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ORIGINAL RESEARCH

Correlations between modified early warning scores in emergency departments and predictions of prognosis in South Korea

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Abstract

We explored whether modified early warning scores (MEWS) could be used as a tool for triage in pre-hospital settings by comparing MEWS with patient triage on arrival to the emergency department (ED) and prognosis. Adult patients ($\geq$20 years old) admitted to EDs between 2016 and 2018 were enrolled from National Emergency Department Information System data in this retrospective study. A total of 8,609,955 participants were included in the analysis. EDMEWS of the dead (4.74 ± 2.51) was higher than that of admitted (1.86 ± 1.72) and discharged patients (1.18 ± 1.15) ($p < 0.001$). In admitted patients, non-survivors had higher EDMEWS than survivors ($p < 0.001$), and as the level of the Korean Triage and Acquisition Scale was severe, EDMEWS increased ($p < 0.001$) accordingly in these patients. EDMEWS had an adjusted hazard ratio (HR) of 1.164 (95% confidence interval: 1.135 ± 1.194) for mortality ($p < 0.001$). When an EDMEWS of 0 was used as a reference value, the HR increased with an increase in the EDMEWS. As EDMEWS increased from 1 to 7+, HR also increased from 1.115 to 2.508. EDMEWS has a positive correlation with mortality and admission rates in EDs. Moreover, admitted patients with higher EDMEWS had a longer duration of hospitalization and they had a higher mortality rate compared to patients with lower EDMEWS. MEWS can be a useful tool to provide evidence to support decision-making processes involving transportation to the ED and selection of the appropriate level of ED for pre-hospital EMS and long-term care facilities.

Keywords

Emergency department; Modified early warning Score; Korean triage and acquisition scale; Pre-hospital; Triage

1. Introduction

Emergency department (ED) overcrowding is one of the major problems in the emergency medical system. ED overcrowding negatively impacts not only patients and physicians, but the entire healthcare system, as it reduces the quality of patient care, decreases physician job satisfaction, and drives up healthcare costs [1–8]. ED overcrowding and congestion is caused by a number of complex factors. The emergency medical system can be divided into three main components. The first is the pre-hospital phase, the second is the hospital phase, and the third is the inpatient, operating room, and intensive care unit phases [9, 10]. In Korea, the pre-hospital stage is inadequate, and the role of 119 paramedics, in particular, is to provide simple first aid and to transport patients, and the Emergency Patient Information Center is not efficiently operated due to diversity of the reporting system, lack of cooperation with each agency, and poor communication systems such as non-response to dispatches [11].

EDs that are severely overcrowded represent contributing factors to the fact that many elderly patients transferred from long-term care facilities are not receiving final treatment and are being transferred to other medical institutions, a phenomenon that may intensify as we enter an ultra-elderly society in the future [12]. 63.5% of elderly visits to EDs are reported to be non-urgent [13]. One study showed that approximately 3.2% of patients are transferred from nursing hospitals, and 63.2% are semi-urgent and non-urgent [14]. They are often transferred from nursing homes and sent back to nursing homes without receiving final care. ED overcrowding due to these unnecessary transfers can lead to increased staff fatigue, less complete patient care, and repeat visits, all of which contribute to higher healthcare costs [14, 15].

In order to properly allocate the limited resources of EDs to provide proper care to patients and prevent overcrowding, it is important to properly triage patients at the pre-hospital stage and transfer them to the appropriate level of care. However, in Korea, institutions such as nursing homes and nursing hospitals do not have a suitable triage tool to assess patients to determine

ED transfer.

Since 2016, South Korea has been using a triage system, the Korean Triage and Acquisition Scale (KTAS), for ED in-hospital patients. The purpose of KTAS is to reasonably distribute the severity of a wide range of symptoms such as major trauma, minor injury, cardiovascular problems, obstetric emergency problems, neuropsychiatric disorders, and pediatric problems [16]. However, in the case of using KTAS, sufficient information must be obtained such as critical first look, medical history, subjective symptoms and vital signs. Some of this information is gathered from the patient or guardian to determine the patient's symptoms and severity, a therapeutic communication relationship (rapport) must be formed therein, and educated medical staff and programs are required accordingly. Therefore, emergency medical services (EMS) or nursing hospitals are constrained in difficult situations to classify patients using KTAS.

There is a growing interest in more accurate ways of assessing patients, such as their severity, whether they should be admitted or discharged, and whether they need intensive care unit (ICU) care. In response, several studies have examined the feasibility of using a screening test, such as the Modified Early Warning Score (MEWS), for early assessment of patient severity and prognosis in EDs [17–19].

We sought to validate the suitability of MEWS as a prehospital triage tool in adult patients presenting to the ED to provide a scientific basis for the formulation of effective and systematic emergency medical service delivery policies.

2. Materials and methods

2.1 Setting and data collection

This descriptive study used retrospective anonymized routine data collected from the NEDIS from January 2016 to December 2018. Thirty-six regional emergency medical centers exist (Level 1), 117 local emergency medical centers (Level 2), and 119 local emergency medical rooms (Level 3) in South Korea. Between 2016 and 2018, 399 out of 401 emergency medical institutions participated in the NEDIS data collection. Information on patients who visited EDs was sent from each ED to the National Emergency Medical Center database in real time.

From the initial attendance to NEDIS between 01 January 2016 and 31 December 2018, patients with incomplete parameters, underaged, and who visited ED with non-disease cause are excluded from analysis.

2.2 Variables and outcome measures

The NEDIS collects demographic data and clinical data: age, sex, ED visit date, ED visit time, insurance types, means of visit, consciousness of patients in EDs, KTAS level, consciousness level (alert, verbal, pain and unresponsiveness (AVPU) score), systolic blood pressure (SBP), diastolic blood pressure, pulse rate (PR), respiratory rate (RR) and disposition after ED care (discharge, transfer to another hospital, admission to general ward, or intensive care unit (ICU)). For admitted patients, final medical results (expire or discharge, duration of hospitalization) on discharge were considered for the study. The ED visit time was further divided into dawn (00:00–05:59 h), morning (06:00–11:59 h), afternoon (12:00–17:59 h), and night (18:00–23:59 h).

MEWS includes five physiological vital signs: SBP (mmHg), RR (breaths per minute), PR (beats per minute), body temperature (°C), and consciousness (AVPU score). MEWS was calculated by summing the five scores. MEWS ranged from 0 to 14 (Table 1). This study was to determine whether prehospital patients' MEWS is a tool related to patient outcomes. Thus, SBP, RR, PR, body temperature, and consciousness measured immediately upon arrival at the emergency department were used. Emergency department MEWS (EDMEWS) was defined as MEWS calculated at the time of ED arrival.

The primary outcome of this study was all-cause, in-hospital mortality, and we did not evaluate the association between MEWS and cause-specific mortality.

