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Modified Early Warning Scoring (MEWS) versus Epic Deterioration Index (EDI): Battle royale for which has the best patient outcomes in the inpatient setting

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Modified Early Warning Scoring (MEWS) versus Epic Deterioration Index (EDI): Battle royale for which has the best patient outcomes in the inpatient setting

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Abstract

Background: The increased workload bedside nurses face today requires new tools to assist with the identification of deteriorating patients during hospitalization. The Modified Early Warning Score (MEWS) tool has formed the background of early warning tools. Newer, more complex tools, like Epic's Deterioration Index (EDI), have been developed to identify patient deterioration earlier. There is lack of evidence in the literature comparing different early warning tools, implementation, and patient outcomes.

Objective: The purpose of the study was to examine models for EWS notification for RRT and patient outcomes between the use of the MEWS and EDI in an adult, acute care in-patient setting.

Methods: This study was a retrospective analysis of admitted adult patients hospitalized during two different 3-month intervals. This study compared the 3-tier alert trigger (RN: 45, Provider: 55. Rapid Response Team: 65) for the EDI to the MEWS' one alert trigger (MEWS >6). The study endpoints examined were Rapid Response notifications, in-hospital mortality rate, hospital length of stay (LOS), code blue activations, unexpected transfers to the intensive care unit (ICU), mechanical ventilation after a rapid response activation, and the use of supplemental oxygen after rapid response activation. Data analysis was performed using descriptive and correlational statistics.

Results: A total of 12,210 patients were examined (n = 6,602 in MEWS cohort and n = 5,608 patients in the EDI cohort). Significant differences were found in Rapid Response notifications (MEWS: 370, EDI: 251, p=0.005), LOS (median: MEWS 1.99, EDI 1.79, p=0.012), unintended ICU transfers (MEWS: 243, EDI 145, p = <.001), mechanical ventilation after a rapid response notification(MEWS: 23.5%, EDI: 16.7%, p= 0.044), and supplemental oxygen after a rapid response notification (MEWS: 27.8%, EDI: 20.7%, p=0.044).

Conclusions: The EDI in tandem with a proactive model of monitoring for deteriorations demonstrated to have better patient outcomes as compared to the MEWS' reactive model.

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Background

Problem Statement

In the past 10 years, a nursing shortage has steadily taken its toll on the U.S. Healthcare system, and the COVID-19 has compounded the problem. One of the areas where this is most evident is patients' health and safety. The risks to patient safety have been amplified with increased nurse-to-patient ratios. These increased ratios, coupled with greater complexity and more acutely ill patients, has created higher workloads for bedside registered nurses (RNs). This has been associated with a decrease in patient safety because the bedside nurses have less time to make difficult decisions regarding care (Wood et al, 2019; Haddad LM & Toney-Butler, 2021). As a result, the bedside nurses are missing the early signs of patient deterioration (Haddad LM & Toney-Bulter, 2021).

Current Evidenced Based Interventions

Pre-pandemic, as a result of staff shortages, hospitals started implementing various tools to help identify and detect patient deteriorations more easily (Helfand, Christensen, & Anderson, 2016). These early warning scoring (EWS) tools make up the first of three pillars of a rapid response system (RRS) or medical emergency response within a hospital. The second pillar consists of the nurses, clinicians, and their ability to recognize a deteriorating patient (Ying Siaw et al, 2015). The third pillar is the Rapid Response team (RRT). These components rely on each other to be effective in mitigating the negative effects of a patient deterioration (Barkowiak et al, 2019; Creutzburg et al, 2021; Danesh et al, 2019; Lee et al, 2020; McGaughey et al, 2021; Ying Siaw et al, 2016; Goellner et al, 2022).

Of the three pillars, the early warning system has seen the greatest evolution since the conception of the RRS. The most common tool used is the Modified Early Warning Signs Score

(MEWS), also known as the "What about Bob?" score (Subbe et al., 2001). It is a simple, physiological scoring system based on systolic blood pressure, heart rate, respiratory rate, temperature, age, body mass index, and mental status (Figure 1). It has been shown to identify patients at risk for catastrophic deteriorations in a variety of patient populations, except until recently in the COVID-19 patient population (Subbe et al., 2001; Somasundaram & Santhiyagappan, 2018; Amanzai et al., 2021). It has been a simple and effective tool, but researchers have been steadily developing tools that show greater sensitivity and specificity with fewer false positives. Some of these EWSs currently in use consist of the National Early Warning Score (NEWS), the Sepsis alert, the Worthing Physiological Scoring System, the Electronic Cardiac Arrest Risk Triage Score, and EPIC's Deterioration Index (Misunaga et al., 2019; Haruna et al, 2021; Sprogis, et al., 2021; Bartkowiak et al., 2019; Malycha et al., 2021; Ratnayake et al., 2019; Esmaeilzadeh et al., 2022). EPIC's Deterioration Index (EDI) was found to have consistently higher sensitivity and specificity at detecting patient deteriorations with a greater positive predictive value (PPV) compared to the other early patient deterioration warning tools (Figure 2). The EDI is built into EPIC's electronic health record program. The EDI score was developed using artificial intelligence and is a predictive analytical model that utilizes patients' vitals, labs, and nursing assessments to monitor for early signs of deterioration (EPIC, 2020; EPIC 2021; D'Aquisto, 2021) (Figure 3).

Site Specific Interventions

At UK Healthcare, the Office of Performance Improvement Services formed the Advancing Best Practice (ABC) committee. This committee was tasked in evaluating and implementing the EDI within UK Healthcare. The committee brought together providers, nurses, and members of the RRT to from a core team to assist with implementation of the EDI that will be replacing the MEWS. The core team was responsible for selecting trigger points and education for the RNs and providers.

The EDI has a score range of 0-100 with three risk categories (Figure 2). The risk categories were labeled low (0-30), medium (31-60), and high risk (61-100). The core teams selected trigger points for alerts to be sent to the bedside RN, provider, and then RRT. The first trigger was selected at 45 and to be sent to the bedside RN. The second trigger was set at 55, to be sent to the provider. Lastly, an EDI score of 65 triggered sending to the RRT. The rationale was first to give the RN opportunity to assess the patient to see if there were any nursing interventions that could improve the patient's clinical status. Examples would be performing pulmonary hygiene, oral care, repositioning the patient, assessing for pain or discomfort, delirium mitigation interventions, or re-evaluating the patient's neurological status to see if there were any acute changes related to medications, metabolic related encephalopathy, and/or acute strokes. If there is something present that could not be corrected after applying nursing interventions, then the nurse is expected to notify the provider or RRT.

