Process Improvement for Rapid Response Activation

Michael Marmer

Ping-Jung Liu

Monmouth University Summer Research Program

Professor Richard Eng

Monmouth University

Abstract

A local medical center uses Rapid Response Teams (RRTs) to detect sudden changes in patient conditions before they become a crisis. The team explored 3 months of data from a dataset to better predict the need for calling a medical RRT. Findings from data showed that weekdays had more medical RRTs called than weekends. The dataset however, was missing necessary vital information to help determine the cause for a RRT. The team researched more objective ways to predict when a patient has a significant health status change and proposed adopting the National Early Warning Score (NEWS), published by the Royal College of Physicians in 2007.

The NEWS categorizes seven different vital signs from a score ranging from 0-3. From an aggregate score of the seven parameters, the scale determines necessary interventions for patients. NEWS not only finds strong correlations in predetermining behaviors in patient conditions (i.e. cardiac arrest), but can also determine the longevity of patient conditions (i.e. hospital admission, length of patient stay, and mortality rates). The team created preliminary recommendations to the local medical center on data collections and implementing an early warning score, such as NEWS.

Predicting patient outcomes based on the NEWS vital signs may not solely warrant the need of a medical RRT. Certain scenarios (i.e. cardiac arrest in elderly patients vs. in non-elderly patients) vital sign "norms" can differ between patients. Patient actions, such as facial expression or reactivity, could determine a decline in patient health status much faster than reviewing a longitudinal trend of patient vital signs. The team believes that implementing the NEWS for patients, along with additional parameters, will help determine whether a RRT is warranted. In the next steps of the project, the team plans to use machine learning to create a predictive model that can anticipate patient deterioration based on historical vital signs data and incorporate the work into a mobile application to help process necessary patient information in near-real-time.

Introduction

Working with a local medical center, the team was given three months of data to analyze the trends and patterns in Rapid Response records to improve process efficiency. The dataset contained patient information (date of call, day of the week, time called, age, gender, etc.); the dataset also recorded the vital signs which triggered an RRT call (respiration rate, heart rate, blood pressure, etc.) However, this type of information showed no indication of whether an RRT could have been called due to multiple vital sign failures.

The team focused on finding the patterns, based on the provided data, in Time RRT Called, Day of the Week, Gender, and Age through the data analytic tool Tableau. Through analytics, it was found that medical RRTs were more frequently called on weekdays rather than weekends. Unfortunately, the team did not have enough data to determine the reason behind this pattern and whether an RRT was appropriately being called.

Several other disadvantages of the current data collection process and the dataset were observed. The name of the person who called the RRTs is not recorded. This lack of data may prevent the hospital from investigating whether it was a proper RRT call or a panicking action. The dataset also lacks actual numbers of the numerous vital signs related to patients' critical conditions, so the team was currently unable to build predictive models of patients' situations.

Through the aid of research, the team found the National Early Warning Score (NEWS) system (described in the Methods of this paper), that would benefit the local medical center when collecting vital signs and to help determine if a medical RRT is warranted. The team also found case scenarios of NEWS being implemented throughout various hospitals, and how implementing NEWS along with other medical parameters, can benefit medical RRT processes. The primary goal of our research was to find objective ways to predict when a patient has a significant health status change and how to implement these findings.

Methods

National Early Warning Score (NEWS)

NEWS was introduced by the Royal College of Physicians, located in London, in 2007. The purpose, or the remit, proposed by the Royal College of Physicians was to create (2012) "a standardized track-and-trigger system for acute illness in people presenting to, or within hospitals…[including] the need for recommendations on the urgency of clinical response

required, the clinical competency of the clinical responders and the most appropriate

environment for ongoing clinical care" (pg. x). The following two sections are introduced by the

Royal College of Physicians explaining how the NEWS should be implemented within a medical

environment:

NEWS Scoring Card

Figure 1 is a diagram representation of the NEWS scoring system:

National Early Warning Score (NEWS)*

PHYSIOLOGICAL PARAMETERS	3	2	1	0	1	2	3
Respiration Rate	≤8		9 - 11	12 - 20		21 - 24	≥25
Oxygen Saturations	≤91	92 - 93	94 - 95	≥96			
Any Supplemental Oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic BP	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart Rate	≤40		41 - 50	51 - 90	91 - 110	111 - 130	≥131
Level of Consciousness				A			V, P, or U

*The NEWS initiative flowed from the Royal College of Physicians' NEWS Development and Implementation Group (NEWSDIG) report, and was jointly developed and funded in collaboration with the
Royal College of Physicians, Royal College of Nursing, National Outreach Forum and NHS Training for Innovation

Figure 1 – National Early Warning Score Scoring Card

Figure 1 shows the seven physiological parameters analyzed using the NEWS. The seven

parameters analyzed are as followed: Respiration Rate, Oxygen Saturations, Any Supplemental

Oxygen, Temperature (in Celsius), Systolic Blood Pressure, Heart Rate, and Level of

Consciousness. All parameters are scored, depending on a patient vital sign, from a scale ranging

zero to three. It is important to note that the letters provided in Level of Consciousness stand for

the following: A (Alert), V (Verbal), P (Pain), and U (Unconscious).

NEWS Aggregate Scoring System

Each of the seven parameters provided by the NEWS scoring card are then aggregated

into one final score. The aggregate score determines the frequency in which a patient should be

monitored, and the necessary clinical response. Figure 2 below represents the aggregate scoring

and the necessary responses:

NEWS SCORE	FREQUENCY OF MONITORING	CLINICAL RESPONSE
0	Minimum 12 hourly	• Continue routine NEWS monitoring with every set of observations
Total: 1-4	Minimum 4-6 hourly	• Inform registered nurse who must assess the patient; • Registered nurse to decide if increased frequency of monitoring and / or escalation of clinical care is required;
Total: 5 or more or 3 in one parameter	Increased frequency to a minimum of 1 hourly	• Registered nurse to urgently inform the medical team caring for the patient; • Urgent assessment by a clinician with core competencies to assess acutely ill patients; • Clinical care in an environment with monitoring facilities;
Total: 7 or more	Continuous monitoring of vital signs	• Registered nurse to **immediately** inform the medical team caring for the patient – this should be at least at Specialist Registrar level; • Emergency assessment by a clinical team with critical care competencies, which also includes a practitioner/s with advanced airway skills; • Consider transfer of Clinical care to a level 2 or 3 care facility, i.e. higher dependency or ITU;

Figure 2 – Aggregate NEWS Scoring

Figure 2 breaks down the necessary patient monitoring system a medical center should be
following when implementing the NEWS. It is important to note that in the third section there
are two different scenarios. If an aggregate NEWS is 5 or more, a patient should be monitored a
minimum of every hour, and the necessary personnel are notified of the patient's status. This
section also includes a 3 in one parameter, which is what the Royal College of Physicians refers
to as a "Red Score." If one of the seven parameters have a score of 3 when medical staff is
checking a patient's vitals, it should be treated with the same urgency as an aggregate score of 5
or more, following the necessary protocols. If an aggregate score is 7 or more, a patient's vitals
should be continuously monitored, and the necessary medical staff should be notified
immediately, as well as emergency medical teams (or RRTs). For the purpose of our research,
we are looking to find trends in data within the type of scenarios described above.

Findings

The following are research findings based on the implementation for NEWS in a medical
center setting.

Problems in Medical Staffing

While implementing NEWS, one study shows problems based on current medical staff within a medical center. According to Kolic, Crane, McCartney, Perkins, and Taylor (2015), "Often a large portion of staff working on weekends are more junior and less experienced than those who work on weekdays and are often temporary staff and not familiar with the patients or workplace" (pg. 88). If medical staff is unaware of medical protocol, or if unaware of a specific patient's status, the margin of error in patient health status can significantly increase. Implementing an early warning score like NEWS can be beneficial, but only if the medical staff is properly trained. Understanding the threshold of a patient's health status based on NEWS scoring can help determine if a patient's health status is declining at an alarming rate and if an RRT is warranted.