2.3 Statistical analysis

We analyzed each variable by dividing in-hospital patients in the ED into groups of discharged, hospitalized, and deceased as the outcomes of ED treatment.

The hospitalized group was compared for each variable after being classified into the non-survival and survival groups. Regression analysis was conducted with variables that were significant in the univariate analysis among the hospitalized groups. Since EDMEWS and age have interaction effects, regression analysis and survival analysis were conducted for each of the non-elderly and elderly groups based on their age (65 years). We compared and analyzed the variables of the patients who visited EDs. Categorical variables were analyzed using the chi-square test, and the Student's *t*-test was used for

TABLE 1. Modified early warning sign.

Vital Sign	Score						
	3	2	1	0	1	2	3
Systolic pressure (mmHg)	≤70	71–80	81–100	101–199	-	≥200	-
Pulse rate (bpm)	-	<40	40–50	51–100	101–110	111–129	≥130
Respiratory rate	-	≤8	9	10–18	19–20	21–29	≥30
Temperature (°C)	-	≤35.0	-	35.1–38.4	-	≥38.5	-
AVPU				A	V	P	U

Abbreviations: A/V/P/U: alert/verbal/painful/unresponsive.

continuous variables. Statistically significant variables in the multivariate analysis were subsequently analyzed using a univariate analysis. A Cox proportional hazard regression model was used to investigate the correlation between mortality, age and MEWS.

The Statistical Package for the Social Sciences Statistics for Windows, version 21 (International Business Machines Corporation, Armonk, NY, USA) was used for analysis. Statistical significance was set at a two-tailed p-value of < 0.05, and 95% confidence intervals were considered statistically significant.

3. Results

3.1 Epidemiological and clinical characteristics of the patients who were admitted to EDs (Table 2, Figs. 1,2)

This study included all patients over 20 years of age who were admitted to the ED. The initial attendance to NEDIS between 01 January 2016 and 31 December 2018 was 27,657,459. A total of 14,081,048 patients visited EDs with trauma. 300,728 patients had incomplete clinical information due to cardiopulmonary resuscitation (CPR) (n = 78,414) and transfer to other clinical facilities (n = 207,628), and 4,665,771 patients were underaged (n = 1,061,755) or were enrolled with incomplete parameters (n = 3,604,016) (Fig. 1).

A total of 8,609,955 participants were included in the analysis. We compared data among the three groups (ED discharged as group 1, admitted from ED as group 2, and ED death as group 3) The mean ages were 49.97 $\pm$ 18.19, 62.24 $\pm$ 17.84, 73.16 $\pm$ 13.76 years for groups 1, 2 and 3, respectively ($p < 0.001$). The proportion of patients aged 65 or older accounted for 23.3%, 50.0% and 75.2% of the groups 1, 2 and 3, respectively ($p < 0.001$).

The proportions of male patients in groups 1, 2 and 3 were 44.2%, 52.5% and 57.2%, respectively.

When visiting the ED, 24.0% of group 2 used 911 ambulances, and 15.3% used other ambulances. In the case of group 3, 46.3% used 911 ambulances and 29.1% used other ambulances. KTAS levels showed a statistically significant difference among the three groups ($p < 0.001$). In group 1, 38.8% were in level 3 (urgent), 44.7% were in level 4 (less-urgent), and 12.0% were in level 5 (non-urgent) cases. In group 2, there were 16.1% in level 2 (emergent), 56.6% in level 3 (urgent), and 22.3% in level 4 (less-urgent) cases. In group 3, there were 21.5% in level 1 (resucitation), 42.8% in level 2 (emergent), and 31.1% in level 3 (urgent) cases. Thus, the three groups clearly differed in severity.

The EDMEWS of groups 1, 2 and 3 were 1.18 $\pm$ 1.15, 1.86 $\pm$ 1.72 and 4.74 $\pm$ 2.51, respectively, and there was a statistically significant difference between each group when examined by EDMEWS scores ($p < 0.001$).

3.2 Comparison survivors and non-survivors who were admitted to wards from EDs (Table 3, Fig. 3)

Patients admitted to the ED were further characterized to analyze the variables that mediated mortality. The average age of survivors was 61.66 $\pm$ 17.9, and the average age of non-survivors was 71.72 $\pm$ 13.59. The proportions of elderly survivors and non-survivors were 48.7% and 71.0%, respectively ($p < 0.001$). The mean of EDMEWS in non-survivors (3.22 $\pm$ 2.23) was higher than that of the survivor group (1.78 $\pm$ 1.65). The percentage of survivors who were admitted to the general ward was over five times higher (84.1%) than that of those admitted to the ICU (15.9%). Non-survivors were admitted to the ICU and general ward at roughly similar rates of 59.3% and 40.7%, respectively.

The hospital length of stay of the survivor group was 10.65 $\pm$ 14.54 days, while the hospital length of stay of the non-survivor group was 17.21 $\pm$ 24.08 days, which was statistically significant ($p < 0.001$) (Table 3). The analysis of length of hospital stay/mortality by EDMEWS of hospitalized patients revealed that the higher the EDMEWS score, the longer the hospitalization period and higher the mortality rate in the ward (Fig. 3).

3.3 Predictors for in-hospital mortality and survival curves by EDMEWS (Tables 4,5, Figs. 4,5)

Multivariate Cox proportional hazards regression analysis for admitted patients was performed to identify prognostic factors for in-hospital mortality (Table 4). The adjusted hazard ratio (HR) for age was 1.041 (95% confidence interval (CI) 1.041–1.043). This was a statistically significant prognostic factor. When using alertness as a reference, verbal response had 1.535 (95% CI: 1.505–1.565), pain response had 2.597 (95% CI: 2.510–2.687), and unresponsiveness had 1.327 (95% CI: 1.304–1.351) HR for mortality. Vital signs also had a statistically significant effect on mortality. As the PR and RR increased, the survival probability decreased for the patient. Further, when SBP and body temperature decreased, the survival probability also decreased for the patient. EDNEWS had a HR of 1.164 (95% CI: 1.135 $\pm$ 1.194) for mortality. When an EDMEWS of 0 was used as a reference value, the HR increased with an increase in the EDMEWS. As EDMEWS increased from 1 to 7+, HR also increased from 1.115 to 2.508 (Table 4).

As the number of hospital days increased, the survival probability decreased for patients. When a weighted EDNEWS of 0 was taken as a reference, survival probability resulted in a statistically significant decrease as EDNEWS increased (Fig. 5).

Considering that both age group and EDNEWS showed statistically significant interaction effects with mortality, we performed the interaction effect with age group and EDMEWS ($p < 0.001$).

Since the interaction effect of age group and EDMEWS was statistically significant, Cox regression analysis for mortality HR and survival curve analysis for each MEWS score were performed separately by age group (Table 5).

In the non-elderly group, EDMEWS shows 1.258 (95% CI: 1.211–1.306) HR, and the HR increases from 1.189 to 3.744 as EDMEWS increased from 1 to 7+. The survival curve according to EDMEWS shows that the survival probability decreases as EDMEWS increases (Fig. 4).