If the patient's EDI score continued to climb to a score of 55, then the provider would be notified along with the bedside RN again. The purpose here is to alert the providers, give the providers an opportunity to review the patient's chart and clinical status to see if any additional labs, tests, or medication need to be ordered. If the patient's EDI score continues to climb reaching a score of 65, then RRT would be notified along with the RN and provider. RRT will be expected to review the patient's chart, communicate with bedside RN and provider about the elevated score, then decide if further RRT involvement is required, or if prescribed interventions need more time to work effectively.

After the different alert levels were selected, the ABC committee and the core team analyzed the trigger points to see how often they would alert for a 24-hour period. These results were brought to different sub-committees that represented providers, RNs, and RRT. The sub committees were responsible for signing off on the levels and acceptable number of alerts for a 24-hour period. The purpose of this was to reduce the chance of alarm fatigue among the three different groups so the triggered alerts would not be ignored. The alert trigger levels approved by the subgroups are the ones used to assess non-critical care patients experiencing a clinical deterioration.

Lastly, the core team was responsible with assisting in the development and reviewing education for pre-implementation of the EDI. The education centered around what the EDI is, how it works, how to add it to a clinical rounding report, who is alerted at specific EDI scores, and what alert notification looks like with the expected actions to be taken. The RNs were educated via a web-based training module (Appendix I). Part of the development and outcomes of this DNP study were the development and initiation of these training modules. The providers received education via a symposium and email; this education was conducted prior to the EDI going live enterprise wide.

Purpose of Project

There is a lack of evidence in the literature with comparing the MEWS to a multi-algorithmic program or tool (i.e., EDI) in detection of patient deterioration. Additionally, there is a lack of evidence on how their implementation affects patient outcomes. The purpose of this project was to examine hospitalized, non-critical care patients experiencing a clinical deterioration and how the use of a multifactorial tool, such as the EDI, in the detection of a deterioration and how it affects patient outcomes compared to the MEWS.

Objectives

The objectives for this purposed study were:

1. Compare UK HealthCare's current notification model of the MEWS versus the EDI notification model.
2. Compare patient outcomes, hospital length of stay, unintended ICU transfers, Rapid Response Activations, Code Blues, and mortality rates for the MEWS and EDI

Theoretical Framework

The Iowa Model (Figure 4) was utilized for its ease of use for nurses (White & Spruce, 2015). The model focuses on organization and collaboration that allows for target knowledge and problem-focused triggers; this was why it was selected for this project. This model encourages personnel to question current practices and determine whether care can be improved by using current research findings. If current practices were found to be inadequate the Iowa Model sets the groundwork for improving evidence-based practice (White & Spruce, 2015).

After finding a current practice that needs updating and a suitable intervention is found, then the implementation of an intervention starts with the selection of a topic that can be derived from knowledge-focused or problem-focused triggers. In this case, the need for an EWS tool that is validated in all patient populations on acute and progressive floors care was the selected topic. After this topic was selected, the next step was to form a team that was composed of interested interdisciplinary stakeholders, in this case, the ABC committee (White & Spruce, 2015). The ABC committee and core members, described above, focused on how to implement the EDI hospital wide by developing and disseminating a solution. During the process of implementing the selected solution, the ABC committee and core team searched and retrieved all evidence available on EWS tools with a focus on the MEWS and EDI (White & Spruce, 2015). This allowed for evaluation and comparison of available clinical practice guidelines on the latest evidence-based practice on implementation and comparisons of EWS before implementing one at UK Healthcare. Once the ABC committee, with the assistance of the core team, had decided on which practice guidelines to use, they began the "pilot the change" step (White & Spruce, 2015).

The "piloting the change" step involves selecting outcomes to be achieved, collecting baseline data, developing written evidence-based guidelines, testing the guidelines, evaluating the process and outcomes of the trial, and then modifying the guidelines based on process and outcome data (White & Spruce, 2015). How this was achieved was by piloting the EDI on four different floors that cared for four different patient populations. Providers, organizational and nursing leaders, and RRT were responsible for interacting throughout this process with the committee and core team. When implementing the "pilot the change" step, the Iowa Model suggested several strategies; these strategies included creating awareness and interest, building knowledge and commitment, promoting action and adoption while pursing integration with sustained use (White & Spruce, 2015). The ABC relied on focus groups made up of providers and nurses on these different floors that provided feedback on the implementation of the EDI. The strategies are designed to create acceptance and sustained use within the organization (White & Spruce, 2015). The sustainability strategies fall to the nursing leadership within the organization to implement. The full implementation required leadership to communicate a multi-faceted approach that emphasized the advantages and benefits of the new evidence-based guidelines (White & Spruce, 2015). Furthermore, it required creating awareness and excitement for the implementation of the EDI to aid in the sustainability of the continued use of the tool in practice. (White & Spruce, 2015). This and the next step were achieved through the web-based training module that was required before the roll out of the EDI enterprise wide.

After this, the ABC committee and leadership worked with managers and clinical nurse specialists to determine how the new guidelines affected the daily workflow of personnel involved, identify a process to ensure skill competency, discuss how to troubleshoot implementation issues at the bedside and allow personnel to provide input during the entire process and post implementation (White & Spruce, 2015). The goal was to connect everyone from clinicians, organizational leaders, and stakeholders to build an organizational support system for the new guidelines. This process will occur at a pre-selected time post implementation when enough data is collected and presented before the ABC committee and leadership.

At the pre-selected time for evaluation of the newly implemented guidelines it is essential to identify their significance. This will allow the ABC committee and leadership to examine the effectiveness of guidelines by comparing pre and post implementation data (White & Spruce, 2015).

