure (17% vs. 2%, $p < 0.05$), and chronic kidney disease (38% vs. 7%, $p < 0.05$); however, there was no significant difference in the proportion of patients with a past history of coronary artery disease between the two groups.

There were no significant differences between the two groups in terms of the vital signs upon initial presentation to the ED (body temperature, heart rate, respiratory rate, and mean arterial pressure). However, the patients in the mortality exhibited had significantly lower GCS scores (13.6 vs. 14.5, $p < 0.05$) and SpO_2 levels (86.7% vs. 94.8%, $p < 0.05$).

We determined the median values of each EWS for nonsurvivors and survivors and found that the nonsurvivors exhibited significantly higher NEWS (7.0 vs. 3.6, $p < 0.05$) and MEWS (4.0 vs. 2.2, $p < 0.05$) indices. However, there was no significant difference in REMS between the two groups. Finally, we compared the AUROCs of the three EWSs for in-hospital mortality. REMS, MEWS, and NEWS demonstrated good predictive value (AUROC ≥ 0.7), with MEWS demonstrating the highest AUROC. All the indices were statistically significant. The graphical presentations of AUROC and detailed characteristics of each EWS are shown in Figure 2 and Table 3.

4. Discussion

To the best of our knowledge, this study is the first to evaluate the three most used EWSs among geriatric patients with COVID-19. Herein, we found that MEWS exhibited a higher predictive ability than NEWS and REMS, thus indicating that MEWS could aid emergency physicians during the triage of geriatric patients with COVID-19.

EWSs should not be mistaken for other severity scores such as the Sequential Organ Failure Assessment (SOFA) score or the Acute Physiology and Chronic Health Evaluation II (APACHE II),[3] as severity

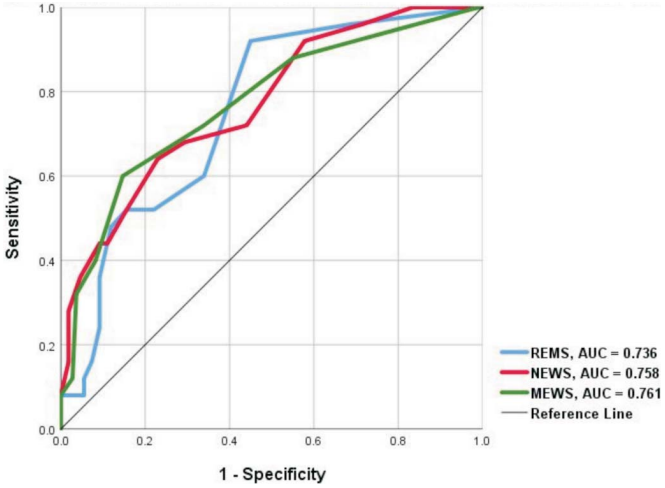

Figure 2. ROC curves for the early warning scores for in-hospital mortality of geriatric patients with COVID-19.

Table 3
Detailed characteristics of each early warning score in study cohort.

	AUC	95% CI	p value	Cutoff value	Sensitivity	Specificity	PPV	NPV	PLR	NLR
REMS	0.736	0.637–0.834	< 0.05	> 10.5	33.30%	90.10%	42.10%	86.20%	3.36	0.74
NEWS	0.758	0.654–0.861	< 0.05	> 5.5	62.50%	77.60%	37.63%	90.54%	2.79	0.48
MEWS	0.761	0.651–0.871	< 0.05	> 3.5	58.30%	85.60%	39.39%	89.94%	3.01	0.52

Abbreviation: AUC, area under curve; 95% CI, 95% confidence interval; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; REMS, Rapid Emergency Medicine Score; NEWS, National Early Warning Score; MEWS, Modified Early Warning Score.

scores influence serum examination results within a 24-h period. However, EWSs enable the instant recognition of at-risk patients. Former studies have reported the importance of EWSs in identifying geriatric patients with COVID-19 whose conditions are likely to become critical. However, to the best of our knowledge, there has been no study comparing the most used EWSs (REMS, MEWS, and NEWS).

