Pediatric Early Warning System (PEWS)

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Executive Summary

Since 1964, Children’s Hospital of Orange County (CHOC Children’s) has been steadfastly committed to providing the highest quality medical care to children. Affiliated with the University of California, Irvine, our regional pediatric healthcare network includes a state-of-the-art 279-bed main hospital facility in the City of Orange, and a 54-bed hospital-within-a-hospital in Mission Viejo. CHOC also offers many primary and specialty care clinics in Orange County and beyond; more than 100 additional programs and services; residency programs in Pediatrics, pharmacy and nursing; support for multiple fellowship programs; and four centers of clinical excellence – The CHOC Children’s Heart, Neuroscience, Orthopedics and Hyundai Cancer Institutes.

CHOC Children’s Hospital began its journey to a fully-implemented Cerner Millennium EHR in 2002. The Hospital’s dedication to patient safety was evident in the acronym chosen for CHOC’s EHR, “CUBS,” which stands for Connecting Users and Building Safety. Today, CHOC Children’s dedication to safety, quality, and the patient experience is supported by over fourteen ensuing years of patient-centered Healthcare IT design. These efforts led to our recognition as a Stage 7 HIMSS Analytics Inpatient awardee in 2015 and support this case study.

After an internal review of three years of data, leadership found that more than 80 percent of patients in non-intensive care unit (ICU) areas who underwent resuscitation displayed early, identifiable signs of pediatric deterioration up to eight hours prior to coding. CHOC Children’s spent the next year developing an electronic tool, referred to as Pediatric Early Warning System (PEWS), to standardize language and process of clinical deterioration observation in non-ICU areas. After
several stakeholder discussions, leadership decided to pilot giving nurses and other caregivers an objective and uniform way of assessing a patient and if necessary calling the Rapid Response Team (RRT), which is a team of critically-trained personnel, to the bedside.

The PEWS team designed and developed a table to physiologically score patients in non-ICU medical surgical and neuroscience units, and specific algorithmic workflows to follow dependent upon the assigned score. The EHR table is used manually by nursing to assign each patient a score based on three physiologic systems. The system, however, automatically notifies the nurse with a step-by-step workflow after the score is calculated. The PEWS score is also automatically pushed to various spaces within the EHR, including electronic whiteboards, to enhance situational awareness of each individual patient and collective unit.

The initial implementation of the CHOC rapid response team dropped the annual code rate from 0.8 to 0.3/1000 patient days in the medical-surgical and neuroscience units. The introduction of PEWS decreased the non-ICU code rate even further to approximately 0.1/1000 patient days, which has been sustained for eight years. In so doing, it is estimated that some 369 children have avoided resuscitation, with potentially as many lives saved. To date as a result of this program, CHOC Children’s has gone a maximum of 1003 days without a non-ICU cardiac arrest and continues to strive to break its record number of days without a code of any kind. Internally, this effort is called “Chasing Zero,” and applies to numerous other harm-reducing efforts as well. The project also reduced the number of critical transfers to the ICU from medical-surgical, indicating the success of identifying potential codes earlier in the deterioration continuum. Lastly, the overall CHOC mortality rate has declined by 29.3% during the interval, and is 31% lower than the severity-calculated “expected” mortality rate.

Local Problem

In 2004 the Institute for Healthcare Improvement (IHI) launched the 100,000 Lives Campaign. This quality improvement effort called for saving at least 100,000 patient lives in U.S. hospitals through improvements in safety and quality. Among the six possible ways suggested to reach the 100,000 lives saved goal, one listed initiative was the deployment of Rapid Response Teams (RRTs) to the bedside of patients identified to be deteriorating. Many hospitals adopted such emergency teams as a result of the effort, and probably also because of the increasing regulations and expectations regarding quality. As is common in the medical industry, RRTs in the pediatric sector were not as quickly studied, validated, and adopted, but the basic logic stood that RRTs could also assist in preventing deterioration in children.
In 2008, after an internal review of three years of data, CHOC Children’s leadership found that more than 80 percent of patients in non-ICU areas who eventually coded displayed early, identifiable signs of clinical deterioration up to eight hours prior to arrest. Leadership thus decided to deploy a Rapid Response program. In addition to the RRTs, CHOC Children’s decided to develop an electronic physiologic assessment tool, referred to as Pediatric Early Warning System (PEWS), to standardize language and process of clinical deterioration observation in non-ICU areas. The system leverages patient data from the electronic health record (EHR) to assess all children for risk of deterioration. The score is calculated using physiological measurements and evidence-based risk factors, and is then electronically communicated through the EHR, nursing station electronic whiteboards (e-boards) and remote access, enabling the care team to provide more timely detection and interventions.

