

ORIGINAL RESEARCH

General Medicine

A customized early warning score enhanced emergency department patient flow process and clinical outcomes in a COVID-19 pandemic

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Abstract

Objective: Patient crowding and boarding in the emergency department (ED) is associated with adverse outcomes and has become increasingly problematic in recent years. We investigated the impact of an ED patient flow countermeasure using an early warning score.

Methods: We conducted a cross-sectional analysis of observational data from patients who presented to the ED of a Level 1 Trauma Center in Pennsylvania. We implemented a modified version of the Modified Early Warning Score (MEWS), called mMEWS, to address patient flow. Patients aged ≥ 18 years old admitted to the adult hospital medicine service were included in the study. We compared the pre-mMEWS (February 19, 2017–February 18, 2019) to the post-mMEWS implementation period (February 19, 2019–June 30, 2020). During the intervention, low MEWS (0–1) scoring admissions went directly to the inpatient floor with expedited orders, the remainder waited in the ED until the hospital medicine admitting team evaluated the patient and then placed orders. We investigated the association between mMEWS, ED length of stay (LOS), and 24-hour rapid response team (24 hour-RRT) activation. RRT activation rates were used as a measure of adverse outcome for the new process and are a network team response for admitted patients who are rapidly decompensating. The association between mMEWS and the outcomes of ED length of stay in minutes and 24 hour-RRT activation was assessed using linear and logistic regression adjusting for a priori selected confounders, respectively.

Results: Of the total 43,892 patients admitted, 19,962 (45.5%) were in the pre-mMEWS and 23,930 (54.5%) in the post-mMEWS implementation period. The median post-mMEWS ED LOS was shorter than the pre-mMEWS (376 vs 415 minutes;

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$P < 0.01$). After accounting for potential confounders, there was a 4.57% decrease in the ED LOS after implementing mMEWS (95% confidence interval [CI], 4.20–4.94; $P < 0.01$). The proportion of 24 hour-RRT did not differ significantly when comparing pre- and post-mMEWS (33.5% vs 34.4%; $P = 0.83$).

Conclusion: The use of a modified MEWS enhanced admission process to the hospital medicine service, even during the COVID-19 pandemic, was associated with a significant decrease in ED LOS without a significant increase in 24 hour-RRT activation.

KEYWORDS

admission, COVID-19, hospital medicine, hospital rapid response team, isolation, length of stay, vital signs

1 | INTRODUCTION

1.1 | Background

Emergency department (ED) overcrowding is a longstanding problem in the United States. Patient crowding and boarding in the ED are associated with delays in treatment, decreased overall patient satisfaction with care during hospitalization, decreased quality of care, reduced adherence to treatment guidelines, increased rate of patients who left without being seen, and increased mortality.^{1–7}

Early warning scores (EWS) use vital signs to detect early indicators of clinical deterioration. A higher EWS score indicates a higher probability of the patient experiencing a medical crisis requiring expedited and more critical care interventions, whereas those with a lower EWS score are less likely to require such interventions. Several EWS have been developed, including VitalPAC Early Warning Score (ViEWS), Standardized Early Warning Scoring system (SEWS), National Early Warning Score (NEWS), Cardiac Arrest Risk Triage (CART), and the Modified Early Warning Score (MEWS).^{8–11} The clinical value of EWS has been assessed in both the hospital and prehospital settings. In the hospital setting, EWS have been used in the prediction of mortality, cardiac arrest, and resource use in terms of ICU transfers, need for rapid response team (RRT) and Code Blue, and length of stay (LOS).^{8,11–14} In the prehospital setting, the addition of MEWS to clinical judgment has been found to improve detection of critical illness and survival.^{15–17}

1.2 | Importance

Interventions to improve patient flow and address patient ED crowding and boarding have significant potential to positively affect patient outcomes. For patients awaiting admission to the inpatient unit, the time to an admitting clinician's assessment of clinical stability may negatively impact patient flow and lead to ED bottlenecks. Alternatively, there is a risk that a patient who is not seen in the ED prior to going to the inpatient unit may clinically decompensate prompting the need for urgent evaluation by activation of the RRT.