Review of Literature

Methods of Search

Databases utilized for this literature review included the Cochrane Database of Systematic Reviews, the Cumulative Index for Nursing and Allied Health literature (CINAHL), and PubMed. Due to the availability of healthcare-related academic articles within these databases, no other search methods were utilized. Keyword and title searches used to search for related articles included combinations of and/or were patient deterioration, clinical deterioration, early warning score, modified early warning score, shock index, EPIC deterioration index, deterioration index, track and trigger, failure to rescue, vital signs, rapid response, medical emergency team, hospital risk prediction, predicting patient deterioration, inpatient, electronic health records, and electronic medical records. Inclusion criteria for the articles included written in English, full text, population 18 years or older, and inpatients. Exclusion criteria included pediatrics or obstetric populations, non-inpatient settings, and non-English text.

The literature search yielded 684 articles. These articles were further narrowed down by title and abstract review to articles that specifically investigated EWS and evaluation of EWS within an RRS; this produced 37 articles. These articles were appraised for validity and reliability using the AGREE II instrument (AGREE Next Steps Consortium, 2017). Upon completion of AGREE II evaluation, ten articles were evaluated and graded using Melnyk and Fineout-Overholt's (2005) hierarchy of evidence. All ten articles were published in peer-reviewed journals and selected to be the basis for this literature review.

Synthesis of Evidence

The evidence gathered revealed two main themes: an arms race for the most accurate EWS tool and the practical examination of a single EWS tool by looking at nursing performance and/or patient outcomes. The first focuses on comparing the different EWSs; most of the modern EWS tools are the result of Artificial Intelligence (AI)-based deep learning tools. Using AI has led to the development of tools such as electronic Cardiac Arrest Risk Triage (eCART), the Deep Learning-based Early Warning Systems (DEWS), Predicting Intensive Care Transfers and Other Unforeseen Events (PICTURE), and EDI (Bartkowiak et al., 2019; Cho et al., 2020; Cummings et al., 2021). From these comparisons, researchers found that tools like PICTURE and EDI performed very well in unique patient populations, such as patients with COVID-19, while the MEWS was not validated in these same populations, making the more advanced tools versatile and useful in an acute care population (Cummings et al., 2021; Singh et al, 2020; Amanzai et al., 2021). However, in less developed countries where the healthcare infrastructure and resources are not robust, the MEWS and limited MEWS still prove to be more useful than the more complex tools because they do not require an electronic infrastructure like the more complex EWS tools (Abbey et al., 2021).

Review of the literature that focused on single EWS tools and patient outcomes produced mixed results. The main reason for the mixed results was related to a lack of an agreement on a method of how best to implement and evaluate the different EWS tools (McGaughey et el., 2021). The poor methodology of the studies demonstrated a concern with limiting the number of false positives, leading to setting EWS trigger points high and causing most rapid response models to become reactionary rather than proactive (McGaughey et el., 2021). However, the literature did show that EWS tools had positive effect on clinical staff and thus had a positive effect on patient outcomes. Specifically, Lee et al. (2020) demonstrated through meta-analysis that a significant association between nurses' clinical performance with the implementation of the EWS reduced in-hospital mortality, the number of cardiac arrests and unexpected ICU transfers. Danesh et al. (2019) examined the use of an EWS tool in a proactive Rapid Response model. The results showed that RNs were able to recognize vital sign derangement sooner, leading the RN to mitigate further clinical deterioration; this was evident by the significant drop in the number of unplanned ICU transfers (Danesh et el., 2019). Regardless of the Rapid Response model or type of EWS tool utilized, universally the largest barrier was associated with the failure to recognize the deterioration, thus delaying the notification to the provider or RRT. This gets further compounded by patient loads, staffing shortages, and communication between beside staff, providers and RRT (Lee, Kim, Kim, & Oh, 2020; Danesh et al., 2019; Singh et al., 2020; Creutzburg, Isbye, & Rasmussen, 2021).

There is no direct comparison between the EDI and the MEWS. The literature directly compares early warning tools that are similar to both the EDI and MEWS. For example, the EDI has greater sensitivity and specificity than the NEWS, which is similar enough to the MEWS that one could infer that the EDI is more sensitive and specific than the MEWS as well (Cummings et al., 2021). In another example the DEW, which is similar to the EDI, showed evidence that it had greater sensitivity and specificity compared to the MEWS further implying the EDI might be better than MEWS (Cho et al., 2020). Additionally, there is a lack of direct comparison between MEWS and EDI regarding patient outcomes in the current body of literature. However, there is evidence that compares patient outcomes pre and post implementation of a single EWS tool.

Those results showed that EWS does have a positive effect on unintended ICU transfers (Danesh et al., 2019). The literature was helpful in directing which patient outcomes would be the most beneficial to evaluate along with how to best to evaluate and report them. The most common patient outcomes are unintended ICU transfer, cardiac arrests, hospital length of stay, hospital mortality rate, and number of RRT activations/notifications. Despite the lack of consensus on methodologies with evaluating early warning scoring tools, the use of an early warning scoring tool reduced the number of unintended ICU transfers while enhancing nursing performance in the identification of patient deterioration (Liaw et al., 2016).

Methods

Project Design

This study was a retrospective design to evaluate the efficacy of the EDI compared to the modified early warning score (MEWS) to see if the implementation of EDI has a positive effect on patient outcomes. This study evaluated patient demographics, Case Mix Index, Rapid Response notifications, in-hospital mortality rate, hospital length of stay (LOS), Code Blue activations, unexpected transfers to the ICU, mechanical ventilation after RRT notification, and supplemental oxygen after RRT notification. The definitions for variables are as follows: case mix index was used to compare acuity and complexity between each sample; in hospital mortality is all cases of mortality in the hospital; hospital length of stay is measured in days; code blue activations are activations for cardiopulmonary arrest; Rapid Response notifications are notification triggered by the EWS tool in use or by nurse, provider, or other hospital staff; unintended ICU transfers are a proxy indication for quality of RRS and its components; mechanical ventilation after RRT notification is any intubation occurring on the floor;

supplemental oxygen after RRT notification is any type of supplement oxygen ranging from nasal cannula to noninvasive ventilation.

