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REVIEW ARTICLE

Modified Early Warning System improves patient safety and clinical outcomes in an academic community hospital

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Background and objective: Severe adverse events such as cardiac arrest and death are often heralded by abnormal vital signs hours before the event. This necessitates an organized track and trigger approach of early recognition and response to subtle changes in a patient's condition. The Modified Early Warning System (MEWS) is one of such systems that use temperature, blood pressure, pulse, respiratory rate, and level of consciousness with each progressive higher score triggering an action. Root cause analysis for mortalities in our institute has led to the implementation of MEWS in an effort to improve patient outcomes. Here we discuss our experience and the impact of MEWS implementation on patient care at our community academic hospital.

Methods: MEWS was implemented in a protocolized manner in June 2013. The following data were collected from non-ICU wards on a monthly basis from January 2010 to June 2014: 1) number of rapid response teams (RRTs) per 100 patient-days (100PD); 2) number of cardiopulmonary arrests 'Code Blue' per 100PD; and 3) result of each RRT and Code Blue (RRT progressed to Code Blue, higher level of care, ICU transfer, etc.). Overall inpatient mortality data were also analyzed.

Results: Since the implementation of MEWS, the number of RRT has increased from 0.24 per 100PD in 2011 to 0.38 per 100PD in 2013, and 0.48 per 100PD in 2014. The percentage of RRTs that progressed to Code Blue, an indicator of poor outcome of RRT, has been decreasing. In contrast, the numbers of Code Blue in non-ICU floors has been progressively decreasing from 0.05 per 100PD in 2011 to 0.02 per 100PD in 2013 and 2014. These improved clinical outcomes are associated with a decline of overall inpatient mortality rate from 2.3% in 2011 to 1.5% in 2013 and 1.2% in 2014.

Conclusions: Implementation of MEWS in our institute has led to higher rapid response system utilization but lower cardiopulmonary arrest events; this is associated with a lower mortality rate, and improved patient safety and clinical outcomes. We recommend the widespread use of MEWS to improve patient outcomes.

Keywords: *Modified Early Warning System*; *mortality*; *rapid response system*; *patient safety*

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Recognition, response, and treatment of deteriorating patients are essential elements of improving patient outcomes and reducing unanticipated inpatient hospital deaths (1–3). Appropriate management of the deteriorating patient is often insufficient when not managed in a timely fashion (1, 3–6). Worsening of physiological and vital parameters frequently herald catastrophic deterioration of patients in the hospital. Clinical deterioration or new complaints were observed in 84% of patients within 8 h preceding cardiopulmonary arrest, and of those 70% had decline in either respiratory or mental function (7). Recognition of these clinical changes, along with early appropriate intervention, may prevent adverse outcomes including cardiac arrest and death (7).

Based on the Institute for Healthcare Improvement's 100,000 Lives Campaign, the rapid response team (RRT) concept has been implemented in many hospitals across the United States in an effort to reduce cardiopulmonary arrests and other serious adverse events since 2004. The conventional rapid response system is activated when a patient meets predefined clinical criteria such as an extreme change in a particular vital sign or a change in the level of consciousness. As a patient's condition deteriorates further and compensatory mechanisms fail to respond, the

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patient's vital signs approach and may eventually meet the pre-established rapid response system (RRS) activation threshold (7). Hence, the RRS alone is in essence more reactive than preventive in nature.

In 1997, Morgan, Williams, and Wright introduced the Early Warning System (EWS) of five physiological parameters of the patient's vital signs (heart rate, respiratory rate, systolic blood pressure, temperature, and consciousness level) not only to predict outcomes but also to serve as a track and trigger system to recognize early signs of deterioration (8). In the United Kingdom, EWS was subsequently modified to Modified Early Warning System (MEWS). In 2007, the National Institute for Health and Clinical Excellence (NICE) recommended that MEWS should be used to monitor all adult patients being admitted to acute care settings to enable the recognition of patient deterioration and to ensure a timely escalation of care. Points are assigned to abnormal values in an effort to guide interventions and to monitor their efficacy. These systems replaced traditional charts which include values plotted on graphs and not specified intervention levels (9). Upon reaching a predefined threshold, the RRT is triggered. At our institution the RRT consists of a hospitalist attending, a third-year medical ICU resident, on call first- and second-year medical residents, and a surgical resident on call, in addition to a respiratory therapist, and an ICU nurse.