The RRT, whose members include a hospitalist, critical care nurse, bedside nurse, nursing supervisor, and a respiratory therapist, is activated in cases when there is a concern that a patient's condition is rapidly deteriorating in a non-critical care unit. Because these units do not typically require critical care clinicians, the RRT must deploy them to the unit in which the crisis is taking place. This process can disrupt the normal workflow of the unit in question and requires significantly more resources than if the patient was originally transferred from the ED to an appropriately higher level of care. Using mMEWS to place patients in the appropriate level of care could potentially reduce resource usage in the hospital setting and increase the quality of care provided. This investigation examines a measure taken to streamline the admission process during a time of unprecedented demand on our health care system.

1.3 | Goals of this investigation

We aimed to determine the results of an EWS-mediated patient flow intervention to the admission process from the ED of a tertiary medical center in terms of its impact on the ED, length of stay for hospitalized patients, and the risk for an adverse outcome requiring activation of inpatient RRT within 24 hours of admission. Additionally, given the strain placed by the COVID-19 pandemic on the health care system, we sought to assess the impact of COVID testing and admission-related factors on this patient flow process.

2 | METHODS

2.1 | Study design and setting

We conducted a retrospective cross-sectional analysis of observational data from patients who were admitted from the ED of a Level 1 Trauma Center in Northeastern (NE) Pennsylvania with an annual census of approximately 90,000 all-cause ED visits. Approximately 20% of these ED visits are admitted to the adult hospital medicine service. This study was approved by the institutional review board.

The Bottom Line

To avoid admitting emergency department (ED) patients to the inappropriate level of care, ED physicians often wait for an independent hospitalist assessment and orders. Using a modified Early Warning Score, ED clinicians were able to expedite directly admitting patients to the appropriate level of care without any increase in untoward rapid response events.

2.2 | Selection of participants

Patients aged ≥ 18 years old admitted to the adult hospital medicine (HM) service spanning the time period of February 19, 2017 through June 30, 2020 were included in this study. We included only admitted patients, because we were determining the impact of the EWS-mediated flow intervention on the admission process *after* the decision to admit had been made. The intervention was not used as an indicator for admission.

2.3 | Intervention

The MEWS is an EWS derived from heart rate, systolic blood pressure, respiratory rate, temperature, and an AVPU (alert, verbal, pain, unresponsive) level of consciousness score, which has been described elsewhere.¹⁰ Our study intervention used a modification of the MEWS, referred to as modified MEWS (mMEWS). Table S1 displays the components of MEWS and mMEWS scores.

Briefly, mMEWS consists of all components of the original MEWS score, with the exception of the level of consciousness component. The mMEWS patient flow intervention consisted of the automated calculation and display of a patient's mMEWS score on their electronic health record. Patients with a low (less acute) mMEWS score of 0–1 requiring admission from the ED to the adult HM service were admitted using an abbreviated order set, referred to as “streamlined admission orders,” by the emergency medicine clinician (either an attending physician, resident physician, nurse practitioner, or physician assistant). This process expedited the transition of the patient from the ED to the inpatient unit where the HM clinician (either an attending physician, resident physician, nurse practitioner, or physician assistant) subsequently conducted the patient encounter. In contrast, patients with a mMEWS score > 1 awaited the HM clinician to conduct the patient encounter while the patient remained in the ED. The total mMEWS score is the sum of the individual point contributions from the heart rate (0–3 points), systolic blood pressure (0–3 points), respiratory rate (0–3 points), and temperature (0–2 points) and can have a maximum possible value of 11.

We compared the study time periods of pre-intervention (pre-mMEWS) (February 19, 2017–February 18, 2019) to that of post-

intervention (post-mMEWS) (February 19, 2019–June 30, 2020) based on the date of implementation (February 19, 2019) of a patient flow intervention aimed to expedite the ED to inpatient admission process using a modified MEWS (mMEWS) score. The pre-mMEWS admission process consisted of the usual care prior to the implementation of the patient flow intervention. Usual care was that all patients admitted to the hospital medicine service were seen and evaluated by the admitting clinician in the ED before admission orders were placed.