The data was collected over three-month intervals at two different times: post initiation of the EPIC electronic health record (EHR) (7/1/21-10/31/21), and then 3 months after initiation of EDI (11/1/22-01/31/23). The expectation was the EDI would show decreased in-hospital mortality rate, LOS, Code Blue activations, Rapid Response activations, transfers to the ICU and ICU readmission.

Setting

Agency Description: This project was conducted at the University of Kentucky (UK) medical center in Lexington, Kentucky. UK Healthcare is a level 1 trauma acute care academic facility that has 965 in-patient beds. UK HealthCare has more than 37,000 discharges per year with another 1.9 million outpatient encounters per year (University Health Care Committee, 2021). UK has specialty services that include anesthesia, cardiac, neurosciences, oncology, general surgery, vascular surgery, pediatrics, psychiatry, obstetrics, neonatology, emergency medicine, and women's care (UK HealthCare, n.d.).

Agency's Missions/Goals/Strategic Plan: UK HealthCare's mission centers on a commitment to the pillars of academic health care: research, education, and clinical care. The values UK HealthCare emphasizes are the five DIReCT values of Diversity, Innovation, Respect, Compassion, and Teamwork (UK HealthCare, n.d.). This project aligns itself with the mission and values of UK HealthCare by seeking ways to increase patient safety through research, education innovation and teamwork.

Stakeholders: The stakeholders for this project included the DNP project committee which consists of Dr. Sheila Melander, the chair, Dr. Lacy Buckler, Dr. Ashley Montgomery and Dr. Jacob Higgins, clinical mentors, and Dr. Amanda Wiggins, the statistician. On site stakeholders are Sherry Kopser, Rapid Response Nurse Manager, Dr. Kim Blanton, Chief Nursing Officer, Dr. Lee Vermeulen, Chief Performance and Organization Efficacy Officer, Dr. Phillip Bernard, MD Associate Professor Medical Director of Physician Information Technology Services, Dr. Andrew Bernard, MD Division Chief of Acute Care Surgery and Trauma, Trauma Medical Director, and MD Chair of Trauma Surgery, Dr. Terren Trott, MD Medical Director of Rapid Response, and the Rapid Response Team. Lastly, the peripheral stakeholders are the individuals impacted by the project, this includes the RNs, patient care assistants (PCAs), patients, and providers.

Site-Specific Facilitators and Barriers: The Advancing Best Care (ABC) Committee, the office of Performance Improvement Services, the Center for Clinical and Translational Science (CCTS), and the Clinical Nursing Specialist (CNS) at UK medical center helped with distribution of education and aided with the implementation and evaluation of the DI and MEWS. The primary barriers include staff and faculty understanding, ability to utilize EPIC, burnout, turnover, and lack of participation. To overcome these barriers, education will be provided on the use of early warning scoring tools, and timely follow-up education after implementation will assist with continued participation.

Sample

A convenience sample of all patients admitted to the hospital during the two 3-month intervals was used. The inclusion criteria for this study were: 1) greater than or equal to 18 years of age, 2) admitted for >24 hours with floor, telemetry, or progressive orders, 3) transfers out of the ICU. The exclusion criteria were: 1) any patient admitted with ICU orders from the emergency department or an outside hospital 2) patients in the ICU, procedural area, OB, or emergency department.

Procedure

IRB Approval: The application for project approval was submitted to the UK Institutional Review Board (IRB) and Nursing Research Council. UK IRB approved an exempt study on September 23, 2022, with clarifications to the study accepted on February 15, 2023. All data obtained from the study was de-identified and stored according to CITI group and UK HealthCare standards. This included a password protected computer that is further protected by a firewall with an encrypted link to UK Healthcare and University of Kentucky servers.

Study Intervention: Based on the literature review, the proposed study evaluated patient outcomes of the EDI compared to the MEWS. This study also examined how each tool was implemented.

Measures

Data Collection: All patients in the sample were de-identified and given a unique identifier. A crosswalk table that links to the patient's MRN was created and kept separately from the study data on a an encrypted, password-protected laptop. All data was organized onto an Excel spreadsheet before being transferred to SPSS for analysis.

The information collected included patient demographics such as age, sex, ethnicity/race, and case mixed index (CMI). Outcome measures that were collected included hospital length of stay, in-hospital mortality, rapid response notifications, cardiopulmonary arrest activations (code blue), unintended transfers to the ICU, mechanical ventilation after RRT activation, and supplemental oxygen after RRT activation. The data was collected in two 3-month intervals starting with 7/1/2021-10/31/2021, and then between 11/1/2022-1/31/2023, after the implementation of the EDI hospital wide.

Data Analysis: Statistical analysis was performed through the utilization of the statical computer software SPSS version 24. Descriptive statistics were utilized and included frequency distributions, means, and standard deviation in describing patient demographics. For patient outcomes that statistical test used for comparison were made using the median, interquartile ranges, Mann-Whitney U test, and Pearson Chi-Square.

Results

The sample consisted of 12,210 patients over the span of two 3-month intervals (Table 1). For the MEWS cohort, there were 6,602 patients and 5,608 patients for the EDI cohort. The sample age range was between 18-98 years of age. The mean age for the MEWS cohort was 55.25 ±17.098 years. The EDI cohort's mean age was 56.17 ± 16.723 years. The MEWS comprised 47.7 % men and 52.3% women while the EDI consisted of 49.6% men and 50.4% women. Both EWS tool cohorts were composed mostly of Caucasians with 89.1% for the MEWS, and 89.5% for EDI. Patients of African descent made up 7.9% and 7.7%, respectively. The case mix index (CMI) was 2.1998 for the MEWS and 2.1668 for the EDI (Table 1).

