

RESEARCH ARTICLE

## Emergency department Modified Early Warning Score association with admission, admission disposition, mortality, and length of stay

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**Background:** Geisinger Health System implemented the Modified Early Warning Score (MEWS) in 2011 and is fully integrated to the Electronic Medical Record (EMR). Our objective was to assess whether the emergency department (ED) MEWS (auto-calculated by EMR) is associated with admission to the hospital, admission disposition, inpatient mortality, and length of stay (LOS) 4 years after its implementation.

**Methods:** A random sample of 3,000 patients' first encounter in the ED was extracted in the study period (between January 1, 2014 and May 31, 2015). Logistic regression was done to analyze whether mean, maximum, and median ED MEWS is associated with admission disposition, mortality, and LOS.

**Results:** Mean, maximum, and median ED MEWS is associated with admission to the hospital, admission disposition, and mortality. It correlates weakly with LOS.

**Conclusion:** MEWS can be integrated to the EMR, and the score automatically generated still helps predict catastrophic events. MEWS can be used as a triage tool when deciding whether and where patients should be admitted.

Keywords: *Early Warning Score; transition of care; triage, inpatient mortality; admission disposition*

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Received: 28 February 2016; Accepted: 28 March 2016; Published: 25 April 2016

The Modified Early Warning Score (MEWS) was validated in 2001 in the UK as a bedside tool to identify patients at risk of catastrophic events including death. It is based on five physiologic variables (systolic blood pressure, heart rate, respiratory rate, temperature, and neurological status) and is useful as a triage tool for broad range of medical conditions, as a mean to assess efficiency of medical intervention and to identify patients who can benefit from ICU admission (1).

Few studies have explored the association between emergency department (ED) MEWS with hospital admission and inpatient mortality; higher MEWS is associated with higher probability of being admitted to the hospital and higher inpatient mortality. These findings suggested that MEWS could be used as a tool to identify patients requiring admission to the hospital and at an increased risk of death (2, 3).

Since the validation of the MEWS, further studies have documented improved safety and better clinical outcomes when used as a trigger for rapid response team activation (4, 5). Many hospitals in the United States have implemented this tool to monitor patients and recognize those that may

deteriorate and might benefit from escalation of care. In Geisinger Medical Center, a slightly modified MEWS (Table 1) was successfully implemented in 2011 as evidenced by >90% nursing process compliance (6). It is automatically calculated for every patient older than 18 years of age from recorded Electronic Medical Record (EMR) vital signs (7). Nursing protocols guide how health-care personnel react to an elevated MEWS: for example, a MEWS of three prompts retaking vital signs, notifying the registered nurse, and documenting vital signs and urine output more frequently; MEWS of four prompts notifying the provider; and MEWS of five activating the rapid response team.

Although MEWS is part of nursing protocols at Geisinger Medical Center, it is mostly used in the inpatient setting. MEWS could help admitting physicians decide whether and where patients should be admitted. Evidence of association of high MEWS with mortality at our institution might help reinforce its use among health-care personnel. Our goal was to retrospectively assess whether the ED MEWS (auto-calculated by EMR) is associated with admission to the hospital, admission disposition,

**Table 1.** Modified Early Warning Score used at Geisinger Medical Center

Points	3	2	1	0	1	2	3	4
Temperature (°C)		35 or less		35.1–38.4		38.5 or higher		
Heart rate (bpm)		39 or less	40–50	51–100	101–110	111–129	130 or higher	
Systolic blood pressure (mm Hg)	70 or less	71–80	81–100	101–199		200 or higher		
Respiratory rate		8 or less	9	10–18	19–20	21–29	30 or higher	
Glasgow Coma Scale <sup>a</sup>				15	13–14	10–12	6–9	0–4

<sup>a</sup>Neurological status is graded by using the Glasgow Coma Scale instead of AVPU Score.

inpatient mortality, and length of stay (LOS) 4 years after its implementation.

**Methods**

The study protocol was reviewed and approved by Geisinger Medical Center’s IRB. Patients seen in the ED between January 1, 2014 and May 31, 2015 (either discharged from the ED or admitted to General Internal Medicine or Critical Care Medicine) were identified. Variables of interest were extracted from the EMR of a simple random sample of 3,000 of these patients. Variables of interests included demographics (age, gender, and ethnicity), mean of arrival to the ED (ambulance, other, missing), date and time of clinical events (ED admission, admission order placed, and transfer to inpatient bed), ED MEWS, and defining variables (ED MEWS was defined as MEWS from the time the patient was admitted to the ED up until the time the patient was transferred to an inpatient bed). In addition, outcomes of interest including admission to the hospital, mortality, and date of discharge were extracted. Analysis was performed by a member of the biostatistics core.

