Design and Development of a Proactive Rapid Response System

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Timely identification of patient deterioration can prompt intervention and prevent the escalation of care and unplanned intensive care admissions. However, both personal experience and professional literature reveals that staff nurses in the acute care setting may not notice subtle signs of patient deterioration or may be reluctant to activate the rapid response system. To overcome these barriers, a proactive rapid response system with early warning signs was created and studied. Using a quasi-experimental design, data were collected from two medical-surgical nursing units at one large tertiary medical center over a 6-month period. One unit used the new rapid response system and early warning sign criteria with real-time data entry and trigger activation. A second unit served as the control and relied on the nurse for rapid response system activation. Findings revealed that the use of the newly developed rapid response system demonstrated significantly greater sensitivity to subtle signs of patient deterioration and prompted early evaluation and intervention.

KEY WORDS: Early warning signs, Patient deterioration, Rapid response system

Studies show that 84% of patients demonstrate early warning signs (EWSs) of clinical deterioration within 8 hours preceding a cardiopulmonary arrest. Further, the survival statistics for these patients are grim, with fewer than 20% of resuscitated patients surviving to be discharged from the hospital.[1,2] Rather than intervening when a cardiac arrest occurs or is imminent, the purpose of this study is to identify patient deterioration early, to proactively intervene, and to reduce the need for patient transfer to a higher level of care. To accomplish this, a set of newly developed EWSs system criteria was introduced and fully integrated into the patient's electronic medical record (EMR). Any criterion that was under or over the given parameters was assigned a score. Scores for each patient were then auto-tallied by the EMR for a total score. Any total score exceeding an assigned threshold prompted a *trigger*, and a resulting follow-up of the patient by the crisis nurse, the leader of the rapid response team (RRT).

BACKGROUND

An RRT, sometimes called a medical emergency team or critical care outreach, is defined as a team of healthcare professionals who bring critical care expertise to the patient's bedside.[3] The first RRT was introduced in Sydney, Australia, in 1990 and in the United States in 1997.[4] Since then, the use of RRTs or a similar system to access expert assistance for inpatient acute care has been endorsed by the Institute of Healthcare Improvement, Agency for Healthcare Research and Quality, and the Joint Commission.[5–7] The composition of RRTs varies by institution but often includes a crisis nurse, a respiratory therapist, and a nursing supervisor.[8] Regardless of composition, the premise is the same, to enable early detection and early intervention, thus preventing intensive care admission or cardiac arrest.[3,9]

In contrast to a RRT, a rapid response system (RRS) is an umbrella term that includes the RRT and an escalation protocol based on the specific EWSs. Rapid response systems consist of an afferent limb (identification) and an efferent limb (response).[10] Early warning signs vary by institution and are composed of select physiological variables and predetermined parameters for each.[11] Early warning system scoring systems can take one of two forms, those based on the deviation of a single physiological parameter and those based on an aggregate score of multiple physiological criteria. The latter involving an aggregate score is considered superior.[10]

A nurse noting patient deterioration may activate the RRS. However, many times, EWSs go unnoticed or unreported.[11] "Failure to rescue," a phrase denoting the inability of bedside caregivers to note or report patient deterioration and take action to intervene, is often applied in retrospect to the hours preceding these types of adverse patient events.[1,12] As a result, subtle changes in vital signs and physiological alterations may be overlooked until compensatory mechanisms fail and the patient requires emergent intervention.[13] Furthermore, while early identification of

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patient deterioration is essential, many other factors have been linked to failure to rescue; among these are insufficient clinical knowledge, breakdown in communication, heavy workloads, difficulty with technology, and lack of vital sign documentation.[13]

In an effort to promote optimal patient outcomes and to bypass barriers preventing activation of the RRS, the researchers devoted more than 6 months to the design and development of highly sensitive EWS criteria and computerized integration of the criteria within the EMR. Once the physiological measures are entered, the system autopopulates a score for criteria outside of the given parameters, tallies the scores for each patient, and generates an alert to the crisis nurse. To determine the efficacy of the new system, the following research question was posed: In the general medical-surgical adult patient population, how does a proactive crisis nurse rounding model using customized EWS criteria integrated into the RRS compare to a reactive call to the crisis nurse by staff affect early recognition of patient deterioration, clinical intervention, and escalation of care?