The same study also suggests that the medical center being studied was greatly understaffed on weekends. Kolic, Crane, McCartney, Perkins, and Taylor state that (2015), "Staffing levels have been shown to be lower on the weekends, which results in a greater workload per healthcare provider. During times of high workload in intensive care setting it was shown that patients had higher mortality rates" (pg. 88). If a medical center is understaffed during certain hours of the week, it makes it increasingly difficult to properly monitor patients. In the case that one patient needs serious medical attention, x number of other patients are left unattended, which can lead to serious medical implications – or even expiration. If the medical center was fully staffed at all hours during the week, a patient with a serious change in health status can be properly maintained, and can potentially save a patient's life.

Problems with Patient Mortality

In two different studies, both implementing NEWS, found that complications based on the condition of the patient can lead to extreme changes in a patient's health status. As reported by Alam, Vegting, Houben, Van Berkel, Vaughan, Kramer, and Nanayakkara (2015), "…NEWS was significantly correlated with patient outcomes, including 30 day mortality, hospital admission, and length of stay at all-time points" (pg. 113). By viewing trending NEWS vital signs, a medical center was capable of trending important factors of patient outcomes. Viewing historical trends in a patient's health status can help determine early patient deterioration or the potential onset of a severe change in health status. By knowing this vital information, the

medical center was more capable of intervening and preventing worse-case-scenarios from occurring.

NEWS does not only aid in determining patient outcomes, but can be used to determine early warning factors for specific medical conditions. According to Abbott, Dorothy, Cron, Wells, Torrance, and Emmanuel (2015), "Current evidence from studies of acute medical patients suggests NEWS is more strongly associated with cardiac arrest, unexpected Intensive Care Unit (ICU) admission or death within 24 h of NEWS being calculated compared to other scoring systems" (pg. 89). While implementing NEWS, a medical center found strong correlations with patient health status and, based on trending vitals, determine where the patient will be located. Reviewing historical trends in patient vital signs can potentially prevent patients from entering critical care, or perhaps even prevent patient mortality 24 hours upon entering a medical clinic.

Differences in Patient Age

A study shows how the age of a patient, based on vital signs, can relate to patient health status and patient location. Churpek, Yuen, Winslow, Hall, and Edelson claim that (2015), "If differences between elderly and nonelderly patients were discovered, it could have important implications regarding how vital signs and early warning scores are used for the identification and triage of high-risk ward patients" (pg. 817). Certain fluctuations in vital signs can be relevant to current patient status. However, based on the age of the patient, serious changes in health status can be more frequent in older patients rather than younger patients (i.e. cardiac arrest).

<u>Use of Medication</u>

As important as following NEWS scoring based on vital sign information is, there are other factors – such as medication – that can fluctuate patient health status. In the same study, Churpek, Yuen, Winslow, Hall, and Edelson present that (2015), "In addition, medications taken for medical conditions, such as β-blockers, can blunt the physiologic response to stress and are more commonly used by older patients" (p 820). Knowing what type of medication a patient is using, regardless of age, is important when reviewing patient NEWS scoring. If a patient's blood pressure is low, but the patient is on β-blockers, the need of a medical RRT may not be warranted due to this being a reaction to the medication. However, if their blood pressure spikes, it may be an indication that the β-blockers are wearing off, or that the medication is not working. Further analysis of the patient would be required and a medical RRT may be warranted.

Patient Physical Symptoms

In some patient cases, implementations of an early warning score may not be relevant. In other cases, additional factors about the patient are more prevalent than vital sign indications. In a medical study, Taulaimat, Gueret, Wisniewski, and Samuel found that patient physical symptoms were stronger indicators of distress than reviewing patient vital signs and they claim (2014), "Breathing frequency, heart rate, and S_{pO_2} explained only a small part of the variability of distress. This suggests that the physicians relied heavily on other observations such as the subjects' facial expressions and use of accessory muscles" (p 1342). Instead of checking patient vital signs, they noticed that in some patient cases that a patient was showing physical signs of distress. It was found that this indication allowed a quicker and necessary response than a response based on checking vital signs and comparing to an early warning score.