The patient outcomes examined were Rapid Response Team (RRT) notifications, hospital length of stay (LOS), unintended ICU transfers, in-hospital mortality, Code Blue activations, mechanical ventilation after RRT activation, and Supplement oxygen after RRT activation (Table 2). The EDI cohort had fewer rapid response notifications (251 activations, 4.5%) than the MEWS cohort (370 activations, 5.6%) with an associated $p = 0.005$. The EDI cohort had a shorter hospital LOS of 1.79 days (1st IQR: .82, 3rd IQR: 4.56 days) compared to the MEWS which was 1.99 days (1st IQR: .71, 3rd IQR: 5.24 days, p= 0.012). The MEWS cohort had a lower in-hospital morality rate of 2.0% where the EDI had 3.1% ($p<0.001$). For unintended ICU transfers, the EDI had 145 transfers as compared to the MEWS which had 243 transfers (2.6 % and 3.7%, respectfully; ($p<0.001$). Code Blue activations were not statistically significant when the two EWS tools were compared with each having only 27 activations (MEWS: 0.4%, EDI: 0.5%; p=0.547). For mechanical ventilation after an RRT activations, the EDI had less patients mechanically ventilated with 16.7% of patients while the MEWS had 23.5% patients (p = 0.041). Lastly, the EDI had less patients on supplemental oxygen after a RRT activation with 52 patients (20.7%) where the MEWS had 103 patients (27.8%) with a p = 0.044.

Discussion

Overall, the EDI outperformed the MEWS in this study, however there are some important take aways when setting up a new EWS tool. Setting up any EWS tool requires a balancing act with multiple factors that need to be taken into consideration. These important considerations are patient population, resource availability, the hospital infrastructure, and the RRS in place (Burke et al, 2022; Connell et al, 2016; Liaw et al, 2016). These are all very important factors to take into consideration but what is often overlooked is alarm fatigue when designing and implementing a new tool or process (Simpson & Lyndon, 2019; Peterson & Constanzo, 2017). An EWS tool needs to be set to a level that catches possible deteriorations early enough to be stopped but at the same time does not alert the nurse, provider, or RRT so much that the alert gets ignored (Peterson & Constanzo, 2017). This requires due diligence by validating the EWS tool for the hospital population while monitoring how often an alert gets triggered at certain points to avoid alarm fatigue and enhance patient safety at the same time. For this study, EDI was set at a score of 45 (positive predictive value (PPV) of 27% of a decline) for the bedside RNs, the providers' score set at 55 (PPV: 42.65%) and notify RRT at a score of 65 (PPV: 63%). These alert levels were picked and the number of alerts per day was calculated to assess the risk of alarm fatigue and brought forth to the focus groups of RNs, RRT members, and providers. The number alerts were deemed accessible by focus groups of bedside RNs, providers, and RRT members; the trigger alerts were finalized for the implementation hospital wide.

These three levels of alerting gave the EDI an advantage over the MEWS because it allows for more proactive alerting. The EDI has a greater numerical range (0-100) while the MEWS' range is 0-15 (Subbe et al., 2001; Singh et al., 2020; EPIC, 2020; EPIC, 2021) (Figure 1; Figure 2). At the institution where the project was conducted the MEWS score was set to trigger at a higher level, MEWS of 7 or greater, than what the literature suggests, a MEWS of 5 or greater (Amanzai et al., 2021; Abbey et al., 2021; Bartkowiak et al., 2019). The multiple alerts allowed for increased opportunities for patient deterioration to be identified and for timely interventions to be carried out to mitigate further deterioration. The MEWS was set up to alert the bedside RN and RRT one time. This causes the MEWS to be used as a safety net with fewer opportunities to mitigate the deterioration before it requires high levels of care.

The EDI demonstrated better patient outcomes overall when compared to the MEWS. The MEWS and EDI were similar clinically and sociodemographically. After implementation of the EDI there was a decrease in ICU transfer which is a benchmark in evaluating RRS systems (Danesh et al., 2019; Lee et al, 2020). The EDI also had a decrease in Rapid Response notifications, decrease in intubations after a Rapid Response notification, the implementation of supplemental oxygen after a Rapid Response notification, and hospital length of stay. This shows that RNs and providers are recognizing clinical deteriorations. As result of the recognition, they are taking the necessary steps to further mitigate the patient decline thus reducing the need for RRT involvement and transfers to the ICU.

There was no statistical or clinical difference between code blue activations between the two early warning scoring tools. However, this is clinically significant because the EDI did not fare worse than MEWS and might improve with additional intervention centering on improving usage and understand of the EDI and its implementation. The in-hospital mortality was worse with the EDI as compared to the MEWS but the CMI for both time periods is close enough that it cannot account for the difference in mortality. The increase might be associated with greater utilization of palliative and hospice care within the institution and could account for the decrease in median hospital LOS within the EDI cohort (Table 2).

Implications for Future Practice

There are several implications for practice, research, and cost. For practice, this project provides a basis for implementation of a complex EWS tool to be used in a proactive model for identifying patient deteriorations. It has shown to reduce ICU transfers, shorten hospital length of stay, mechanical ventilation, the use of supplemental oxygen and rapid response notification. Continued support and education on the use of the EDI coupled with further encouragement in using the tool to assist in identifying patient deteriorations early could increase utilization; that will allow the nurses and providers even more time to take the necessary interventions thus improving patient outcomes. A good example of an educational and research implication for the EDI would center around the use of score and positive predictive value in determining nursing assignments or triaging.

Future research will need to focus on improving nursing and provider education on the use of the EDI. The current nursing education focused on what the EDI was but not how to utilize the tool to evaluate their interventions along with assist in monitoring the acuity of their patients. Evaluation of the different implementation strategies that focus on application of existing knowledge to encourage higher order thinking process might prove fruitful. On the provider side, developing strategies that allows for wider dissemination and adoption of new hospital policies, tools, and/or care guidelines could help with provider adoption. The education the provider received on the use of the EDI was minimal and as a result not widely adopted. Future studies should review the retention and utilization of the education along with additional education needed to expand utilization of the EDI. Even with this inconsistent adoption of the EDI among both groups, it proved to have positive effects on patient outcomes.

Hospitals are constantly looking for new ways to save money and cut cost. Utilizing the EDI could save a hospital money by implementing it in their RRS. The typical cost for the first day in the ICU for a non-mechanical ventilated patient was approximately $5,000 in 2017 (Kramer et al., 2017). Using this as a minimum cost for an unintended ICU transfer, the institution saw 98 (1% difference) fewer unintended ICU transfers with the implementation of the EDI which equals to $490,000 saved over one 3-month period. If this is extended out to a full year it becomes a minimum of $2 million saved.