2.4 | Measurements

The independent variables assessed included ED mMEWS score, demographics (age, gender), admission bed type, ED acuity score, and disease-related group (DRG) at discharge. For purposes of variable definition, the admission bed type at the institution studied has 4 levels, with each having an increased level of care provided: medical-surgical, medical-surgical with telemetry, low level, and high level (including medical, surgical, cardiac, or neurosurgical ICUs). The ED acuity score was based on the Emergency Severity Index (ESI) at time of arrival to the ED, which is a 5-level triage algorithm that provides clinically relevant stratification of patients into 5 groups from 1 (most urgent) to 5 (least urgent) on the basis of acuity and resource needs. In regard to the DRG category, we report on complication or comorbidity and major complication or comorbidity of respective DRGs. We looked at the process during the COVID-19 pandemic by using indirect markers such as viral testing orders (COVID, flu/respiratory syncytial virus [RSV], comprehensive respiratory viral panel) and orders for isolation precautions (eg, droplet).

2.5 | Outcomes

The outcome of interest for the study included the ED length of stay (minutes) and the activation of inpatient RRT within 24 hours of admission (24 hour RRT). The RRT provides critical care to patients that are located in non-critical care units. The 24 hour-RRT activation was used as a measure of an adverse outcome of the new process. We compared pre- and post-mMEWS values for both metrics to determine the impact of its implementation. The association between mMEWS and the outcomes of ED LOS in minutes and 24 hour-RRT activation was assessed using linear and logistic regression adjusting for a priori selected confounders, respectively.

2.6 | Analysis

Descriptive statistics were used to describe continuous and categorical variables. According to the results for tests of normality, both graphically and by the Shapiro Wilk test, continuous variables were presented by either means (\pm SD) or the median (25% quartile, 75% quartile). Categorical variables were presented as frequencies and percentages. Inferential statistics for continuous variables were based on

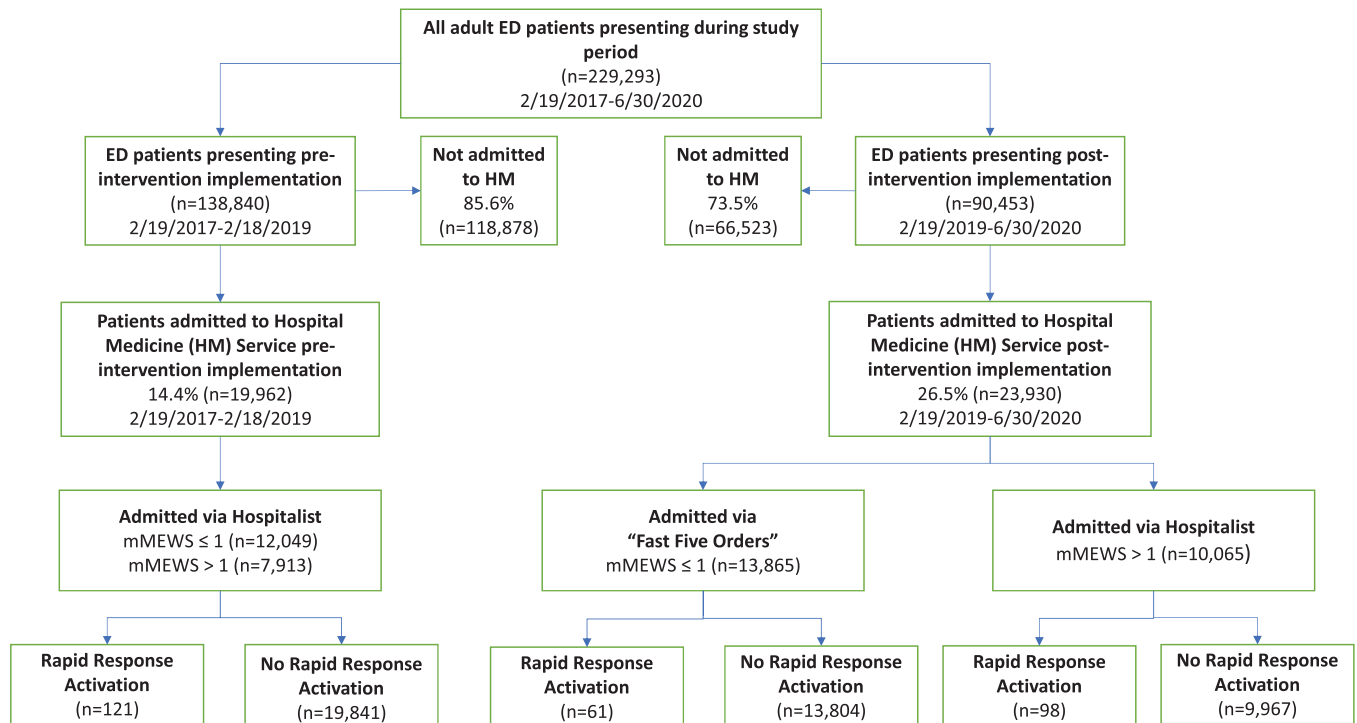


FIGURE 1 Flow diagram of pre- versus post-mMEWS admission process and the RRT activation rates of each. Abbreviations: mMEWS, modified version of Modified Early Warning Score; RRT, rapid response team