Relative Norm

A patient condition norm is all relative to the specific patient. In a study that checks multiple patient vital signs, Forkan and Khalil argue that (2017), "For a normal patient, the threshold of abnormality is different, i.e. the same MBP [mean blood pressure] value can be abnormal for a normal patient but deemed as normal for a hypertensive patient. Hence for many health parameters, normal is actually a relative value for the patient" (pg. 2). Based on current patient status, vital signs waver between case type. However, it does not mean that when a patient scores a 1 or higher on the NEWS scoring system for a single vital sign that they are in danger. If they are steadily within the range of a certain vital sign, though it may be higher, it may be a patient norm for their given health status. Knowing patient history, or current medical status, is just as important as following necessary protocol when implementing NEWS.

Results/Analysis

Based on research findings and proper analysis, the team provides the following results.

Problems with Medical Staffing

When staffing a medical center, it is important to ensure medical staff is properly caring for patients. In the case of newly hired medical staff, it is important to determine who is completing what for a given patient. Recording vital sign information based on NEWS is to be expected, based on the Recommendation section of our paper; however, it is still important to record which medical staff is currently recording and caring for a patient. If a patient's health

status is to change unexpectedly, it is important to know who was caring for that patient at the time, or prior time, to the patient condition changing. In the case of a medical center being understaffed, it is important to ensure those who are working are properly equipped, received proper training, and possess the wherewithal to handle crisis situations. It is equally as important to not only record who is taking care of a specific patient, but the date and time they were last visited and checked. If trends in data seem to spike on off hours when the medical center has less staff, it may be a necessary consideration to increase the staff during those hours.

Problems with Patient Mortality

By implementing the NEWS scoring system, the medical center will be more capable of handling events before they become crises. By viewing continuous records in patient vital signs, there may be early indications that a patient's current health status is about to change. If the medical staff is more aware of these fluctuations or declinations, they will be able to catch cases earlier on to prevent them from becoming crises, thus saving the medical RRT calls for severe crisis situations.

Use of Medication

If it is necessary for a patient to be administered medication based on their condition, it is important to note the type of medication, the dosage, and the time administered. If a patient's health status were to change, it may be that the medication has worn off, or that the medication is not properly helping the patient recover. By knowing the type of mediation being administered, the medical staff will be able to attempt to use a different medication, or note that the wrong medication was being administered to the patient and correct the error before the situation becomes a crisis.

Patient Physical Symptoms

Checking historical vital sign trends takes time. Sometimes, the patient will be in crisis long before an indication in their vital sign records is shown. Physical symptoms such as eyes, skin, respiration quality or rhythm, can be strong indications that a patient is deteriorating. By keeping a close eye on physical symptoms, as well as keeping a record of patient vital signs, there may be earlier indications that a patient's health status is about to change and the proper preventions can be applied.

Relative Norm

It is important to note that all patients have what constitutes his or her own normal. For patients who have hypertension, their blood pressure is always assumed to be high. For elderly patient with cardiac arrest, their fluctuations in vital signs may be normal for their age compared to that of a non-elderly patient with cardiac arrest. All patients are situational, and based on their current primary condition, which may determine what constitutes as normal. Knowing the primary condition, and prevalent medical history can determine the necessary course of action to help ensure patient safety.