LITERATURE REVIEW

Articles related to RRSs, also known as *early warning systems* or *track and trigger systems*, are plentiful. A search of Google Scholar, MEDLINE, PubMed, OVID, and CINAHL databases located an extensive number of articles and research studies related to these search terms. In MEDLINE alone, the search terms *early warning signs* found 547 results; the search terms *early warning systems* found 318 references; the search terms *track and trigger systems* found 71 results; and the search terms *rapid response systems* found 281 results. Due to the number of synonyms and overwhelming volume of results, this literature review is limited to publications deemed substantive historical reports related to EWS criteria and studies addressing activation of the RRS, a recognized barrier in failure to rescue.

Early Warning Sign Criteria

The first EWS criteria were proposed in 1997 by Morgan, Williams, and Wright of the United Kingdom and referred to as the Morgan EWS system.[14] The criteria included five physiological measures: heart rate (HR), systolic blood pressure, respiratory rate (RR), temperature, and level of consciousness. Based on the value of each criterion, a predetermined score of 0 to 3 was assigned. The farther away each physiological measure was from the defined normal value, the higher the assigned score. All scores were then totaled for an aggregate score. The selected physiological measures, the parameters, and the assigned value were determined by the authors based on published literature and professional expertise.[15,16]

Building on the five physiological measures proposed by the Morgan EWS system, Stenhouse and colleagues[17] added oxygen saturation and urine output, for a total of seven criteria. Subbe and Welch[12,15] later proposed and validated the Modified Early Warning Score (MEWS) criteria using the same physiological measures proposed by Morgan and Wright,[12,15] but with different parameters. The MEWS was also based on an aggregate score of selected physiological measures with a score between 0 and 3 assigned to each criterion based on its recorded value. The higher the score, the farther away from the defined norm for the given criterion. For example, an RR of less than 8, or between 21 and 29, earns a score of 2. The final score is the sum of all scores for all criteria. Subbe and Welch[12] found that any score of 5 or greater was associated with an increased risk for the escalation of care or patient death.

With so many different EWS criteria, the ambiguity of terms used, and the variations in parameters for selected physiological measures, it is difficult to trace the evolution of EWS criteria and to identify quintessential criteria and weights. However, of the EWS systems reviewed, the MEWS appears to be the most mentioned in the literature, yielding 64 results in PubMed alone using the search terms *MEWS* and *early warning signs*. The MEWS has also been integrated into an electronic format and adopted and customized for specific populations and diagnoses, such as, pediatrics, obstetrics, and patients with sepsis.[18,19]

Activation of the Rapid Response System

To promote the early identification of patient deterioration by the staff nurse, Burns[20] integrated an early warning scoring system into one hospital's EMR. To successfully log into the hospital's electronic system, the staff nurse was forced to acknowledge the patient's EWS score. Results indicated that the electronic integration did improve early identification by staff nurses and a perception by staff that earlier intervention resulted. However, there were no reports comparing scores warranting intervention and activation of the RRS. This must be considered since staff nurse activation of the RRS has been identified as a primary problem in multiple studies.[20–25]

Factors related to this communication breakdown have been attributed to the nurse's fear of reprisal if the call is not viewed as justified, feeling a necessity to contact the primary healthcare provider (HCP) before activating the RRS and a perception by staff nurses that they should effectively manage their assigned patients.[11,21] Overall, we are reminded that for a RRS to be effective, a comprehensive approach is needed to promote optimal patient outcomes.[10]

METHODS

A quasi-experimental design was used to conduct this study. Approval was obtained from the institutional review board. Prior to implementation and data collection, more than 6 months was devoted to developing a EWS tool and working with information technology to integrate the tool into the EMR.

Early Warning Sign Tool Development

Based on the literature review of common EWS criteria and parameters for each criterion and the researchers' own professional experience with critical care, EWS criteria using select physiological measures and parameters were developed and integrated into the EMR. Selected physiological measures included RR, HR, temperature, pulse oximetry (SPO_2), and mean arterial pressure (MAP).