In the elderly group, EDMEWS shows 1.063 (95% CI: 1.026–1.101) HR, and the HR increases from 1.082 to 2.147

TABLE 2. Epidemiological and clinical characteristics of patients who admitted emergency departments.

	ED discharged		Admitted from ED		ED death		Total		*p*-value
	n	%	n	%	n	%	n	%	
Age (years), (mean ± SD)	49.97 ± 18.19		62.24 ± 17.84		73.16 ± 13.76		53.43 ± 18.92		<0.001
Age group									
20–64 years	4,749,855	(76.7)	1,202,160	(50.0)	3334	(24.8)	5,955,349	(69.2)	<0.001
over 65 years	1,441,787	(23.3)	1,202,718	(50.0)	10,100	(75.2)	2,654,605	(30.8)	
Sex (male)	2,737,964	(44.2)	1,262,375	(52.5)	7685	(57.2)	4,008,024	(46.6)	<0.001
Insurance									
National health insurance	5,676,753	(91.7)	2,147,912	(89.3)	11,523	(85.8)	7,836,188	(91.0)	
Medicaid	398,633	(6.4)	228,016	(9.5)	1721	(12.8)	628,370	(7.3)	<0.001
Others	116,256	(1.9)	28,950	(1.2)	190	(1.4)	145,396	(1.7)	
ED visit time									
Dawn	1,109,884	(17.9)	245,368	(10.2)	1823	(13.6)	1,357,075	(15.8)	
Morning	1,458,100	(23.5)	686,520	(28.5)	3663	(27.3)	2,148,283	(25.0)	<0.001
Afternoon	1,563,673	(25.3)	896,980	(37.3)	4388	(32.7)	2,465,041	(28.6)	
Night	2,059,985	(33.3)	576,010	(24.0)	3560	(26.5)	2,639,555	(30.7)	
Means of visit									
911	995,471	(16.1)	576,627	(24.0)	6239	(46.4)	1,578,337	(18.3)	
Other Ambulance	99,436	(1.6)	368,643	(15.3)	5250	(39.1)	473,329	(5.5)	
Car	5,015,489	(81.0)	1,425,367	(59.3)	1828	(13.6)	6,442,684	(74.8)	<0.001
Walk	65,887	(1.1)	22,827	(0.9)	30	(0.2)	88,744	(1.0)	
Others	15,359	(0.2)	11,414	(0.5)	87	(0.6)	26,860	(0.3)	
KTAS									
Level 1 (Resucitation)	9014	(0.1)	51,216	(2.1)	2891	(21.5)	63,121	(0.7)	
Level 2 (Emergent)	276,261	(4.5)	386,289	(16.1)	5744	(42.8)	668,294	(7.8)	
Level 3 (Urgent)	2,396,718	(38.8)	1,360,413	(56.6)	4171	(31.1)	3,761,302	(43.7)	<0.001
Level 4 (Less-urgent)	2,761,219	(44.7)	534,937	(22.3)	544	(4.1)	3,296,700	(38.3)	
Level 5 (Non-urgent)	739,738	(12.0)	68,918	(2.9)	78	(0.6)	808,734	(9.4)	
Consciousness									
Alert	6,106,530	(98.6)	2,204,956	(91.7)	6718	(50.0)	8,318,204	(96.6)	
Verbal	54,771	(0.9)	108,126	(4.5)	2152	(16.0)	165,049	(1.9)	<0.001
Pain response	28,152	(0.5)	79,328	(3.3)	3128	(23.3)	110,608	(1.3)	
Unresponsiveness	2189	(0.0)	12,468	(0.5)	1436	(10.7)	16,093	(0.2)	
Vital signs									
Systolic blood pressure (mmHg)	133.45 ± 23.49		132.19 ± 28.35		105.71 ± 35.71		133.05 ± 24.99		<0.001
Diastolic blood pressure (mmHg)	80.14 ± 14.09		78.01 ± 16.27		63.76 ± 22.61		79.52 ± 14.93		<0.001
Pulse rate (beats/minute)	84.42 ± 16.52		89.62 ± 20.45		99.96 ± 28.66		85.9 ± 17.90		<0.001
Respiratory rate (per minute)	19.31 ± 2.50		19.99 ± 3.56		22.72 ± 6.38		19.51 ± 2.87		<0.001
EDMEWS (mean ± SD)	1.18 ± 1.15		1.86 ± 1.72		4.74 ± 2.51		1.38 ± 1.38		<0.001
EDMEWS									
0	1,627,988	(26.3)	456,284	(19.0)	343	(2.6)	2,084,615	(24.2)	
1	2,999,229	(48.4)	862,457	(35.9)	1006	(7.5)	3,862,692	(44.9)	
2	853,046	(13.8)	428,074	(17.8)	1402	(10.4)	1,282,522	(14.9)	
3	407,605	(6.6)	276,368	(11.5)	1817	(13.5)	685,790	(8.0)	<0.001
4	173,338	(2.8)	170,732	(7.1)	1887	(14.0)	345,957	(4.0)	
5	86,728	(1.4)	103,965	(4.3)	1980	(14.7)	192,673	(2.2)	
6	32,430	(0.5)	57,249	(2.4)	1750	(13.0)	91,429	(1.1)	
7+	11,278	(0.2)	49,749	(2.1)	3249	(24.2)	64,276	(0.7)	

EDMEWS: emergency department modified early warning score; SD: standard deviation; KTAS: Korean Triage and Acuity Scale.