Recommendations

Based on the numerous findings and results, several recommendations could be made to improve the efficiency of the current Rapid Response system. The NEWS is currently the most widely used early warning system in England and can provide medical institutions with a standardized track-and-trigger scoring system to predict patient deterioration. The team found that the seven NEWS vital signs are important factors to determine emergent changes in patient's health status and suggests correctly collecting the seven NEWS vital signs by utilizing the NEWS scorecard. This will help determine how likely a certain patient needs a rapid response team. Figure 3 is a clip-image for the template created by the team to be implemented by the local medical center specifically focusing on the NEWS scoring system:
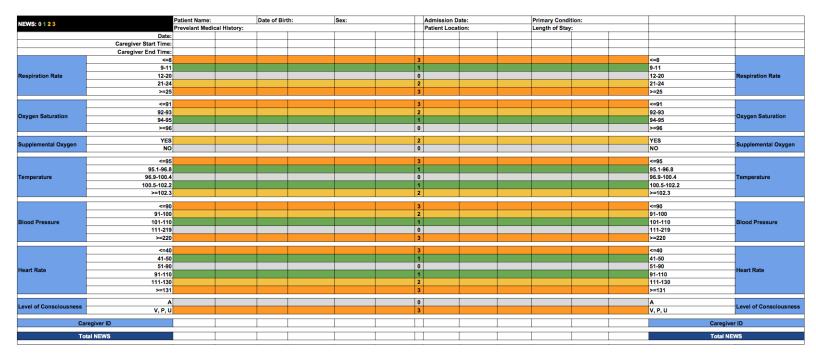
NEWS: 0 1 2 3			Patient Name:	Date of Birth:		Sex:		Admission Date:	Primary Condition:			
		Prevelant Medical History:						Patient Location:	Length of Stay:			
		Date:										
		Caregiver Start Time:										
		Caregiver End Time:										
Respiration Rate	<=8						3				<=8	Respiration Rate
	9-11						1				9-11	
	12-20						0				12-20	
	21-24						2				21-24	
	>=25						3				>=25	
Oxygen Saturation	<=91						3				<=91	Oxygen Saturation
	92-93						2				92-93	
	94-95						1				94-95	
	>=96						0				>=96	
Supplemental Oxygen	YES						2				YES	Supplemental Oxygen
	NO						0				NO	
Temperature	<=95						3				<=95	Temperature
	95.1-96.8						1				95.1-96.8	
	96.9-100.4						0				96.9-100.4	
	100.5-102.2						1				100.5-102.2	
	>=102.3						2				>=102.3	
Blood Pressure	<=90						3				<=90	Blood Pressure
	91-100						2				91-100	
	101-110						1				101-110	
	111-219						0				111-219	
	>=220						3				>=220	
Heart Rate	<=40						3				<=40	Heart Rate
	41-50						1				41-50	
	51-90						0				51-90	
	91-110						1				91-110	
	111-130						2				111-130	
	>=131						3				>=131	
Level of Consciousness	A						0				A	Level of Consciousness
	V, P, U						3				V, P, U	
Caregiver ID												Caregiver ID
Total NEWS												Total NEWS

Figure 3: NEWS Scoring System Template

Figure 3 represents how the medical center can efficiently collect historical data of all the relevant indicators of whether a RRT call is appropriate. Following a similar template created by the Royal College of Physicians, the template also utilizes color schemes to indicate the severity of an indicator in the context of NEWS. All vitals should be collected and recorded as their numerical value within the proper box. The team felt it was equally important to understand how to improve processes with potentially new or weekend medical staff, and added the Caregiver ID to help indicate whom was taking care of a patient at a given time of day. Figure 3 also displays additional parameters such as Admission Date, Primary Condition, Prevelant Medical History, Patient Location, and Length of Stay. These parameters will allow medical staff to determine if a medical RRT is warranted based on a patient's medical history and primary condition. The other additional parameters will allow the process improvement to determine and to predetermine, based on information such as Primary Condition and Length of Stay, similar health status of incoming patients and how to properly care for them based on historical trending data.

Aside from implementing the National Early Warning Score system to predict immediate changes in patient's health status, the team found several other indicators through literature research and exploring the three months worth of data set provided by the local medical center that could be crucial to the prediction process. The team recommends analyzing the following

few signs in addition to the NEWS vital signs: Eyes Condition, Skin Condition, Medicine Administered, Respiratory Rate Quality, and Respiratory Rate Rhythm.