Level of consciousness, included in the MEWS, was not a component of the newly developed EWS criteria but was evaluated by the crisis nurse as secondary data if a trigger occurred. The criterion of SPO_2 was included. SPO_2 had been used by Stenhouse et al,[17,26] and low values have been reported as common antecedents of RRS calls.[17,26]

Although MAP was not found to be included in any of the EWS criteria that we reviewed, MAP reflects both cardiac output and systemic vascular resistance and concisely addresses both systolic and diastolic values. Further, MAP is commonly used to guide patient care in the treatment of sepsis, stroke, and hypertension and in some situations can be considered superior to systolic blood pressure alone.[27–30] Given this and the researchers' own clinical observations, MAP replaced systolic blood pressure in the newly developed EWS criteria.

Scoring of the EWS criteria was based on predetermined parameters. The degree of variance from the predetermined normal parameter for a given criterion resulted in an EWS score ranging from 1 to 3. Unlike many other EWS criteria, a score of 0 was not included if the criterion measured fell within the normal parameter. (See Table 1 for physiological measurements included in the EWS criteria, parameters for each, and the scoring system used.) Once entered, the EMR auto-tabulated an aggregate score visible to the crisis nurse. Any score of 3 or greater resulted in a *trigger*, a type of red flag or alert. Frequency of data collection was dependent on patient condition and HCP orders. Therefore, data were typically entered at the point of care every 4 to 8 hours on general units.

Because the crisis nurse is constantly on the move throughout the shift, it was important to be able to review the data generated on all patients at any point in time from any location. Integrating the criteria into patients' EMRs enabled the crisis nurse to do this. The crisis nurse remotely reviewed triggers every 4 hours using the EMR from any of the computer kiosks located throughout the medical center. For those individuals with triggers, the crisis nurse would evaluate additional data (white blood cell count, blood glucose, lactate levels, level of consciousness, and confusion assessment method) to gain a more comprehensive picture of the patient and to assess for developing sepsis. The final product was a set of fully customized EWS criteria that was anticipated to be highly sensitive to patient instability.

Before going live with the use of the newly developed EWS criteria and RRS, the constructs of validity and reliability were addressed. Content validity of the proposed EWS criteria was established through the review and agreement of fellow crisis nurses and colleagues in the critical care setting. With the permission of Dr Christian Subbe, one of the MEWS developers, reliability was established by comparing the results of the newly developed EWS criteria with the MEWS criteria. For this testing, retrospective analysis was performed comparing MEWS scores against the scores generated by the newly developed EWS criteria. This analysis examined physiological measurements recorded in the EMR prior to 24 RRT calls over a 1-month period. Findings demonstrated that the MEWS criteria captured 71% of the patients (17/24 patients) 6.5 hours prior to an RRT call compared with the pilot EWS criteria that captured 75% of the patients (18/24 patients) within the same timeframe. This analysis supported the sensitivity and reliability of the newly developed EWS criteria. Further, while the new EWS criteria required real-time data entry of physiological measurements, it did not rely on staff nurse recognition and phone activation of the RRS.

Table 1. Physiological Measurements Included in the Final EWS Tool

Vital Sign	Parameter	Score
RR, per minute	≥28	3
	≤10	3
	24–27	2
	23–20	1
Pulse oximetry	<85	3
	85–88	2
	89–92	1
Temperature, Fahrenheit	>102.4	3
	101.5–102.4	2
	100.4–101.4	1
	≤96.8	3
HR, per minute	>129	3
	111–129	1
	40-50	1
	<40	3
MAP	65.5–70.4	1
	60.5–65.4	2
	<60.5	3

Sample and Setting

The setting for this study was a 600-bed level 1 trauma medical center located in the Midwest. Two medical-surgical nursing units from the medical center were invited to participate in the study, one to serve as a control and one to serve as the intervention unit. The nursing units involved in the study were considered sister units; while geographically separate units, the nurses often work both units, one or more days on one unit and then the other. At baseline, the two units were determined to be equivalent in terms of patient population, staffing, census, and rapid response call rates. The average daily census was 25 for the intervention unit and 23 for the control unit. The typical staffing for each unit was one nurse caring for four to six patients.

Intervention

After integrating the EWS criteria into the EMR, education concerning the EWS system and research study was provided to the unit leadership and the educator of both units. Education included an overview of the study, the purpose of the study, discussion concerning the expected challenges of implementation, and potential benefits to the staff and patients. The importance of real-time data entry of physiological measurements was emphasized to representatives of both units. The unit leadership and educator were accountable to disseminate the information to the nursing staff, including the patient care technicians (PCTs), over a 2-week period. Because physiological measurements are entered into the EMR by both nurses and PCTs, education involving both populations was deemed essential.