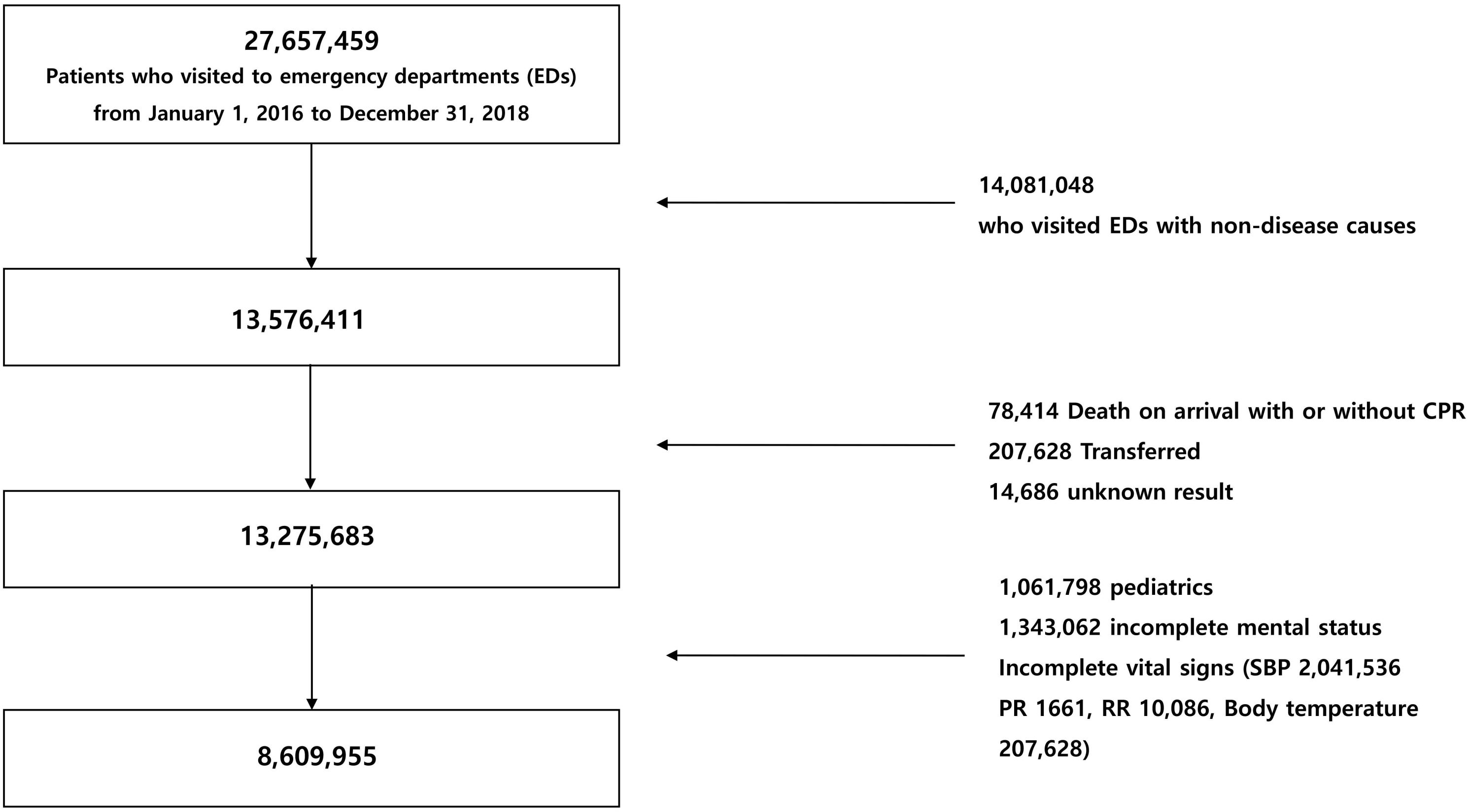

FIGURE 1. Enrolled patients flow chart. CPR: Cardiopulmonary resuscitation; SBP: Systolic Blood Pressure; PR: Pulse Rate; RR: Respiratory rate.

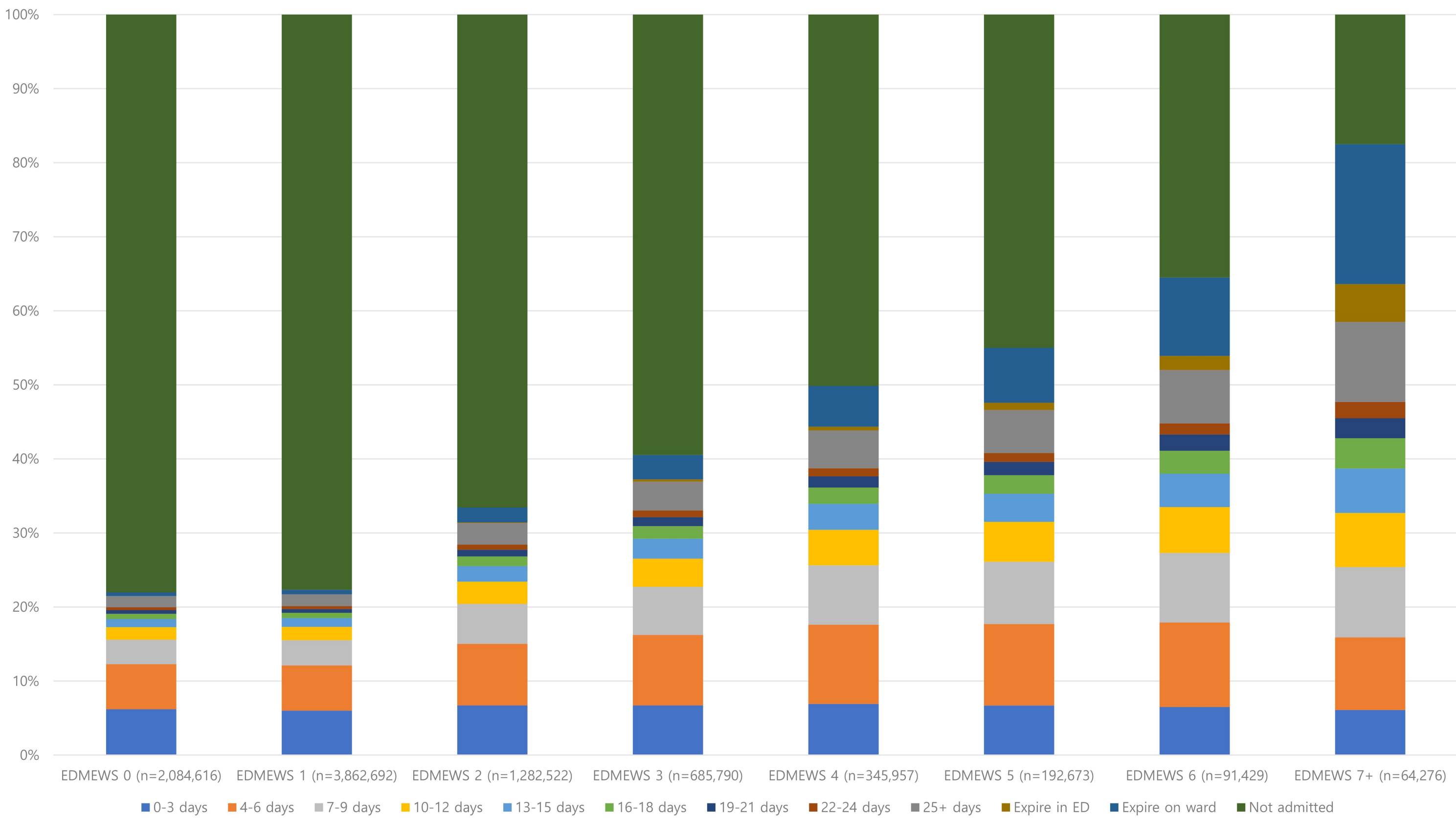

FIGURE 2. Lengths of stay and mortality status by EDMEWS on admission to the ED. EDMEWS: emergency department modified early warning scores.

TABLE 3. Comparison survivors and non-survivors who were admitted to ward.