The implications from the results of this project have shed light on several new areas of study. These areas would focus on effective strategies for provider education, strategies maintaining RN knowledge usage while improving assessment skills, the effects of delayed vital sign input on patient outcomes, and lastly how long of a delay does a delay vital sign input constitutes a negative effect on patient comes. Other areas for possible research focus on identification of factors that influence the presences of codes outside of critical areas, to identify weakness in the current system and develop strategies to avert further code blue activations.

Limitation

There are several limitations to this study. This study was a retrospective design, so extrapolation or generalizability is limited. More data needs to be collected in several RRS models with the same implementation method as this study to verify the improvement in patient outcomes. One of the major issues within the literature is inconsistent methodologies (McGaughey et al., 2021). This study offers a blueprint for implementation of complex EWS tool.

Another limitation of this study was the two 3-month time periods; the time periods were selected out of necessity and convenience. This study would benefit from longer time periods to ensure less variability and verify the positive effects of the EDI and the implementation model.

Lastly, the limited provider education, and nurses lack of understanding on how to use the EDI was barrier to optimal usage of the EWS tool to enhance patient outcomes. This gets further compounded by the high use of travel nurses to fill staffing holes that never received any education on the EDI or don't have any inclination to utilize the EWS tool because of their short-term employment with the hospital.

Conclusion

The purpose of the project was to evaluate two EWS tools to see which had the better patient outcomes and the implementation of each. This project did find that the EDI had better patient outcomes overall. It also found that a proactive model of implementation has better outcomes compared to a reactive model. The EDI proved easier to implement in a proactive manner because of its wider scoring range. The MEWS does not utilize the same scoring range making it more difficult to implement in a proactive manner. The MEWs does have the advantage of being easily calculated at the bedside or if there was a downtime during for an EHR system or with no EHR present. The EDI relies heavily on the EHR. This project does fill the gap within the literature, but further studies need to be conducted to confirm the results of this study. The next step is to formalize a report to the hospital leadership and RRT to inform them of the results of this project and show how the EDI outperformed the MEWS.

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List of Tables

Table 1: Patient Demographics

	MEWS (n = 6602)	EDI (n = 5608)
Age, mean (SD)	55.25 (17.098)	56.17 (16.723
Age, Range	18-98	
Gender, n (%)		
Male	2676 (47.7%)	3275 (49.6%)
Female	2932 (52.3%)	3326 (50.4%)
Race		
White	5885 (89.1%)	5020 (89.5%)
Black	524 (7.9%)	433 (7.7%)
Other race	196 (3%)	155 (2.8%)
Case Mix Index (CMI)	2.1998	2.1668

Table 2: Comparison of outcomes MEWS vs EDI

	MEWS (n = 6602)	EDI (n =5608)	p
Hospital LOS, median (IQR)	1.99 (.71, 5.24)	1.79 (.82-4.56)	.012
ICU transfer			
Yes	243 (3.7%)	145 (2.6%)	<.001
No	6359 (96.3%)	5463 (97.4%)	
In-Hospital Mortality, n (%)	131 (2.0%)	176 (3.1%)	<.001
Code blue, n (%)	27 (0.4%)	27 (0.5%)	.547
Rapid Response notifications, n (%)	370 (5.6%)	251 (4.5%)	.005
Mechanical ventilation	87 (23.5%)	42 (16.7%)	.041
Supplement O_2 [a]	103 (27.8%)	52 (20.7%)	.044

[a] Among Rapid Response Team notification RRT (*n =621*)

List of Figures

Figure 1: Breakdown of the MEWS

MEWS

	3	2	1	0	1	2	3
SBP	=< 70	71-80	81-100	101-199		>=200	
HR		=<40	41-50	51-100	101-110	111-129	>=130
RR		=<9		9-14	15-20	21-29	>=30
TEMP		=<95		95.1-101.1		>=101.3	
AGE				<65	65-74	75-84	>=85
BMI			=<18.5		25.1-34.9	>=35	

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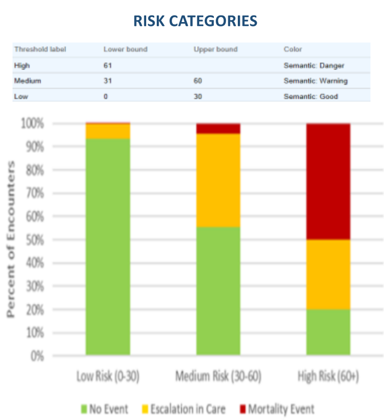
Figure 2: The breakdown of the EDI scores with corresponding PPV for clinical deteriorations, associated risk for mortality, and the three different categories risk.

Epic Deterioration Index



Red – Patient experienced mortality

Yellow – Rapid response team call, or transfer to the ICU

Green – No Event

Essentials: I, III, IV, VII

Threshold	PPV
40	21.40%
43	24.80%
46	28.67%
49	33.00%
52	37.98%
55	42.63%
58	48.88%
61	55.43%
64	62.28%
67	67.94%
70	74.64%
73	80.86%
76	85.41%
79	90.16%

- **True Positive is defined as follows:**
  - **Escalation (ICU or RTT) within the next 12 hours after prediction**
  - **Patient dies in the next 38 hours after prediction**

Threshold	PPV
40	42.03%
41	43.50%
42	44.83%
43	46.59%
44	48.17%
45	49.69%
46	51.66%
47	53.71%
48	55.37%
49	56.99%
50	58.79%
51	60.74%
52	62.69%
53	64.22%
54	65.80%
55	67.29%
56	69.28%
57	71.28%
58	72.91%
59	74.57%
60	76.51%

- **True positive defined as follows:**
  - **Patient dies in the next 38 hours after prediction**