The number and percentage of ED patients discharged and admitted to the hospital are reported. Demographics and ED MEWS (mean, maximum, and median) of patients not admitted to the hospital are compared with those admitted to the hospital by using Pearson’s chi-squared or Wilcoxon rank-sum tests. Those patients admitted to the hospital are categorized by admission disposition (ICU, high dependency unit (HDU), or general ward), and variables are compared using Pearson’s chi-squared, Fisher’s exact, or Kruskal–Wallis tests. Logistic regression was performed to determine whether the mean and maximum ED MEWS is associated with admission disposition after adjusting for variables. To determine the association of the MEWS with inpatient mortality, the aforementioned analysis was repeated. The association between LOS and MEWS is described using Spearman’s correlation coefficients.

**Results**

A total of 44,042 encounters by 26,497 different patients were identified. Of these, a random sample of 3,000 first encounters was extracted. 2,422 (80.7%) patients were

**Table 2.** Demographics and characteristics of the sample

	All patients with MEWS (n = 2,147)	Patients with MEWS discharged from ED (n = 1,574)	Patients with MEWS admitted to hospital (n = 573)	p
Age at ED encounter, median (IQR)	56 (38, 73)	51 (34, 68)	69 (56, 80)	<0.0001
Gender				<0.0001
Female	1,182 (55.1%)	913 (58.0%)	269 (46.9%)	
Male	965 (44.9%)	661 (42.0%)	304 (53.1%)	
Ethnicity				0.1143
Hispanic/Latino	24 (1.1%)	21 (1.3%)	3 (0.5%)	
Not Hispanic or Latino	2,109 (98.9%)	1,543 (98.7%)	566 (99.5%)	
Missing/unknown	14 (0.7%)	10 (0.6%)	4 (0.7%)	
Means of arrival				<0.0001
Ambulance	654 (30.5%)	382 (24.3%)	272 (47.5%)	
Other	1,420 (66.1%)	1,137 (72.2%)	283 (49.4%)	
Missing/unknown	73 (3.4%)	55 (3.5%)	18 (3.1%)	
Mean MEWS Score, median (IQR)	0.3 (0.0, 1.0)	0.2 (0, 1)	1.1 (0.3, 2.0)	<0.0001
Maximum MEWS Score, median (IQR)	1 (0, 2)	1 (0, 1)	2 (1, 4)	<0.0001
Median MEWS Score, median (IQR)	0 (0, 1)	0 (0, 1)	1 (0, 2)	<0.0001

seen in the ED and not admitted to the hospital; 578 (19.3%) patients were admitted to General Internal Medicine or Critical Care Medicine. Of these, 2,147 (1,574 not admitted to the hospital and 573 admitted to the hospital) had auto-calculated MEWS in their EMR and were included for analysis.

A total of 9,128 individual MEWS were analyzed. Patients who were admitted to the hospital were older, got to the ED by ambulance, and were more likely to be male than female (Table 2). They had a higher mean, maximum, and median ED MEWS than patients not admitted to the hospital (1.1 vs. 0.2, 2 vs. 1, and 1 vs. 0, respectively;  $p < 0.0001$ ) even after adjusting for age, gender, ethnicity, and mode of arrival. Patients admitted to the ICU had a higher MEWS than those admitted to HDU and general ward after adjusting for other variables (Table 3).

Patients who died ( $n = 21$ ) during the encounter had a higher mean, maximum, and median ED MEWS than patients who did not die (medians of 2.6 vs. 0.3, 4 vs. 1, 3 vs. 1, respectively;  $p < 0.0001$ ) (Table 4). There was a mild and statistically significant relationship between LOS and mean, maximum, and median ED MEWS, as shown in Table 5.

## Discussion

Our results support the use of MEWS as a triage system in the ED. Similar results were found in a study done in South Africa; the proportion of admitted patients increased as the MEWS increased. However, the mean MEWS among admitted patients (4) and non-admitted (2.7) patients in their study were much higher than the mean MEWS of our patients (2). This is probably related to the different patient population seen in the two

Table 3. ED MEWS association with admission to the hospital

	Unadjusted				Adjusted			
	OR	95% CI		<i>p</i>	OR	95% CI		<i>p</i>
		Lower	Upper			Lower	Upper	
Outcome = Admitted to hospital vs. not admitted Mean ED MEWS <sup>a</sup>								
Mean ED MEWS (continuous)	2.318	2.079	2.584	<0.0001	2.177	1.938	2.446	<0.0001
Age at encounter (continuous)					1.034	1.028	1.040	<0.0001
Gender (male vs. female)					1.647	1.320	2.055	<0.0001
Ethnicity (Hispanic or Latino vs. not)					0.693	0.197	2.441	0.568
Mode of arrival (ambulance vs. other)					1.671	1.320	2.115	<0.0001
Mode of arrival (missing vs. other)					1.046	0.567	1.933	0.8847
Outcome = Admitted to hospital vs. not admitted Maximum ED MEWS <sup>a</sup>								
Maximum ED MEWS (continuous)	1.939	1.799	2.090	<0.0001	1.834	1.696	1.984	<0.0001
Age at encounter (continuous)					1.034	1.027	1.040	<0.0001
Gender (male vs. female)					1.580	1.260	1.982	<0.0001
Ethnicity (Hispanic or Latino vs. not)					0.834	0.235	2.960	0.7789
Mode of Arrival (ambulance vs. other)					1.569	1.233	1.997	0.0003
Mode of arrival (missing vs. other)					1.040	0.557	1.944	0.9017
Outcome = ICU vs. HDU/general ward <sup>b</sup>								
Mean MEWS score in ED (continuous)	1.792	1.478	2.173	<0.0001	1.741	1.421	2.133	<0.0001
Age at encounter (continuous)					0.976	0.956	0.997	0.0241
Gender (male vs. female)					0.949	0.452	1.992	0.8891
Mode of arrival (ambulance vs. other)					2.949	1.231	7.064	0.0152
Mode of arrival (missing vs. other)					2.345	0.265	20.781	0.4438
Outcome = ICU vs. HDU/general ward <sup>b</sup>								
Maximum MEWS score in ED (continuous)	1.539	1.322	1.792	<0.0001	1.508	1.286	1.768	<0.0001
Age at encounter (continuous)					0.977	0.957	0.997	0.0272
Gender (male vs. female)					0.924	0.442	1.932	0.8345
Mode of arrival (ambulance vs. other)					3.218	1.344	7.703	0.0087
Mode of arrival (missing vs. other)					2.485	0.279	22.154	0.4148