	Survivor		Non-survivor		Total		
	n	(%)	n	(%)	n	(%)	*p*-value
Age (years) (mean ± SD)	61.66 ± 17.9		71.72 ± 13.59		62.24 ± 17.84		<0.001
Age group							
20–64 years	1,163,304	(51.3)	38,857	(28.0)	1,202,161	(50.0)	<0.001
over 65 years	1,103,041	(48.7)	99,671	(71.0)	1,202,712	(50.0)	
Sex (male)	1,179,862	(52.1)	82,511	(59.6)	1,262,373	(52.5)	<0.001
Insurance							
National health insurance	2,027,387	(89.5)	120,520	(87.0)	2,147,907	(89.3)	
Medicaid	211,720	(9.3)	16,296	(11.8)	228,016	(9.5)	<0.001
Others	27,238	(1.2)	1712	(1.2)	28,950	(1.2)	
ED visit time							
Dawn	233,291	(10.3)	12,077	(8.7)	245,368	(10.2)	
Morning	644,981	(28.5)	41,538	(30.0)	686,519	(28.5)	<0.001
Afternoon	842,204	(37.2)	54,773	(39.5)	896,977	(37.3)	
Night	545,869	(24.1)	30,140	(21.8)	576,009	(24.0)	
Consciousness							
Alert	2,105,255	(92.9)	99,699	(72.3)	2,204,954	(91.7)	
Verbal	91,633	(4.0)	16,493	(11.9)	108,126	(4.5)	<0.001
Pain response	61,664	(2.7)	17,661	(12.7)	79,325	(3.3)	
Unresponsiveness	7793	(0.3)	4675	(3.4)	12,468	(0.5)	
Vital signs							
Systolic blood pressure (mmHg)	132.85 ± 27.94		121.32 ± 32.51		132.19 ± 28.35		<0.001
Diastolic blood pressure (mmHg)	78.37 ± 16.48		72.22 ± 19.14		78.01 ± 16.73		<0.001
Pulse rate	89.06 ± 20.10		98.64 ± 23.74		89.62 ± 20.45		<0.001
Respiratory rate	19.59 ± 3.39		21.65 ± 5.24		19.99 ± 3.56		<0.001
Body temperature	36.93 ± 0.87		36.81 ± 0.93		36.92 ± 0.87		<0.001
KTAS							
Level 1	38,635	(1.7)	12,581	(9.1)	51,215	(2.1)	
Level 2	347,072	(15.3)	39,213	(28.3)	386,285	(16.1)	
Level 3	1,292,640	(57.1)	67,773	(49.0)	1,360,413	(56.6)	<0.001
Level 4	519,342	(22.9)	15,595	(11.3)	534,937	(22.3)	
Level 5	65,733	(2.9)	3185	(2.3)	68,918	(2.9)	
ED MEWS	1.78 ± 1.65		3.22 ± 2.23		1.86 ± 1.72		<0.001
ED MEWS classification							
0	445,917	(19.7)	10,368	(7.5)	456,285	(19.0)	
1	837,584	(37.0)	34,872	(18.0)	862,456	(35.9)	
2	402,711	(17.8)	25,362	(18.3)	428,073	(17.8)	
3	253,741	(11.2)	22,627	(16.3)	276,368	(11.5)	<0.001
4	151,583	(6.7)	19,148	(13.8)	170,731	(7.1)	
5	89,683	(4.0)	14,281	(10.3)	103,964	(4.3)	
6	47,526	(2.1)	9723	(7.0)	57,249	(2.4)	
7+	37,600	(1.7)	12,147	(8.8)	49,747	(2.1)	
Admission ward							
General ward	1,906,848	(84.1)	82,116	(59.3)	1,988,964	(82.7)	<0.001
ICU	359,497	(15.9)	56,412	(40.7)	415,909	(17.3)	
Hospital length of stay (days)	10.65 ± 14.54		17.21 ± 24.08		11.03 ± 15.33		<0.001

SD: standard deviation; ED: emergency department; KTAS: Korean Triage and Acuity Scale; MEWS: modified early warning scores; ICU: intensive care unit.

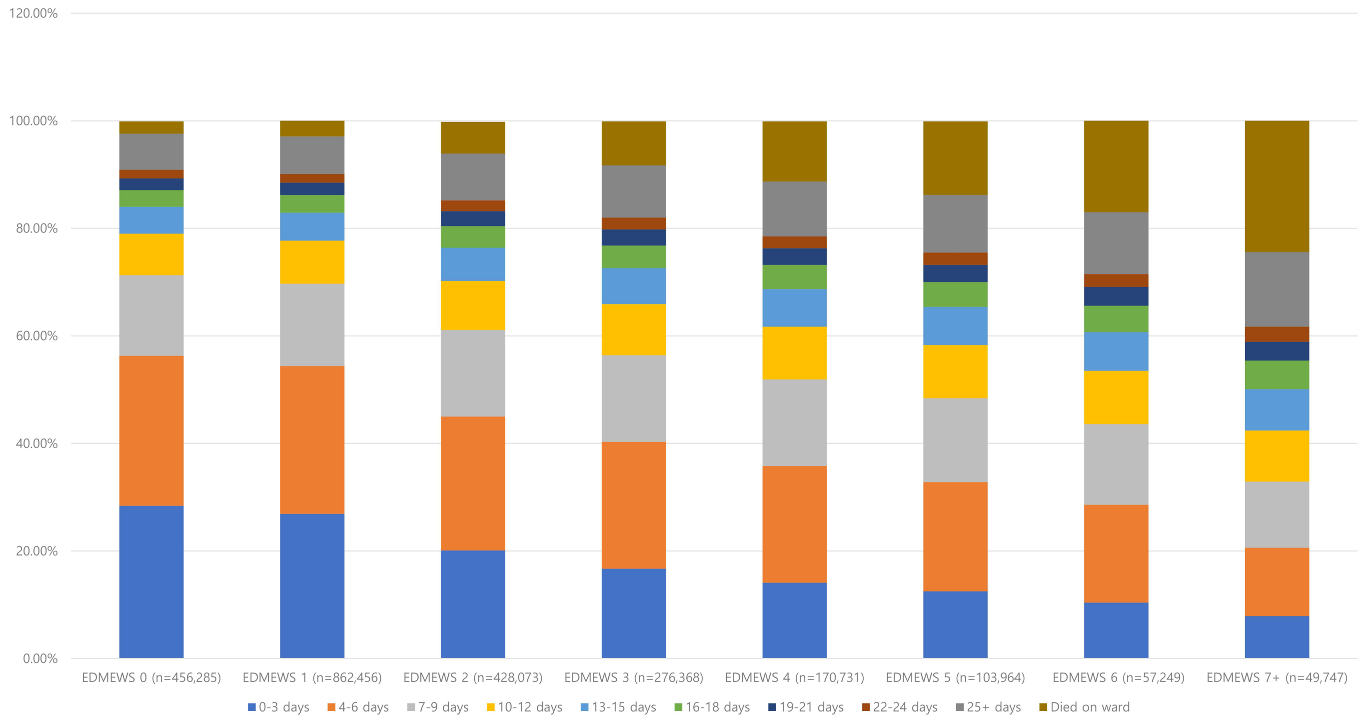

FIGURE 3. Length of hospital stay/mortality by EDMEWS of hospitalized patients. EDMEWS: emergency department modified early warning scores.