the 2-sample *t* test or the Wilcoxon test as indicated. The association between 2 categorical variables was based on the chi-square test. Logistic regression was used to determine the association between a 24 hour-RRT activation and the mMEWS intervention while adjusting for potential confounders. Linear regression was used for the outcome of LOS in the ED. In order to meet the assumption for linear regression, the dependent variable, ED LOS, was log-transformed in the linear regression model and the results are presented as percent change in the ED LOS (minutes) per unit change in the independent variables in the model. The overall significance of a covariate in the multivariable regression model was assessed using the Wald test. The statistical significance was based on a 2-sided test using a significance level of 0.05. All statistical analyses were conducted using the R Foundation for Statistical Computing Platform (version 4.0.2, Vienna, Austria).

3 | RESULTS

3.1 | Characteristics of study subjects

During the overall study period, 229,293 adult ED visits occurred with 138,840 in the pre-intervention period and 90,453 in the post-intervention period. Of those, a total of 43,892 patients were admitted to the HM service, of whom 19,962 (45.5%) were in the pre-intervention and 23,930 (54.5%) in the post-intervention phase (Figure 1). Pre-intervention patients had a median age of 71 (quartile 1[Q1]: 58, quartile 3[Q3]: 82), with 10,135 (50.7%) females and 9827 (49.3%) males. Both pre- and post-intervention patients had a median

age of 71 years. Women slightly outnumbered men in both groups pre-mMEWS: 10,135 (50.7%) females and 9827 (49.3%) males; post-mMEWS: 12,052 (50.4%) females versus 11,878 (49.6%) males. The most frequent ED acuity score of the patients in both pre- and post-implementation phases was level 2, accounting for 61.3% ($n = 26,892$) of the patients. The most common bed type requested on admission was a medical-surgical with telemetry unit (59.5% [$n = 11,883$] pre-implementation vs 63.3% [$n = 15,139$] post-implementation). Of pre-implementation patients, 12% ($n = 2405$) had any form of viral testing whereas 31.6% ($n = 7556$) of post-implementation patients had any viral testing performed. There were 4575 (22.9%) pre-implementation and 7938 (33.2%) post-implementation patients with any form of isolation specified on admission. Among the types of viral tests requested in the ED, the most common was a SARS-CoV-2 (COVID-19) test that was performed in 13.8% ($n = 6061$) of the patients, followed by a comprehensive respiratory viral panel (9.3%, $n = 4086$), and a combined influenza with RSV (2.0%, $n = 872$). Only patients in the post-implementation phase of the study had COVID-19 testing performed. Detailed patient characteristics by mMEWS-mediated process implementation phase can be found in Table 1.

Of the 23,930 post-implementation patients, over half (13,865[57.9%]) had a mMEWS score ≤ 1 . Table 2 displays the characteristics of the patients by mMEWS score (≤ 1 vs > 1). As compared to patients with mMEWS > 1 , those with a mMEWS score ≤ 1 were younger in age, had a greater proportion of ED acuity score of 4, and a greater proportion of medical-surgical bed type requested on admission. A lower proportion of patients with a mMEWS score ≤ 1 had any type of viral testing ordered in the ED or isolation restrictions