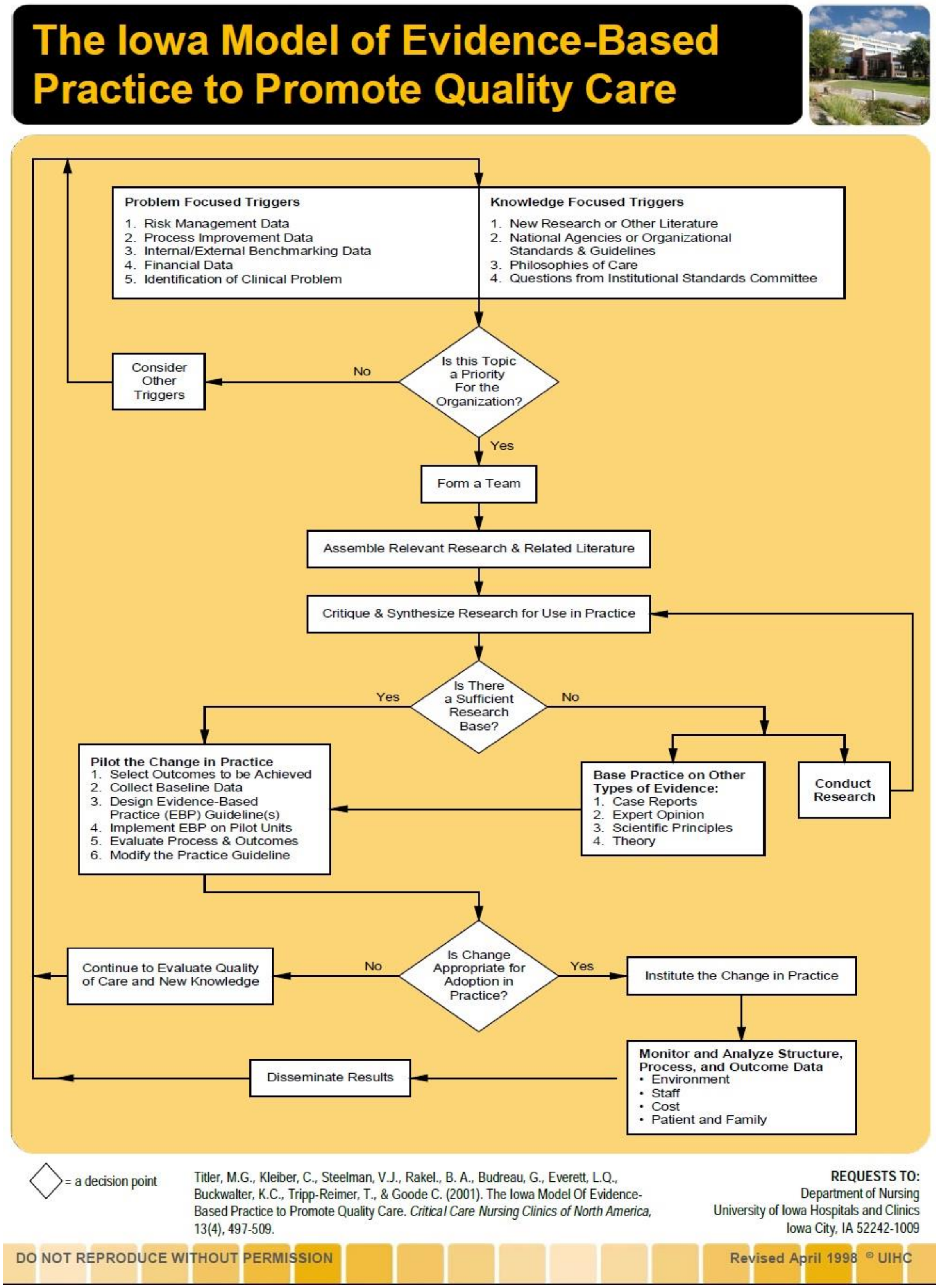
Figure 3: The variables utilized in the EDI's algorithm to generate a score.

APPENDIX A: ALGORITHM VARIABLES

Mnemonic	Display Name	Continuous?
Age	Age	Yes
Risk from Age	Risk from Age	Yes
Systolic	Systolic	Yes
Risk from Systolic	Risk from Systolic	Yes
Temperature	Temperature	Yes
Risk from Temperature	Risk from Temperature	Yes
Pulse	Pulse	Yes
Risk from Pulse	Risk from Pulse	Yes
Respirations	Respiratory rate	Yes
Risk from Respirations	Risk from Respirations	Yes
Pulse Oximetry	Pulse oximetry	Yes
Risk from Pulse Oximetry	Risk from Pulse Oximetry	Yes
Glasgow Coma Scale	Glasgow coma scale	Yes
Risk from Glasgow Coma Scale	Risk from Glasgow Coma Scale	Yes
Neurological Exam	Neurological exam	No
Risk from Neurological Exam	Risk from Neurological Exam	No
Hematocrit	Hematocrit	Yes
Risk from Hematocrit	Risk from Hematocrit	Yes
WBC Count	WBC count	Yes
Risk from WBC Count	Risk from WBC Count	Yes
Potassium	Potassium	Yes
Risk from Potassium	Risk from Potassium	Yes
Sodium	Sodium	Yes
Risk from Sodium	Risk from Sodium	Yes
Blood pH	Blood pH	Yes
Risk from Blood pH	Risk from Blood pH	Yes
Cardiac Rhythm	Cardiac rhythm	No
Risk from Cardiac Rhythm	Risk from Cardiac Rhythm	No
Supplemental Oxygen	Supplemental oxygen	No
Risk from Supplemental Oxygen	Risk from Supplemental Oxygen	No
Platelet Count	Platelet count	Yes
Risk from Platelet Count	Risk from Platelet Count	No
BUN	BUN	Yes
Risk from BUN	Risk from BUN	No

2

Figure 4: Visual representation of Iowa Model.



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Appendix I: RN web-based-training module

What is the Epic Deterioration Index (DI)?