TABLE 4. Predictive value for in-hospital mortality in patients who admitted from ED assessed using the Cox proportional hazards models.

	HR	OR (95% CI)	*p*-value
Age	1.041	(1.040–1.043)	<0.001
Age group	0.856	(0.813–0.901)	<0.001
Consciousness			
Alert	Reference	Reference	<0.001
Verbal response	1.535	(1.505–1.565)	<0.001
Pain response	2.597	(2.510–2.687)	<0.001
Unresponsiveness	1.327	(1.304–1.351)	<0.001
Systolic blood pressure	0.990	(0.990–0.991)	<0.001
Pulse rate	1.008	(1.008–1.009)	<0.001
Respiratory rate	1.019	(1.018–1.021)	<0.001
Body temperature	0.778	(0.774–0.783)	<0.001
EDMEWS	1.164	(1.135–1.194)	<0.001
EDMEWS classification			
EDMEWS (0)	Reference	Reference	<0.001
EDMEWS (1)	1.115	(1.065–1.167)	<0.001
EDMEWS (2)	1.760	(1.669–1.856)	<0.001
EDMEWS (3)	2.143	(2.011–2.285)	<0.001
EDMEWS (4)	2.450	(2.269–2.646)	<0.001
EDMEWS (5)	2.619	(2.390–2.869)	<0.001
EDMEWS (6)	2.580	(2.317–2.874)	<0.001
EDMEWS (7+)	2.508	(2.191–2.871)	<0.001
EDMEWS*AGE	0.998	(0.997–0.998)	<0.001

HR: hazard ratio; CI: confidence interval; EDMEWS: emergency department modified early warning scores; OR: odds ratio.

TABLE 5. Predictive value for in-hospital mortality in elderly and non-elderly patients who admitted from ED assessed using the Cox proportional hazards models.

	Non-elderly (20–64 years) n = 1,202,161			Elderly (over 65 years) n = 1,202,712		
	HR	OR (95% CI)	*p*-value	HR	OR (95% CI)	*p*-value
Age	1.054	(1.052–1.056)	<0.001	1.034	(1.032–1.035)	<0.001
Consciousness						
Alert	Reference	Reference	<0.001	Reference	Reference	<0.001
Verbal response	1.473	(1.416–1.532)	<0.001	1.558	(1.523–1.594)	<0.001
Pain response	2.678	(2.525–2.840)	<0.001	2.563	(2.458–2.697)	<0.001
Unresponsiveness	1.384	(1.332–1.438)	<0.001	1.319	(1.293–1.345)	<0.001
Systolic blood pressure	0.988	(0.988–0.989)	<0.001	0.991	(0.991–0.991)	<0.001
Pulse rate	1.009	(1.009–1.010)	<0.001	1.008	(1.008–1.008)	<0.001
Respiratory rate	1.017	(1.015–1.019)	<0.001	1.020	(1.019–1.022)	<0.001
Body temperature	0.764	(0.756–0.722)	<0.001	0.786	(0.781–0.791)	<0.001
EDMEWS	1.258	(1.211–1.306)	<0.001	1.063	(1.026–1.101)	<0.001
EDMEWS classification						
EDMEWS (0)	Reference	Reference	<0.001	Reference	Reference	<0.001
EDMEWS (1)	1.189	(1.129–1.251)	<0.001	1.082	(1.047–1.117)	<0.001
EDMEWS (2)	1.932	(1.801–2.072)	<0.001	1.523	(1.457–1.593)	<0.001
EDMEWS (3)	2.494	(2.270–2.739)	<0.001	1.762	(1.659–1.870)	<0.001
EDMEWS (4)	30.001	(2.663–3.383)	<0.001	20.001	(1.854–2.160)	<0.001
EDMEWS (5)	3.391	(2.929–3.927)	<0.001	2.072	(1.887–2.275)	<0.001
EDMEWS (6)	3.515	(2.953–4.185)	<0.001	2.213	(1.860–2.473)	<0.001
EDMEWS (7+)	3.744	(2.988–4.690)	<0.001	2.147	(1.860–2.479)	<0.001

HR: hazard ratio; CI: confidence interval; EDMEWS: emergency department modified early warning scores; OR: odds ratio.

as EDMEWS increased from 1 to 7+. The survival curve according to EDMEWS shows that the survival probability decreases as EDMEWS increases (Fig. 5).

We examined the area under the ROC curve (AUROC) of EDMEWS and KTAS for in-hospital mortality (Fig. 6). For the non-elderly group, EDMEWS was 0.721 (95% CI: 0.718–0.724) and KTAS was 0.635 (95% CI: 0.632–0.638), and for the elderly group, EDMEWS was 0.681 (95% CI: 0.679–0.682) and KTAS was 0.613 (95% CI: 0.611–0.615) (Fig. 6).

4. Discussion

We conducted a study to validate the suitability of MEWS as a pre-hospital triage tool in adult patients presenting to EDs.

The study showed that EDMEWS was associated with patient outcomes such as increased mortality and increased length of stay. Therefore, EDMEWS can be used as a tool to determine patient severity and provide evidence to support the decision-making process for ED patient transport and selection of appropriate ED level.

In Korea, an ED patient triage system, KTAS, is used; however, KTAS requires a system with programs and instruments and the judgment of medical staff at each step [16]. Therefore, it is not easily applied to pre-hospital emergency medical centers or long-term care facilities. If MEWS is used as a patient severity classification, which can be easily used by 911 operators and medical staff in long-term care facilities, communication between each other will be improved, ensuring that patients are dispersed to an appropriate hospital for treatment, and thereby solving ED overcrowding.