TABLE 1 Patient characteristics by mMEWS-mediated process implementation phase

	Overall n (%)	mMEWS mediated process phase		P value
		Preimplementation n (%)	Postimplementation n (%)	
Age, years, median (Q1, Q3)	71 (58,82)	71 (58,82)	71 (57,81)	<0.01
Female	22,187 (50.5)	10,135 (50.8)	12,052 (50.4)	0.40
Preadmission mMEWS				<0.01
0 or 1	25,914 (59.0)	12,049 (60.4)	13,865 (57.9)	
>1	17,978 (41.0)	7913 (39.6)	10,065 (42.1)	
Admission bed type				<0.01
Medical-surgical	10,450 (23.8)	5262 (26.4)	5188 (21.7)	
Medical-surgical telemetry	27,022 (61.6)	11,883 (59.5)	15,139 (63.3)	
Low level	6369 (14.5)	2791 (14.0)	3578 (14.9)	
High level	51 (0.1)	26 (0.1)	25 (0.1)	
ED acuity score				<0.01
1	601 (1.4)	267 (1.3)	334 (1.4)	
2	26,892 (61.3)	12,565 (63.0)	14,327 (59.9)	
3	15,869 (36.2)	6876 (34.5)	8993 (37.6)	
4 or 5	480 (1.1)	231 (1.2)	249 (1.0)	
Viral test in ED				
Comprehensive RVP	4086 (9.3)	2175 (10.9)	1911 (8.0)	<0.01
Flu and RSV	873 (2.0)	615 (3.1)	258 (1.1)	<0.01
SARS-CoV-2	6061 (13.8)	0	6061 (25.3)	<0.01
Any viral test	9961 (22.7)	2405 (12.0)	7556 (31.6)	<0.01
Isolation precautions				
Enhanced	5054 (11.5)	0	5054 (21.1)	<0.01
Droplet	6739 (15.4)	3756 (18.8)	2983 (12.5)	<0.01
Contact	2275 (5.2)	1284 (6.4)	991 (4.1)	<0.01
Airborne	230 (0.5)	107 (0.5)	123 (0.5)	0.80
Any isolation	12,513 (28.5)	4575 (22.9)	7938 (33.2)	<0.01
DRG category				<0.01
Neither	7790 (17.7)	3285 (16.5)	4505 (18.8)	
CC	10,557 (24.1)	5057 (25.3)	5500 (23.0)	
MCC	25,545 (58.2)	11,620 (58.2)	13,925 (58.2)	

Abbreviations: CC, complication or comorbidity; DRG, diagnosis-related group; ED, emergency department; Flu, influenza A & B; MCC, major complication or comorbidity; mMEWS, modified version of Modified Early Warning Score; n, represents frequency; Q1, first quartile; Q3, third quartile; RSV, respiratory syncytial virus; RVP, respiratory viral panel.

of any type requested on admission. In terms of COVID-19 testing in the ED, patients with a mMEWS score ≤ 1 had less testing compared to those with mMEWS > 1 (6.1% vs 11.4%).

When ED viral testing was included in the adjusted regression model by the specific viral test, instead of any versus no testing, there was a significant relative increase in the ED LOS with combined Influenza & RSV test (7.8%; 95% Confidence Interval [CI]: 5.64%, 8.54%), comprehensive RVP (3.91%; 95% CI: 3.24%, 4.59%), and COVID-19 (2.08%; 95% CI: 1.38%, 2.79%).

3.2 | Main results

3.2.1 | ED length of stay

When comparing the pre- to post-mMEWS patient flow intervention, there was a significant decrease in ED LOS in the post-mMEWS group from a median of 415 minutes (Q1 to Q3: 315 to 553) to 376 (Q1 to Q3: 283 to 509) minutes ($P < 0.01$). Table 3 displays the unadjusted and adjusted association between ED LOS and the mMEWS intervention