Likewise, members of the RRT were provided similar education regarding the study as well as expectations specific to their roles. At the institution where the study was conducted, the RRT is composed of one crisis nurse (a registered nurse with a background in critical care) and one respiratory therapist with intubation skills. The crisis nurse has a dedicated role; she/he is not assigned to a specific unit or patient. Each shift, the crisis nurse makes rounds of all nursing units within the medical center to inquire about patients previously identified as having a high risk for deterioration. Additionally, the crisis nurse initiates intravenous access on patients deemed *difficult sticks* and attends and assists all cardiopulmonary arrests needing resuscitation efforts. In situations with patient deterioration but without arrest, the crisis nurse is a first responder to all activations of the RRS and initiates further assessments and interventions. Escalation to a higher level of care is often initiated based on the crisis nurse's findings. At the time of the study, there were a total of 11 crisis nurses, each working 12-hour shifts with both days and night shifts rotated to provide 24/7 coverage.

Once all education for the nursing units and RRT members was complete, the use of the new RRS with EWS criteria and EMR integration went live on the intervention unit and data collection of both units began. Physiological measurements (Table 1) were entered into the EMR by the PCTs and/or nursing staff.

The frequency of performing physiological measurement was prescribed by the HCP or done at the discretion of the nursing staff. Nurses working on the intervention units were not aware of specific measurements or parameters that would serve as triggers for RRS activation. Additionally, the RRS was not automatically activated based on triggers. Rather, the crisis nurse was responsible to review the patient trigger scores of 3 or greater in the EMR every 4 hours and to respond using a standardized algorithm of care (see Figure 1). At the crisis nurse's discretion, one or more steps in the algorithm may be omitted to expedite care and promote optimal patient outcomes.

This same algorithm of care was used on the control unit as well. However, unlike the intervention unit, the EMRs of those patients on the control unit were not automatically populated to report triggers. Instead, nursing staff members initiated an RRT event based on perceived patient need.

Data collection ran concurrently for both units over 6 consecutive months. Data collection included the number of patients who triggered assessment and/or intervention by the crisis nurse or RRT on the intervention unit compared with the number of RRT calls generated by staff from the control unit.

RESULTS

At the end of the 6-month period, data were analyzed using an open source program called R, version 3.1.2, a robust and free statistical computing program available online (The R Foundation for Statistical Computing, Vienna, Austria).

Crisis nurse reviews chart, notes number and severity of measurements that served as triggers, and assesses additional values – lactic acid levels, WBC, blood sugar, CAM score, & LOC
Call the unit and speaks to the charge nurse and/or the staff nurse assigned to the patient.
Visits the patient's bedside and assesses the patient.
Fully activates the RRT to gain the assistance of the respiratory therapist and initiates emergency interventions while the HCP is sought.
Recommends and coordinates transfer of the patient to a higher level of care.

FIGURE 1. Crisis Nurse Standardized Algorithm of Care.

R can operate on a variety of platforms and can use either Windows or MacOS operating system.[31] For this study, patients younger than 18 years of age or who were identified as active comfort measures were excluded from the study. Active comfort measures in this study denote individuals who have do-not-resuscitate orders and who have expressed the wish to limit interventions to those that provide comfort and pain relief. They do not wish to have aggressive or invasive interventions to prolong their lives.

On the intervention unit, a total of 794 instances of triggers were found by the crisis nurse during the every 4-hour EMR review. Of those, 412 bedside assessments and or interventions were completed to potentially prevent further patient deterioration. A full RRT was activated on 132 occasions on the intervention unit. On the control unit, staff activated a RRT event 110 times.

Census remained unchanged for each unit in the postintervention timeframe with a census of 25 for the intervention unit and 23 for the control unit. While the intervention unit had 1 cardiopulmonary arrest and the control unit had 3, there was no significant difference.