The results of this study showed that EDMEWS was effective in predicting mortality and prolonged hospitalization. In addition, as the level of KTAS increased in severity, EDMEWS increased accordingly, indicating that KTAS and EDMEWS are associated. The study also revealed a correlation between EDMEWS scores, mortality, and length of stay of patients. In addition, In the non-elderly group, the HR increased from 1.189 to 3.744 as EDMEWS increased from 1 to 7+. In the elderly group, the HR increased from 1.082 to 2.147 as EDMEWS increased from 1 to 7+. The survival curve according to EDMEWS shows that the survival probability decreased as EDMEWS increased. This suggests that MEWS is more sensitive in predicting prognosis in younger patients. The AUROC for in-hospital mortality also showed a better predictive value

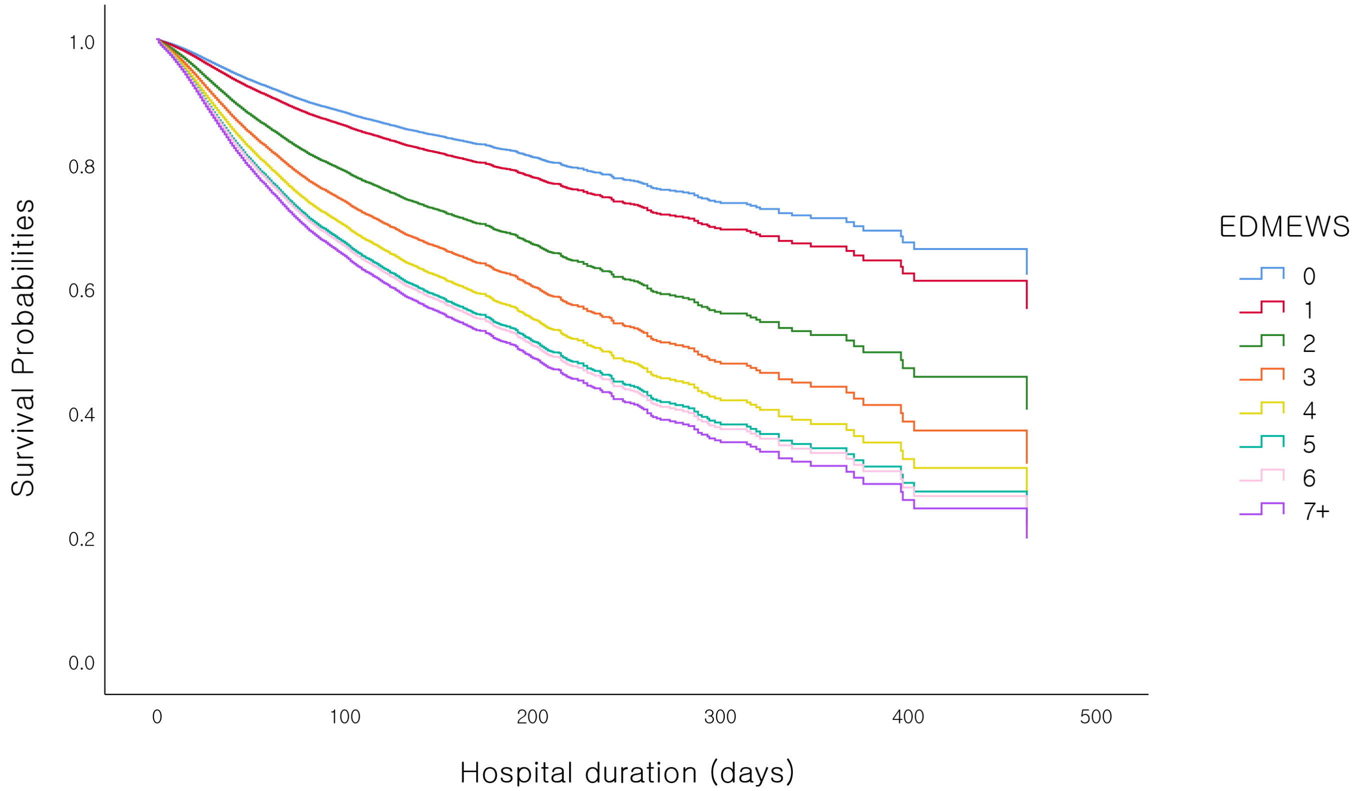

FIGURE 4. Survival curves for the cumulative risk of in-hospital mortality according to the EDMEWS of the non-elderly patients. EDMEWS: emergency department modified early warning scores.

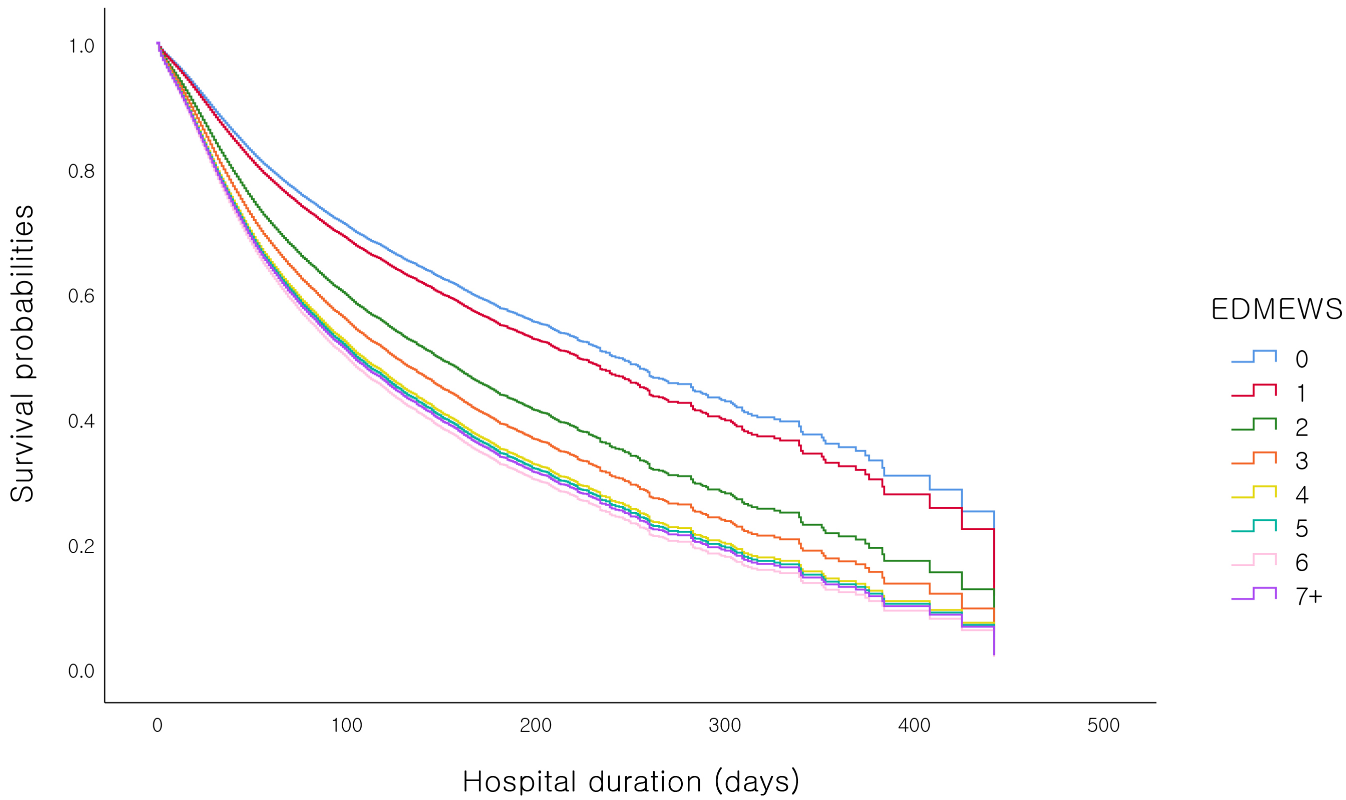

FIGURE 5. Survival curves for the cumulative risk of in-hospital mortality according to the EDMEWS of the elderly patients. EDMEWS: emergency department modified early warning scores.