Background

In 2011 our institute had experienced a slightly elevated overall inpatient mortality rate, namely 2.30% (Fig. 2f), which was above the institution's goal of less than 2%. Extensive root cause analysis was performed and led the organization's senior clinical leaders to request the implementation of an organized approach of early recognition and response to subtle changes in a patient's condition, in an effort to improve patient outcomes. The MEWS was selected based on a review of the literature. Although the idea of MEWS was still relatively new in the United States, it has been applied successfully in many hospitals in the United Kingdom. The implementation of MEWS was actively executed by both nursing and medical staffs in a closely cooperative manner in our institution. In this study, we share our experience and the impact of MEWS implementation on patient care at an academic community hospital in Northeastern Pennsylvania.

Materials and methods

Implementation of MEWS at Easton Hospital

An Easton Hospital MEWS form (Fig. 1) was developed and approved by nurse practice council, forms committee, and the medical executive committee. The form contained both the scoring system and the action guide. Staff education was then conducted on three pilot medical surgical units among all RNs and the medical staff. After a successful pilot project, house-wide implementation occurred. MEWS measurement protocol was implemented as every 4 h. Additional measurements also took place when clinically indicated. Adherence to the MEWS protocol has been monitored by random surveillance and monthly reviews. The MEWS protocol covered all patients who were admitted to all medical floors, telemetry, and stepdown (non-ICU) settings.

A RRT was called when a patient experienced a clinical deterioration that could lead to cardiopulmonary arrest. A Code Blue was called when a cardiopulmonary arrest actually occurred.

Data collection and statistics

The following data were collected from non-ICU wards on a monthly basis from January 2010 to June 2014. (MEWS was formally implemented in our facility in June 2013.)

1) Number of RRTs per 100 patient-days (100PD)
2) Number of Code Blue per 100PD
3) Result of each RRT and Code Blue (RRT progressed to Code Blue, higher level of care/ICU transfer, etc.)

Categorical variables were expressed as percentages, numerators, and denominators and were compared with the chi-square test. P value less than 0.05 is defined as statistically significant.

Ethics

The study was formally IRB exempt as it was a QI project and entailed only retrospective collection of data. The study was observational in nature. All data were de-identified and patient confidentiality protected.

Results

In June 2013, MEWS measurement was started in a protocolized manner. Table 1 shows the major clinical measurements from January 2010 to June 2014.

Figure 2a (raw data in Table 1) depicts the trend of annual RRT numbers normalized by 100PD over the recording 4½ years. It is evident that the number of RRT has been increasing since the MEWS has been implemented. As compared to 2011, when 120 RRTs had been called over 480 100PD, 176 RRTs had been called over 463 100PD in 2013 (absolute data); a chi-square test has been performed and the statistic is 18.5306. The P value is 1.7E −05. This result is significant at $p < 0.01$. Similarly, RRTs number in 2013 is also significantly higher than 2012 (chi-square 17.834, $p = 2.4E-05$). Based on the first 6 month's data, we're anticipating a further increase of RRT number to 0.48 per 100PD in 2014 as compared to 0.38 per 100PD in 2013 (Fig. 2a, normalized data).