TABLE 2 Patient characteristics by preadmission mMEWS Score

	MEWS score		P value
	mMEWS ≤ 1 n = 25,914	mMEWS > 1 n = 17,978	
Age, years, median (Q1, Q3)	71 (57,81)	71 (58,82)	<0.001
Female	13,137 (50.7)	9050 (50.3)	0.47
Admission bed type			<0.001
Medical-surgical	7390 (28.5)	3060 (17.0)	
Medical-surgical telemetry	15,139 (61.4)	11,109 (61.8)	
Low level	2589 (10.0)	3780 (21.0)	
High level	22 (0.1)	29 (0.2)	
ED acuity score			<0.001
1	306 (1.42)	295 (1.6)	
2	14,465 (55.9)	12,427 (69.2)	
3	10,744 (41.5)	5125 (28.5)	
4 or 5	376 (1.5)	104 (0.6)	
Viral testing in ED			
Comprehensive RVP	1608 (6.2)	2478 (13.8)	<0.001
Flu and RSV	325 (1.3)	548 (3.0)	<0.001
SARS-CoV-2	1568 (6.1)	2048 (11.4)	<0.001
Any viral testing	4525 (17.5)	5436 (30.2)	<0.001
Isolation precautions			
Enhanced	2189 (8.4)	2865 (15.9)	<0.001
Droplet	2791 (10.8)	3948 (22.0)	<0.001
Contact	1213 (4.7)	1062 (5.9)	<0.001
Airborne	105 (0.4)	125 (0.7)	<0.001
Any type isolation	5627 (21.7)	6886 (38.3)	<0.001
DRG category			<0.001
No CC/MCC	4722 (18.2)	3068 (17.1)	
CC	6715 (25.9)	3842 (21.4)	
MCC	14,477 (55.9)	11,068 (61.6)	

Abbreviations: CC, complication or comorbidity; DRG, diagnosis-related group; ED, emergency department; Flu, influenza A & B; MCC, major complication or comorbidity; mMEWS, modified version of Modified Early Warning Score; n, represents frequency; Q1, first quartile; Q3, third quartile; RSV, respiratory syncytial virus; RVP, respiratory viral panel.

study period while accounting for other patient characteristics. After adjusting for other potential confounders, there was a 4.57% decrease in the ED LOS in the post- relative to the pre-mMEWS intervention time periods. Characteristics that were associated with a longer ED LOS in the adjusted model included female gender (0.72%), any viral testing in the ED (2.11%), any type of isolation restrictions placed on the admission bed request (1.41%), any type of non-medical-surgical bed relative to medical-surgical admission bed type with the largest relative change noted in the Low Level (3.91%), and the ED acuity score with the largest relative change noted in the level 3 relative to level 1 (7.3%). Factors associated with a relative decrease in the ED LOS

included a mMEWS >1 (1.18%) and increasing age where every 10-year incremental increase in age was associated with a 1.16% decrease in ED LOS.

3.2.2 | Rapid response team activation

In the cohort studied, there were 822 (1.9%) RRTs, of which 280 (34.1%) occurred within the first 24 hours of admission. There was no significant difference in the overall rate of RRT (1.8% vs 1.9%; $P = 0.38$) or the proportion of the overall RRTs occurring within first 24 hours of admission when comparing the pre- to the post-intervention time periods (33.5% vs 34.4%; $P = 0.83$) (Figure 1). Compared to those with mMEWS score ≤1, patients with mMEWS > 1 had a higher overall rate of RRT during their hospitalization (2.5% vs 1.4%; $P = 0.02$), as well as a higher proportion of the overall RRTs occurring within first 24 hours of admission (37.5% vs 29.8%; $P < 0.001$). Table 4 displays the odds of RRT within 24 hours of admission. There was no significant change in the risk of RRT within the first 24 hours of admission in the post-mMEWS relative to the pre-mMEWS intervention phase, after adjusting for other potential confounders. Characteristics associated with an increase in the risk of RRT within 24 hours included mMEWS >1, which was associated with a 38% increase in the relative odds and patient age where every 10-year increase in age was associated with a 14% increase in the relative odds of RRT. Although the occurrence of any viral testing in the ED was associated with a decrease in risk for RRT (odds ratio [OR], 0.82; 95% CI: 0.67–0.99), patients with any isolation requirement for their admission had increased risk of RRT (OR, 2.53; 95% CI: 2.11–3.02).

4 | LIMITATIONS

Limitations to this study include the fact that findings may not be generalizable, because it was conducted at a single site in NE Pennsylvania. Additionally, because subjects were placed in an admission cohort based on ordered viral polymerase chain reaction (PCR) testing rather than actual viral (COVID-19) test results, it is unclear if study outcomes would be different if viral tests results were immediately available in the ED setting. The study began before the COVID-19 pandemic and continued to collect data after the pandemic had begun. The difference in number and composition of patient populations before and after the pandemic may have affected the data presented here. We also studied mMEWS only as a tool for triaging more expediently from the ED to the inpatient floor. Comparison data for mMEWS on the patients transferred from other institutions or that were direct admissions were not collected. Finally, a shortened length of stay may not always be a positive outcome; the impact of choosing only this and RRT as indirect measures of the intervention's success is not known.