<sup>a</sup>Patients excluded from model if they had missing values for MEWS score or ethnicity.

<sup>b</sup>Patients excluded from model if they had missing values for MEWS.

**Table 4.** ED MEWS association with mortality

Outcome = Death during encounter	Unadjusted				Adjusted			
	OR	95% CI		p	OR	95% CI		p
		Lower	Upper			Lower	Upper	
Mean ED MEWS (continuous) <sup>a</sup>	2.181	1.780	2.672	<0.0001	2.019	1.622	2.513	<0.0001
Age at encounter (continuous)					1.041	1.010	1.074	0.0089
Gender (male vs. female)					2.052	0.793	5.310	0.1383
Mode of arrival (ambulance vs. other)					1.216	0.449	3.292	0.7002
Maximum ED MEWS (continuous) <sup>a</sup>	1.716	1.462	2.014	<0.0001	1.608	1.350	1.915	<0.0001
Age at encounter (continuous)					1.041	1.010	1.072	0.0088
Gender (male vs. female)					1.883	0.745	4.757	0.1808
Mode of arrival (ambulance vs. other)					1.346	0.510	3.605	0.5411

<sup>a</sup>Patients excluded from model if they had missing values for MEWS, ethnicity, or mode of arrival.

**Table 5.** ED MEWS association with LOS

Spearman’s correlation coefficients for relationship between LOS and MEWS	Mean MEWS		Maximum MEWS		Median MEWS	
	Correlation	p	Correlation	p	Correlation	p
	LOS (difference between date stamps in days)	0.177	<0.0001	0.178	<0.0001	0.172
LOS (difference between date stamps and rounded to nearest whole number of days)	0.175	<0.0001	0.179	<0.0001	0.169	<0.0001

hospitals. A more recent study based on a US National Survey found that for every 1 point increase in the MEWS, patients were 33% more likely to be admitted to the hospital (AOR = 1.33) (8).

In-hospital mortality has been associated with higher MEWS in multiple studies. In the validation study, a maximum MEWS of 5 was associated with an increased risk of death (OR 5.4), ICU admission (OR 10.9), and HDU admission (OR 3.3) (1). In another study, the mean MEWS was higher among those patients who died (4.5) than those who lived (3.8) (2). Although the association of mean, maximum, and median MEWS with LOS was statistically significant, it is weak and probably not clinically relevant.

Our study has some limitations. Although there is no protocol guiding patient disposition based on MEWS, admitting physicians were not blinded to the ED MEWS and may have used these scores in their decisions about patient disposition. Because of the retrospective nature of this study, there were missing individual MEWS. We therefore had to exclude patients from analysis and could have introduced selection bias; however, most of the patients without MEWS were not admitted to the hospital. Despite our limitations, we believe our study has many strong points. We analyzed many individual ED MEWS, our sample size was large, and we had very few exclusion criteria, making our results more generalizable.

To have the impact on quality of care and mortality that has been described in the past (4, 9, 10), the MEWS has to be implemented and used in a systematic and protocolized way. Health-care personnel must remember that this, as any other triage system, should just support clinical decision making. As one study suggested (10), we believe that the use of EMR is helpful when implementing and using the MEWS and might have eased its implementation at our institution. It facilitates accuracy, ease of scoring, and documentation of action. Physicians have real-time access to auto-calculated MEWS and graph trends, which could be beneficial when providing care.

### Conclusions

Our results support previously published data on ED MEWS’ association with clinically relevant events. We also provide evidence that this association is maintained when using an auto-calculated MEWS, based on vital signs documented in the EMR. There is convincing evidence that ED MEWS is associated with higher odds of admission to the hospital, admission to ICU and HDUs, and mortality.

Further studies might explore inpatient MEWS association with patient’s flow through the hospital including transfer to different level of care, discharge, and effects of its implementation on quality and mortality at our institution.

## Disclosure

This study was funded by a grant from Geisinger Health System.

## Conflict of interest and funding

The authors have nothing to disclose.

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