REMS was introduced in 2003 in a prospective study involving 865 nonsurgical patients from the ED and reportedly exhibits outstanding performance in predicting in-hospital mortality (AUC = 0.910).[16] The findings of a large cohort study involving 12,006 patients also validated that REMS of ≥ 3 should prompt aggressive intervention.[6] Moreover, the in-hospital mortality rate significantly increased when REMS was ≥10.[6] However, REMS demonstrated the lowest AUROC among the three EWSs in this study. Furthermore, REMS was the only EWS that did not attain statistical significance during comparisons between the deceased and surviving groups. This phenomenon was also reported in a previous COVID-19 geriatric population study.[17] Although the age parameter in REMS can be used to identify potential critical conditions in the general population, this discriminatory ability is diminished in the older population because such patients may exhibit a composite of similar risk factors.[17]

NEWS was first introduced by the Royal College of Physicians in 2012 to standardize the use of EWSs in the National Health Service of the United Kingdom.[5] A large validation study involving a population of 198,755 individuals reported that NEWS had an AUROC of 0.857 for patient death within 24 h.[18] NEWS 2 was developed in 2017; however, it was found to be inferior to the original NEWS in the former study.[3,19] A NEWS cutoff value of ≥ 6 is referred to as a RED score, which identifies a patient who is in need of immediate assessment.[5] Herein, NEWS demonstrated an AUROC of 0.758, which was higher than that of REMS and similar to that of MEWS. An optimal cutoff value of 5.5, which was nearly similar to the RED score, was observed in our study.[5] The result of NEWS was also identical to that of another single-center study in Italy involving 210 geriatric patients with COVID-19.[20]

MEWS was first mentioned and prospectively validated in a study involving 709 patients admitted from the ED, in which increased scores were associated with clinical decline and mortality.[4] A previous study comparing the predictive value of MEWS and several severity scores in geriatric patients with COVID-19 revealed that MEWS was comparable to APACHE II (pneumonia severity index) and SOFA.[21] Herein, MEWS exhibited the highest AUROC of 0.761, with an optimal cutoff value of 3.5, which was also proposed in older patients with COVID-19 in a previous study.[21] Using basic parameters to fill in for the EWS evaluation, MEWS exhibited the best discriminatory ability for in-hospital mortality of geriatric patients with COVID-19.

Despite MEWS exhibiting the highest AUROC on in-hospital mortality of geriatric patients with COVID-19, all the three most used EWSs demonstrated AUROCs of > 0.7 without significant statistical difference. MEWS used basic parameters and did not factor in age and SpO_2 during its calculation. As we previously mentioned, the age factor of REMS could be excluded as this study focused on older people. We consider that decreased oxygen levels due to COVID-19 can influence other vital signs, such as the heart rate, blood pressure, and respiratory rate, which MEWS has composited.

This study had some limitations. First, it was a retrospective cohort study, which signifies missing demographic entries. Nevertheless, the study has an acceptable exclusion rate of 2.8% (n = 4). Second, this is a single-center study with a limited study population. Future prospective multicenter studies are warranted. Third, the study period was relatively short, which only included geriatric patients with COVID-19 of the alpha variant. A further study with extended period should be conducted afterward. Nonetheless, to the best of our knowledge, this was the first study to compare the three most used EWSs in determining the in-hospital mortality of geriatric patients with COVID-19.

Thus, we evaluated the performance of REMS, MEWS, and NEWS in determining the in-hospital mortality of geriatric patients with COVID-19. According to our findings, MEWS can be used as a simple and immediate risk discrimination tool to gage the possible clinical deterioration of geriatric patients with COVID-19.

Conflict of interest

There are no conflicts of interest to declare.

Funding

This research received no external funding.

Data availability statement

The data are not publicly available due to restrictions regarding the Ethical Committee Institution.

Ethics approval the design and execution of this retrospective study was approved by the Institutional Review Board of MacKay Memorial Hospital (21MMHIS377e).

Consent to participate informed consent was waived because of the retrospective nature of the study and the analysis used anonymous clinical data.

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