Modified Early Warning System (MEWS)

	3	2	1	0	1	2	3
Respiratory rate per minute		Less than 8	8	9–17	18–20	21–29	greater than or = to 30
Heart rate per minute		Less than 40	40–50	51–100	101–110	111–129	greater than or = to 130
Systolic blood pressure	Less than or = to 70	71–80	81–100	101–159	160–199	200–220	greater than 220
Conscious level (AVPU)	Unrespon-sive	Responds to pain	Responds to voice	Alert	Agitation or confusion	New on set of agitation or confusion	
Temperature		Less than 95.0°F (35.0°C)	95.0–96.8° F (35.05–36° C)	96.9–100.4°F (36.05–38° C)	100.5–101.3° F (38.05–38.5° C)	greater than or = to 101.4°F (38.55°C)	

Source: Kathy D.Duncan RN; Christine McMullan MPA; Barbara M. Mills DNP, PNP, RN, ACNPC, ANPC, CCRN, PCCN – Nursing February 2012

Green = 0–2 Score

Yellow = 3 Score

Orange = 4–5 Score

Red = greater than 6 Score

Date												
Time												
6												
5												
4												
3												
2												
1												
0												
*Interventions												
Initials												

Score	* Interventions – All interventions for each level must be completed – enter letter above	
0 to 2	A =	• Continue routine monitoring of vital signs
3	B =	• Continue Q4 hour vital sign monitoring and calculate MEWS score • If patient remains at “3” for three consecutive readings, call the charge nurse to assess patient
4	C =	• Inform charge nurse and patient’s physician • The charge nurse assesses the patient and notifies the nurse manager / director / supervisor of patients status • Increase vital sign monitoring frequency to 2 hour intervals and calculate the MEWS score • Measure intake and output and notify charge nurse if urinary output falls below 100 mL every 4 hours
5	D =	• Inform patient’s physician and request assessment of the patient by a physician or LIP • Increase frequency of vital sign monitoring, including pulse oximetry to hourly • If patient remains at “5” for three consecutive readings, request transfer to higher level of care
6+	E =	• Call RRT and patient’s physician immediately • Transfer to higher level of care

Initials	Signature	Initials	Signature	Initials	Signature

Nursing – Easton Hospital

Modified Early Warning System (MEWS) Form

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Fig. 1. The MEWS form at Easton Hospital.

Interestingly, we see a trend of decreasing percentage of RRT patients who ended up being transferred to higher level of care since MEWS has been introduced (Fig. 2b).

Of importance, the percentage of RRTs that progressed to Code Blue, an indicator of poor outcome of RRT, has been decreasing too (Fig. 2c). In 2013, 4 out of 176 RRTs progressed to Code Blue, which is significantly lower than the rate we saw in 2012 (8 out of 112, absolute data). The chi-square statistic is 4.0655; the P value is 0.043768. The result is significant at $p < 0.05$. The 2013 rate also

Table 1. Various clinical measurements since January 2010 to June 2014

	2010	2011	2012	2013	2014
RRT	152	120	112	176	166
RRT P100PD	0.3	0.24	0.25	0.38	0.48
RRT to higher (%)	72	63	68	64	50
RRT to CB	8	5	8	4	0
% RRT to CB	5.2632	4.1667	7.1429	2.2727	0.0000
NICB	24	27	16	10	8
NICB P100PD	0.0467	0.0540	0.0354	0.0230	0.0232
Survival rate (%)	61	65	43	65	71

MEWS has been implemented since May 2012. The 2014 data are estimations based on results from January to June. Abbreviations are shown.
100PD: 100 patient-day; NICB P100PD: non-ICU Code Blue per 100 patient-day; NICB: non-ICU Code Blue; RRT P100PD: RRT per 100 patient-day; RRT to CB: RRT progressed to Code Blue; RRT to higher: % RRT patients transferred to a higher level of care; RRT: rapid response team.

trended as compared to 2011 and 2010, although P value did reach 0.05. We had no case of RRT to Code Blue progression in the first 6 months of 2014 (Fig. 2c).

In contrast to RRTs, the numbers of Code Blue called in non-ICU floors has been progressively decreasing after the implementation of MEWS (Fig. 2d). In 2013, 10 Code Blue events were called among 463 100PD, whereas in 2011, the numbers were 27 Code Blue events over 480 100PD (absolute data). The chi-square statistic is 7.5068. The P value is 0.006147. The result is significant at $p < 0.01$. As shown in Fig. 2d, Code Blue in non-ICU setting is 0.02 per 100PD in 2013, which is a decrease from 0.05 per 100PD in 2011 and 0.04 per 100PD in 2012 (normalized data). The estimated number in 2014 is 0.02 per 100PD (normalized data).