However, the newly developed RRS did demonstrate increased sensitivity to early patient deterioration. After controlling for unit, census, and month, Poisson regression analysis demonstrated a significant positive association between the intervention unit and RRT count with a P value < .05 (actual P value = .013) when compared with the control unit. This indicates that the introduction of the newly developed RRS significantly increased the chances of a RRT event on the intervention unit. Table 2 shows patient outcomes by unit. Table 3 shows EWS criteria and the frequency that a trigger was generated with a score of 3 or greater.

DISCUSSION AND IMPLICATIONS

Research reveals that approximately 50% of RRT calls result in patient stabilization without the patient moving to a higher level of care.[1] Reduced lengths of stay and increased satisfaction among patients, families, and nurses are also positive benefits related to having RRTs in place.[13,32,33] The intervention unit had fewer cardiopulmonary arrests than the control unit, therefore there was no significant difference. Perhaps extending the length of the study could have shed more light on this important patient outcome. Regardless, the researchers were pleased with the overall sensitivity of the newly developed EWS criteria and the electronic triggers generated through integration into the EMR.

Table 2. Patient Outcomes by Unit

	Intervention Unit	Control Unit
Triggers	868	N/A
RRTs	132	110
Patients experiencing a cardiopulmonary arrest	1	3
Patients that stayed on the unit	18	16
Patients that transferred to a higher level of care	65	75
Patients who died	0	0

Table 3. EWS Physiological Measurements and Frequency of Trigger Activation

Vital Sign	Frequency
RR	282
Temperature	281
Pulse oximetry	126
MAP	92
HR	13

Prior research demonstrates that RR, HR, and low oxygen saturations are the most frequently reported predictors of patient deterioration.[34] In this study, RR was the most frequent trigger, followed by temperature, SPO_2, and MAP. Heart rate ranked last out of the five most frequent measurements to activate a trigger.

In retrospect, the researchers would have tracked additional data for analysis, such as, length of stay (LOS) for patients receiving RRT activation on the interventional unit and control unit. Rapid response teams have been shown to decrease mean LOS.32 Therefore, it would be valuable to understand how proactive rounding versus reactive rounding affects this variable.[32] We also would have done a post hoc analysis of RRT activation using the conventional EWS criteria on both the interventional and control units and compared that data with the actual data to determine overall capture rate with and without proactive rounding.

Additionally, Barwise et al[32] found that delayed activation of the RRT increased mortality. However, none of the patients in either the control or intervention units died. Perhaps a longer time for data collection could shed more light on this aspect of the new RRS.

The proactive rounding model used in this study promotes timely identification of patient deterioration and overcomes the barrier of requiring staff nurse activation of the RRS. Nevertheless, a limitation was realized. The EMRs are reviewed for trigger activation only one time every 4 hours. It would be helpful if technology prompted a mobile alarm for the crisis nurse so as to not wait for the 4 hours increments of time for EMR review. This presents a future opportunity for interdisciplinary collaboration between nursing and information technology specialists.

Lastly, in reflecting on our study, we wish that we would have obtained consent to record anecdotal remarks made by nurses over the course of data collection. Many times, nurses on the intervention unit were surprised by our visits. While they knew that the study was being conducted and that their unit was the selected intervention unit, they did not know when a patient trigger activated a crisis nurse visit. Often, the nurses remarked that they were glad for the crisis nurse visit and appreciated a second perspective on a patient's situation. A future study incorporating qualitative data concerning EWS tools should be considered.

CONCLUSION

Preparing for and implementing this study was a long and rigorous process. It was vital to maintain open and ongoing communication with key people (crisis nurses, managers, and staff) and to collect and organize an enormous volume of information. The process itself was a great learning experience that has prepared us for future research endeavors.

Developing the ideal RRS is still evolving, as are the EWS criteria that drive development. The addition of MAP as an EWS should be considered and suggests further study given the frequency that it was a trigger in this research.

Lastly, the EWS criteria that we have identified and integrated into the EMR demonstrate the role of nursing in advancing patient care. The electronic alert noted by the crisis nurse does not rely on the nurse to note subtle signs of patient deterioration and activate an RRT event. Still, our RRT was dependent on the every 4-hour review of the crisis nurse to note trigger activation. As technology advances, it would seem reasonable that an automated alert could be sent to the crisis nurse via mobile communication. Therefore, it is imperative that nursing continues to pursue interdisciplinary collaboration with information technology specialists and other healthcare professionals to research and refine EWS tools to promote safe and effective care.

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