One major finding in the research on RRT process is that often the rapid response teams were called because of inexperienced staff, not patients reaching critical conditions. In addition to medical staff, anyone who feels an RRT is necessary can press the button for a patient. The team suggests that instead of recording identifications of medical staff, the medical center should directly collect the names of those who call an RRT. Figure 4 is a clip-image of the template created by the team displaying the additional parameters described above:

Section	Parameter											Parameter	Section
RRT Intervention Needed	YES											YES	RRT Intervention Needed
	NO											NO	
	Name of Individual Calling RRT:											Name of Individual Calling RRT:	
	RRT Start Time:											RRT Start Time:	
	RRT End Time:											RRT End Time:	
	Number of Interventions:											Number of Interventions:	
Eyes	PERRL											PERRL	Eyes
	Constricted											Constricted	
	Dilated											Dilated	
	Non-Reactive											Non-Reactive	
Skin	Warm											Warm	Skin
	Dry											Dry	
	Moist											Moist	
	Cold											Cold	
	Flush											Flush	
	Pale											Pale	
Blood Sugar													Blood Sugar
Medicine Administered	Type											Type	Medicine Administered
	Dosage											Dosage	
	Time Administered											Time Administered	
Respiratory Rate Quality	Normal											Normal	Respiratory Rate Quality
	Shallow											Shallow	
	Deep											Deep	
Respiratory Rate Rhythm	Steady											Steady	Respiratory Rate Rhythm
	Fast											Fast	
	Slow											Slow	
	Uneven											Uneven	

Figure 4 – Template Additional Parameters

Figure 4, within the RRT Intervention Needed section, there is a section labeled Name of Individual Calling RRT, which includes the information necessary for when an RRT is called. During a medical RRT, there can be a multitude of interventions necessary to help save a patient. The team felt that knowing the number of interventions necessary may be beneficial to data collection and process improvement. Eyes, Skin, Respiratory Rate Quality, and Respiratory Rate Rhythm are categorical values that will allow medical staff, at the time of patient health status review, to determine physical symptoms of a patient. Blood Sugar should be recorded as a numerical value. Lastly, the Medicine Administered section provides Type, Dosage, and Time Administered. Type will indicate the type of medicine being administered, Dosage indicating the numerical value of the dosage, and Time Administered indicating the timestamp of when the medicine was given to the patient. This information will allow medical staff to determine if there is a medication issue with the patient, and keeping a time interval of when medication is administered will allow the staff to properly mitigate when the next dosage will be required.

Next Steps

With the assistance of the new medical template, the local medical center will be able to monitor the conditions of patients more efficiently, and will also be able to provide systematic data set for data analysts to perform rigorous calculations on historical data.

In addition to implementing the NEWS scoring system, the team found out that accurately knowing all the characteristics of a patient at a given time still cannot warrant the need of a medical RRT. In certain scenarios, like Cardiac Arrest in elderly patients versus that in non-elderly patients, there could be severe discrepancies between vital sign norms of patients. The team planned to create a predictive model using machine learning that can accurately anticipate upcoming patient's deteriorations by calculating the norms of each patient individually based on one's historical conditions.

If given further data from medical centers, the team is looking to implement a decision tree algorithm to determine statistically what are some of the more important features that can influence the results of RRT calls. Then, using clustering methods like k-means or support vector machines, the team can identify certain patterns of patients' historical condition trends that are more likely to lead to sudden changes in patient health status. Combining the NEWS template the team created and the predictive model in progress, the local medical center will be able to minimize the chances of unwarranted RRT and ensure the right amount of resources are appropriated for patients in need.

The team's future goal is to create a user-friendly application that can help in the collection of necessary data and use the potential predictive model to immediately calculate the situation of patients. Though educated personnel will still be required to record patients' status into the app, the data preparation and analysis will be automatic, which can further decrease operational expenses and the cost of inappropriate RRT calls.

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