There is also a trend of better outcomes of Code Blue as the survival rate appears to have improved in 2013 and 2014 as compared to earlier years, although there was no statistical significance on this (Fig. 2e).

Of note, the overall inpatient mortality of our institute decreased from 2.3% in 2011 to 1.5% in 2013, and we are expecting the number to be 1.2% for 2014 (Fig. 2f). The mortality percentage is derived from the number of inpatient mortality (excluding hospice) divided by number of inpatient discharges.

Discussion

Based on the fact that severe adverse events such as cardiac arrest and death, are often heralded by abnormal vital signs hours before the event (10, 11), the NICE (UK) recommended in 2007 that physiologic track and trigger systems should be used to monitor all adult patients in acute hospital settings (12). Until now, greater than 100 different track and trigger systems have been developed and published (13). These systems can be categorized as single-parameter, multiple-parameter, and aggregate weighted systems. A single-parameter system, such as MERIT criteria (14), is composed of a list of individual physiologic criteria. Multiple-parameter systems, such the one developed by Bleyer et al. (15), use combinations of different physiologic criteria, without complex calculation of a score. Aggregate weighted scoring systems (AWSS), in contrast, are complex systems where vital signs and other variables are scored based on degrees of abnormality, thus allowing for risk stratification of patients and responses based on severity level. Typical AWSS includes the original Early Warning Score (16), the MEWS (17) as described in the current study, the Standardized Early Warning Score (SEWS) (18), the CART score (19), and so on.

Recent studies have shown that AWSS appear to be more effective than single parameter systems in achieving optimal care for the deteriorating patient (20), and it is suggested that a 'whole system' approach should be adopted. Among various AWSS, MEWS is one of the most established and studied EWS.

Consistent with previous studies, data from our study show that institution-wide implementation of MEWS has led to more rapid response system usage, but less cardiopulmonary arrest events and overall better outcome of RRT as suggested by less progression from RRT to Code Blue. The patterns of higher level of care/intensive care unit admission and usage has also been altered. These results suggest that the EWS is an effective risk stratification tool that helps clinicians to identify significant changes in a patient's status earlier. Remarkably, the effort seems to translate beneficially to the overall inpatient mortality rates, which showed significant decline from 2.3% in 2011 to 1.5% in 2013. Although the extract contribution of MEWS to the decreasing overall inpatient mortality is hard to quantify, as other QI projects, and/or changes in practice may also contribute, we do see a positive trend