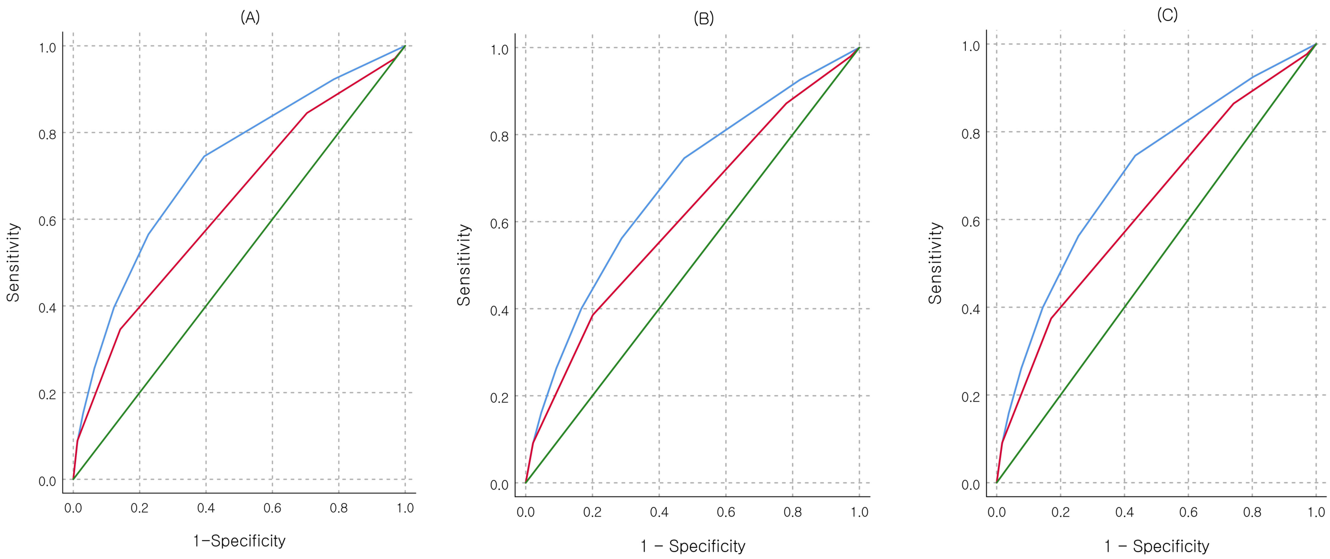

FIGURE 6. Comparison of ROC curve for predicting in-hospital mortality. (A) All-ages group, and (B) Non-elderly group, and (C) Elderly group.

in younger patients. Age itself is considered a risk factor in determining a patient's prognosis [20–22], and while much attention is paid to elderly patients, this suggests that even younger patients should be given greater attention if they have a high MEWS score.

In the non-elderly population, an EDMEWS score of 5 is associated with a 3.391-fold increase in mortality HR compared to a score of 1. This is consistent with previous studies that have shown that patients with increasing MEWS are at higher risk of deterioration, and that a score of 5 or higher increases the risk of ICU admission [23], which is consistent with our results.

In this study, when the cut-off-value was based on 5 and 6 points, the sensitivity was 25.6% and specificity was 93.7% when the cut-off-value was 5 points, and the sensitivity was 15.2% and the specificity was 98.8% when the cut-off-value was 6 points. A study based on a cut-off value of 5 points was the best predictor of transfer to the ICU [24]. In a study involving sepsis patients, it was also found that the morbidity of patients increased when the cut off value was 6 points [25]. Some studies have suggested a cut off value of 4.5 for MEWS in patients with COVID-19 infection [26]. It is believed that differences in scores in the above studies are due to the different disease groups and patients.

Since the cut-off value for predicting high-risk patients who are likely to deteriorate and their prognosis varies depending on the characteristics of the subjects, applying MEWS with a cut-off value that suits the actual situation of the hospital may be useful as a tool for early detection and prognosis of patients with acute deterioration.

In Kao's study, EDMWES was found to be a simple and useful tool that can be used to monitor patient condition and determine prognosis [27]. Our study also proved that EDMEWS works as a precise triage tool.

The study found that EDMEWS at the time of ED admission was significantly correlated with ED clinical outcomes (ED mortality and hospitalization rates) and hospital clinical outcomes (length of stay, mortality and survival probability). Mitsunaga *et al.* [18] evaluated the utility of a pre-hospital modified early warning score (pMEWS) and EDMEWS in predicting hospitalization and in-hospital mortality in elderly patients presenting to the ED at a single hospital. The authors reported that pMEWS was under-utilized as a predictor of hospitalization and in-hospital mortality in elderly patients, whereas EDMEWS was a more accurate predictor of hospitalization and in-hospital mortality [26].

Although this study showed that EDMEWS accurately predicted patient outcomes, more prospective studies are needed to accurately measure vital signs in the pre-hospital setting and apply them accordingly.

This study had certain limitations. First, we retrospectively analyzed nationwide ED arrival and admission data. Therefore, the management of patients was not standardized, and criteria such as hospitalization might have differed for each hospital. Second, because patients with missing data were excluded from the study, there was a chance for occurrence of sampling bias. Third, because we cannot obtain MEWS of pre-hospital and long-term care facilities, we used the MEWS on ED arrival. Since the condition of patients visiting EDs frequently changes, there may exist a gap in determining patient outcomes and prognosis only with the initial EDMEWS score comparing real pre-hospital MEWS. For these reasons, there should be a follow-up study using MEWS of pre-hospital and long-term care facilities.

Fourth, we did not analyze laboratory or imaging findings and procedures that required a prospective study.

5. Conclusions

EDMEWS is a simple and rapid tool for predicting mortality and length of emergency department and hospital stay. EDMEWS can provide evidence to support the decision-making process for ED transport and selection of appropriate ED level; therefore, it may be a useful tool for prehospital EMS and long-term care facilities in determining ED levels. Further prospective studies of prehospital MEWS use are needed.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

DHL and JYL—performed the experiments, authored, analyzed the data, and prepared the tables. JIL—conceived and designed the experiments, authored and reviewed the drafts of the paper and supported with fund. EL—drafted the first manuscript. DHL, JIL and JYL—contributed equally to this work as corresponding authors. All the authors approved the final draft of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Institutional Review Board (IRB) of Ewha Womans' University Mok-dong Hospital (IRB No. 2021-11-013), and informed consent was waived by the IRB because of the retrospective nature of the study, and patient information was anonymized before the analysis.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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