5 | DISCUSSION

In this study, the implementation of the mMEWS-enhanced admission process was associated with a decrease in ED LOS for hospitalized patients without an increase in adverse events, as measured by RRT

TABLE 3 Modified MEWS-mediated patient flow and other characteristics associated the emergency department length of stay

	Unadjusted model		P value	Adjusted model		P value
	%	95% CI		%	95% CI	
Intervention phase			<0.01			<0.01
Pre	Reference			Reference		
Post	-3.84	(-4.21, -3.48)		-4.57	(-4.94, -4.20)	
Preadmission mMEWS			<0.01			<0.01
0 or 1	Reference			Reference		
>1	-0.73	(-1.11, -0.34)		-1.18	(-1.57, -0.79)	<0.01
Age, per 10 years	-1.08	(-1.18, -0.97)	<0.01	-1.16	(-1.27, -1.05)	<0.01
Female	0.47	(0.09, 0.85)	0.01	0.72	(0.34, 1.10)	<0.01
Admission bed type			<0.01			<0.01
Medical-surgical	Reference			Reference		
Medical-surgical telemetry	0.29	(-0.74, 0.002)		0.99	(0.52, 1.47)	
Low level	2.50	(1.86, 3.15)		3.91	(3.23, 4.60)	
High level	-0.98	(-6.33, 4.69)		-1.04	(-6.38, 4.60)	
ED acuity triage score			<0.01			<0.01
1	Reference			Reference		
2	5.29	(3.58, 7.02)		5.04	(3.35, 6.75)	
3	6.59	(4.85, 8.36)		7.03	(5.29, 8.80)	
4 or 5	5.44	(2.91, 8.03)		5.56	(3.04, 8.13)	
Viral testing in ED			<0.01			<0.01
Any viral testing	1.40	(0.94, 1.86)		2.11	(1.50, 2.73)	
Isolation precautions			<0.01			<0.01
Any type isolation	2.01	(1.59, 2.44)		1.41	(0.85, 1.97)	
DRG category			<0.01			0.01
No CC/MCC	Reference			Reference		
CC	-1.24	(-1.83, -0.66)		-0.14	(-0.74, 0.46)	
MCC	-0.55	(-1.06, -0.04)		0.51	(-0.02, 1.04)	

Abbreviations: CI, confidence interval; CC, complication or comorbidity; DRG, diagnosis-related group; ED, emergency department; LOS, length of stay; MCC, major complication or comorbidity; mMEWS, modified version of Modified Early Warning Score.

activation within 24 hours of admission. It is notable that those with a mMEWS >1 had a higher rate of RRT activation, which is consistent with prior studies indicating that EWS can predict clinical instability.^{8,11-14}

These findings are significant, given that ED visit volumes have been on the rise in many countries over the last few decades.^{18,19} During the COVID-19 pandemic, these same institutions experienced dramatic decreases in the numbers of visits to and overall hospital admissions from the ED.²⁰⁻²² The long-term repercussions of mass delays in health care have yet to make themselves apparent, but ED visit volumes are already returning to their prepandemic highs. This has made the importance of efficiently managing patient throughput critical.

At the onset of the COVID-19 pandemic, there were widespread concerns about the availability of critical care resources. Efforts were made to predict pandemic peaks and prepare hospitals to increase their critical care capacity.²³ In many cases, these efforts proved insufficient, and many hospitals had ICU censuses approaching or exceeding

their maximum capacity.^{24,25} These changes in demand for critical care, brought on by the COVID-19 pandemic, have highlighted the importance of maintaining adaptable systems that can balance and compensate for patient load shifts between departments. The first step in this process is developing an efficient method of placing patients with the appropriate level of care.