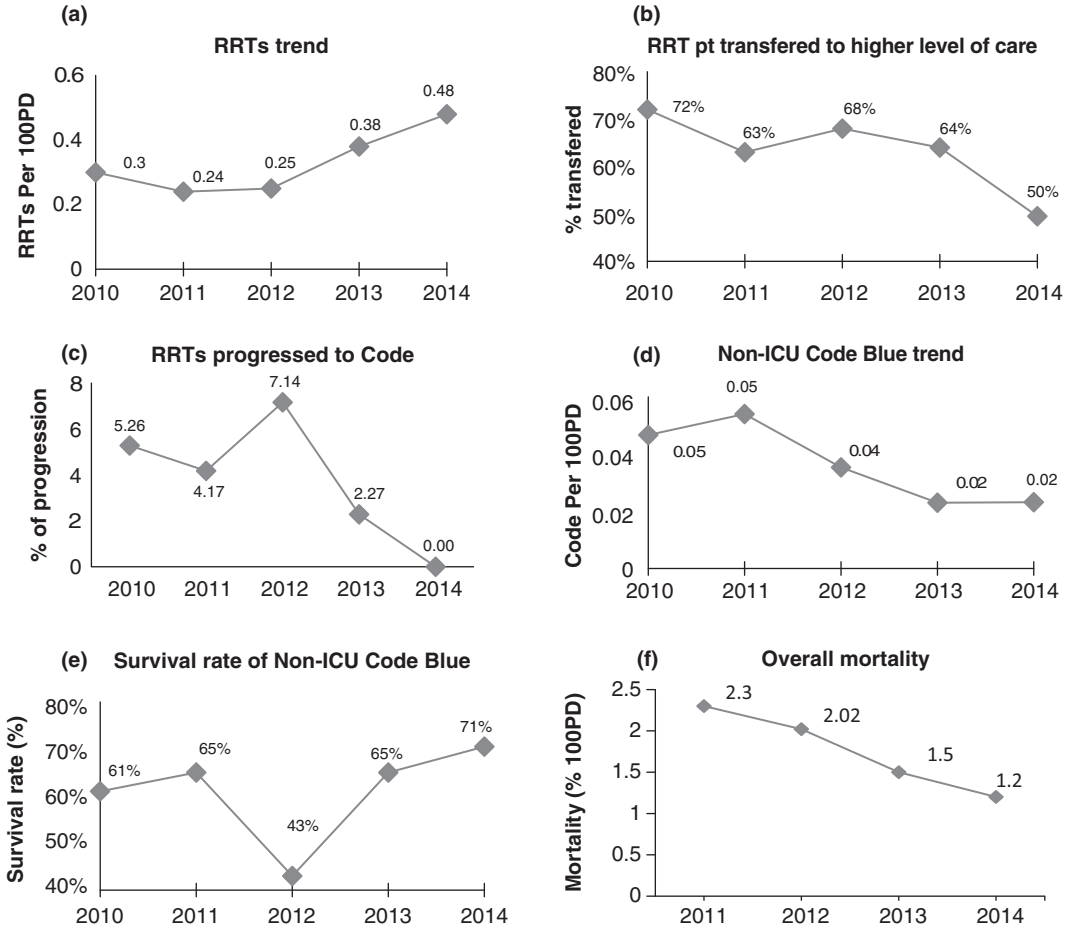

Fig. 2. (a) Annual numbers of RRTs normalized by 100 patient-day since 2010. (b) Percentage of RRT patients been transferred to higher level of care. (c) Percentage of RRTs progressed to Code Blue. (d) Annual numbers of Code Blue normalized by 100PD. (e) Percentage of patient survived Code Blue. (f) Overall inpatient mortality from 2011 to 2014. The 2014 data are estimations based on results from January to June. Abbreviations are shown.

towards improved survival and better clinical outcomes following the introduction of the MEWS. One might also have concern that a RRT might trigger some patients to enter hospice care and therefore indirectly have an impact on overall mortality. We need more detailed data to prove or disprove this possibility.

Although lacking of supporting quantitative data, we do see better communications among different disciplines, in particular, between nurses and physicians with MEWS, likely because MEWS provides a quantitative way for patient severity evaluation. Inexperienced staff nurses feel more confident about when to call a physician or RRT with the aid of MEWS, which provides objective, quantitative scores that guide action. Nevertheless, this by no means suggests that MEWS can replace or undermine critical clinical thinking skills.

We believe that once implemented in an institution, ensuring high levels of adherence to an EWS is necessary to allow for the greatest potential to improve patient outcomes. MEWS were initially recorded on paper-based charts (Fig. 1) in our institute; it is now incorporated into the electronic medical record (EMR) system, allowing standardized and universal implementation of the system throughout the hospital. This process eliminates errors associated with manual calculation and also makes adherence evaluation a lot more effective. The EMR version includes oxygen saturation and thus represents an upgraded version of MEWS, namely SEWS. Of note, the data presented in this study are entirely from paper forms.

A disadvantage of the MEWS system is a relatively high false alarm rate (21). With the wide implication of EMR and large-scale retrospective computations, we anticipate new scoring systems with improved accuracy will be emerging in the near future.

Conclusions

Implementation of MEWS in our institute has led to higher rapid response system utilization but lower cardiopulmonary arrest events; this is associated with a lower mortality rate, improved patient safety, and better clinical outcomes.

Although the study is done in a community academic hospital setting, we are confident that the system can be implemented in all hospitals.

Conflict of interest and funding

Authors declare no conflicts of interest.

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