- Hybrid of the Modified Early Warning Score (MEWS), nursing assessment, and labs
- Intended to be proactive, not reactive
- Scored from 0 to 100
  - The higher the number the greater the risk of adverse outcome requiring rapid response, resuscitation, ICU-level care or death in the next 12-38 hours
  - Calculated every 15 minutes from 17 variables
    - Uses most recent instance in last 72 hours
    - Takes prior data and trends into consideration

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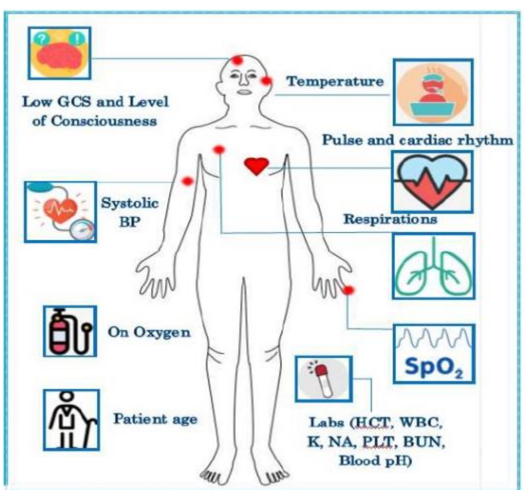
Deterioration Index-Variables



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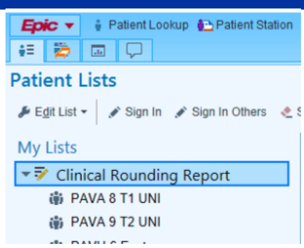
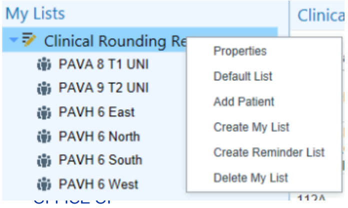
DI Epic display-Patient List Column

Patient Name/Age/Gender	Dept/Room/Bed	Level of Care	Attending & Team	First Call Provider	Deterioration & Sepsis ▲
[redacted]	CH PAVA 9 T2 UNI / 218 / 218A	Progressive	HM CHANDLER 10 James A Troy, MD	TROY, JAMES A	71* 1
	CH PAVA 9 T2 UNI / 224 / 224A	Progressive	SGR VASCULAR SURGERY 1 Dong H Lee, MD	PLATT, BROOKS N	68* 2
	CH PAVH 6 NORTH / 615 / 615A	Progressive	HM CHANDLER 1 Fadzai Chinyengetere, MD	WILKERSON, PAUL K	60* 1
	CH PAVA 10 T1 UNI / 127 / 127A	Progressive	HM CHANDLER 7 Taha Ahmed, MD	AHMED, TAHA	60* 4
	CH PAVA 6 T1 PC / 121 / 121A	Progressive	NEU STROKE WARD Gregory A Jicha, MD	ROBERTS, JAMIE L	60* 2
	CH PAVA 6 T1 PC / 115 / 115A	Progressive	NEU STROKE WARD Saurav Das, MD	CHOI, HANNAH	58* 2
	CH PAVA 6 T1 PC / 127 / 127A	Progressive	NEU STROKE WARD Gregory A Jicha, MD	ROBERTS, JAMIE L	57* 3
	CH PAVA 6 T1 PC / 122 / 122A	Progressive	NS NEUROSURGERY Pranatartiharan Ramachandran, MD	HUFFMAN, CLAYTON A	56* 2
	CH PAVA 7 T1 UNI / 121 / 121A	Acute	SGT FLOOR 3 Meir B Meerkov, MD	DOLL, REBECCA A	54* 2

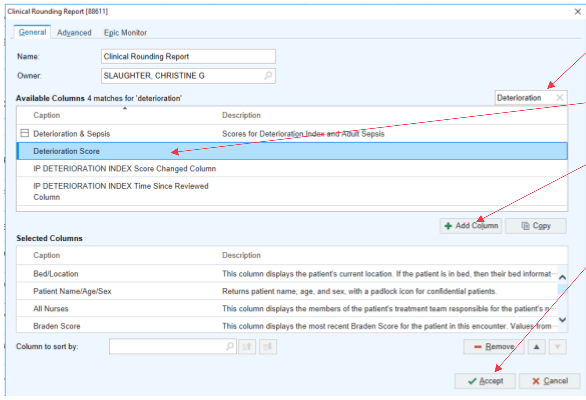
HOW TO ADD THE DI SCORE TO PATIENT LIST



1. Right click on Clinical Rounding Report or My Patients



2. Select “Properties” from the drop down menu



3. In the search window, type “deterioration”
4. Select “Deterioration Score”
5. Click on “Add Column”
6. Click on “Accept”

If you have too many selected columns, you will have to remove one (or more) to view the DI score. Click on “Accept” once you have made your column selections.

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Threshold(s) for “firing”

- **Primary nurse push notification and BPA at 45**
- **First-call provider push notification at 55**
  - Primary nurse receives push notification that provider has been alerted
- **RRT push notification at 60**
  - Primary nurse receives push notification that RRT has been alerted
- **Epic levels of risk**
  - **60-100 High Risk**
  - **30-60 Medium Risk**
  - **0-30 Low Risk**

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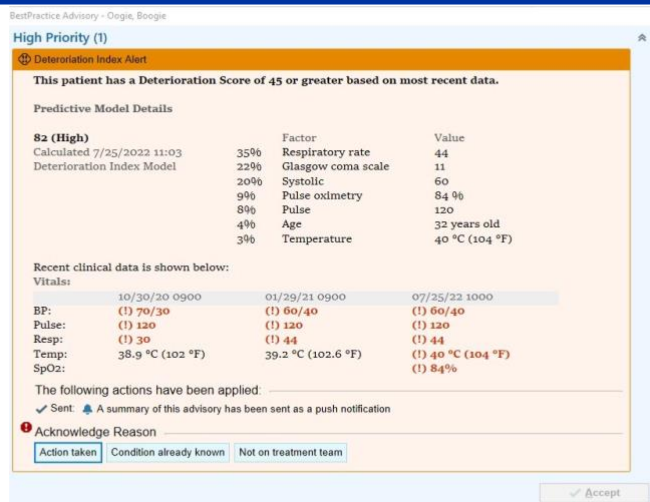
BPA for bedside nurses



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OPTIONS FOR "ACTION TAKEN"

- "Action Taken" will require the nurse to add a comment- listing the action(s) taken.
- During the pilot, please make a list of actions that you think would be appropriate as you respond to the DI BPA.
- Please send list to Chris Slaughter or Paula Halcomb
- GOAL: Develop a list of the most common actions taken to develop a multi-select, drop down list for documentation attached to the BPA

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General

- Rapid response team and/or provider can be called at any time that there is cause for concern
  - No need to wait for DI score to elevate if you have concerns for your patient