At our institution, both emergency and hospital medicine clinical stakeholders had concerns that this admission process could lead to unsafe outcomes for patients who received streamlined admitting orders by emergency clinicians and were transferred out of the ED before being evaluated by the admitting hospitalist. This is a perception that is likely held by others outside our network. This study provides support that using mMEWS is both a safe and effective (as measured by 24-hour RRTs and LOS) method in addressing a bottleneck in ED patient flow. ED overcrowding countermeasures that are safe and effective are crucial, especially during a time when ED LOS has dramatically increased because of the COVID-19 pandemic.²⁶

TABLE 4 Odds of rapid response activation within 24 hours of admission

	Unadjusted model			Adjusted model		
	OR	95% CI	P value	OR	95% CI	P value
Intervention phase			0.36			0.55
Pre	Reference			Reference		
Post	1.07	(0.93,1.23)		0.96	(0.83,1.11)	
Preadmission mMEWS			<0.01			<0.01
0 or 1	Reference			Reference		
>1	1.82	(1.58,2.09)		1.38	(1.19,1.59)	
ED LOS, per 30 minutes	1.00	(0.99,1.01)	0.84	1.00	(1.00,1.01)	0.87
Age, per 10 years	1.12	(1.07,1.17)	<0.01	1.14	(1.09,1.19)	<0.01
Female	1.01	(0.88,1.16)	0.92	1.02	(0.88,1.17)	0.82
Admission bed type			<0.01			<0.01
Medical-surgical	Reference			Reference		
Medical-surgical telemetry	1.58	(1.30,1.93)		1.29	(1.05,1.58)	
Low level	2.60	(2.08,3.27)		1.79	(1.41,2.29)	
High level	3.39	(0.55,11.12)		1.94	(0.31,6.46)	
ED acuity			<0.01			0.20
1	Reference			Reference		
2	0.70	(0.45,1.17)		0.80	(0.51,1.34)	
3	0.47	(0.30,0.80)		0.70	(0.44,1.18)	
4 or 5	0.27	(0.07,0.74)		0.51	(0.14,1.38)	
Viral testing in ED			<0.01			0.04
Any viral testing	1.83	(1.58,2.12)		0.82	(0.67,0.99)	
Isolation precautions			<0.01			<0.01
Any type isolation	2.59	(2.26,2.98)		2.53	(2.11,3.02)	
DRG category			<0.01			<0.01
Neither CC/MCC	Reference			Reference		
CC	0.40	(0.31,0.52)		0.36	(0.27,0.47)	
MCC	1.15	(0.96,1.38)		0.92	(0.76,1.11)	

Abbreviations: % represents percentage; CI, confidence interval; CC, complication or comorbidity; DRG, diagnosis-related group; ED, emergency department; LOS, length of stay; MCC, major complication or comorbidity; mMEWS, modified version of Modified Early Warning Score; OR, odds ratio.

Furthermore, to assess the impact of COVID-19, this study included viral testing orders as the surrogate marker for patients under investigation for COVID-19. This was chosen because it was known to clinicians when making the decision to admit. During the early months of the COVID-19 pandemic, PCR test results could be delayed by up to several days owing to the substantially increased demand placed on testing centers. It was for this reason that actual test results were not used in the data analysis for this study. Interestingly, those with any type of viral testing were shown to have a significantly longer ED LOS. This is consistent with the fact that those with a MEWS score ≤ 1 had a lower proportion of having had viral testing of any type in the ED, and this would be the population admitted with streamlined admission orders.

Last, viral testing was actually associated with a decreased risk for RRT activation, suggesting that this process is safe, even in the context of COVID-19. An area of further investigation includes the evaluation

of the risk that isolation precautions have on patient outcomes. It is counterintuitive that, in our study, any type of isolation increased the risk of RRT when the same cohort of patients with ordered viral panels would presumably also have isolation orders at our institution.

Given that a major area of concern for stakeholders implementing this process is safety, future areas of research should include further outcome measures beyond RRTs and LOS. Additionally, outcomes such as gender-specific outcomes, financial outcomes, and patient satisfaction, among others could be assessed. Our method used a simple “streamlined admission orders” abbreviated order set that included a bed request with the admitting doctor, code status (full code by default was an option that was clarified later by the hospitalist on the floor), diet, ambulation, and venous thromboembolism prophylaxis (compression device). Other variations of the initial order set might result in alternative outcomes.

The use of a modified MEWS-enhanced admission process to the adult hospital medicine service was associated with a significant decrease in ED LOS without a significant increase in adverse outcomes, as measured by RRT events within 24 hours of admission. Using a mMEWS system may help to mitigate ED overcrowding, even during the COVID-19 pandemic.

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CONFLICTS OF INTEREST

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AUTHOR CONTRIBUTIONS

All authors provided substantial contributions to manuscript content. All authors gave final approval of the version of the article to be published.

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