**Design and Implementation**

The development of PEWS began with discussions among CHOC Children’s leadership on the adoption of rapid response teams (RRTs). The discussion evolved into conversations with nurse leaders and specialists on a pilot that would give nurses and other caregivers the power to use objective measures to call a RRT in the medical-surgical and neuroscience units. Nursing was very enticed by the possibility of having a way of objectively calling for escalation, and several more senior nurses became teary eyed at the mere possibility. The project was given clearance by hospital leadership and governance, and a collaboration of quality, nursing, hospitalists and critical care physicians began assessing the best way of developing the system.

Although committed to PEWS from the very beginning, the PEWS team used sequential trial and testing of Deterioration Pilot Programs, each building upon the previous and moving to earlier time points in the internally created Deterioration Continuum (Figure 1). CHOC began by implementing RRTs. Next, as an interim solution, we developed Early Assessment Rounds (EAR), in which night shift unit charge nurses and the senior resident physician would together identify and proactively round on the “sickest” one or two unit patients. The EAR further proved the validity of early detection, but on a limited scale with high resource consumption. Importantly, it was seen that during many months of EAR functionality, deterioration of these patients was largely prevented. Finally, with IT integration completed, PEWS was started.
The Deterioration Continuum, with PEWS in place. This model demonstrates the increasingly proactive approach to patient evaluation and intervention.

Figure 1: The Deterioration Continuum. Interventions earlier in time (i.e., to the left) conceptually reduce the requirement for resuscitation.

With medical literature, three years of CHOC data, and additional information discovered from the RRT and EAR pilots, the committee developed a PEWS scoring table that nurses would use to objectively assess a patient’s likelihood of deterioration. The table uses respiratory, cardiovascular and neuro-behavioral criteria to assist nurses in assigning patients a PEWS score. The score is then used to determine the appropriate algorithmic workflow, which can include immediately calling the RRT.

Besides patients, physicians and nurses are the primary groups affected by PEWS and were, therefore, heavily involved in the design and implementation from all aspects. The committee served as end-users during initial design and other representative end users were incorporated into each trial and testing phase, which allowed for real-life events that shaped the ultimate design of PEWS. It should be noted that the chief nursing officer, medical director of quality and patient safety, medical director of informatics and the chief information officer were the overall project leaders.

The project goal was to detect early deterioration and reduce non-ICU codes. As a result, related operational performance measures would change from Code response to Code Prevention. Ultimately, by earlier detection and intervention, the PEWS team hoped to reduce deterioration, urgent transfers to the Pediatric Intensive Care Unit (PICU), and resuscitation events.
How Health IT Was Utilized

Clinical workflow narrative

Nurses in the medical surgical and neurosciences units used respiratory, cardiovascular and neurobehavioral criteria from the PEWS table (Figure 2) to objectively determine the PEWS score. The calculation also accounts for special criteria to assign additional points for known high risk indicators.

![Figure 2: Pediatric Early Warning Score (PEWS) for Medical-Surgical and Neuroscience Units.](image)

The score determines the workflow each nurse must follow. As seen in the workflow (Figure 3), a PEWS score above 2 will increase the frequency of additional assessments alone up to an overall score of 5, at which point additional notifications begin. A PEWS score greater than or equal to 6 requires an immediate provider visit and/or calling the RRT if criteria are met. Similarly, a patient scoring the maximum of 3 points in any one area – respiratory, cardiovascular or neurobehavioral – is treated identically to a total score of ≥76.
While the PEWS category scores are manually determined by the bedside nurse using the table parameters (Figure 4), the computer-calculated total score auto-populates into the EHR and activates a notification with step-by-step instructions for the nurse to follow (Figure 5). We intentionally designed the process to utilize manual entry of the physiologic assessment category scores as this practice has been demonstrated in human factors engineering to lead to better clinical awareness by caregivers versus auto-population of data.

It is important to note that we designed our patient-centered Rapid Response program so that any concerned caregiver or personnel could activate an RRT call. These concerns can be objective or subjective, e.g., an overall concern about the patient condition. After several years, we expanded that to family members as well. The PEWS algorithm adds to the deterioration escalation capability by regular, objective assessments and tasks. The most important aspect of the program, however, is not the score but the response; that is why a mandated provider notification or visit at high PEWS scores is the focus point. This process works well in our tertiary care hospital because of the many providers present 24/7; it also supports the teaching missions of several healthcare fields.
Figure 4. EHR nurse PEWS scoring form. By human factors design, the four category scores (Respiratory, Cardiovascular, Neuro-behavioral and Extra Points) are assessed and manually entered by the bedside nurse. Once entered, the total score and corresponding alert color are automatically calculated, as are alerts and required next steps (see Figure 5). For reference and trending, the four prior PEWS scores are auto-populated into the form as well.
Figure 5: EHR nurse notification task for a PEWS score greater than or equal to 6, or maximum category score of 3.

Once calculated, PEWS scores will also update on the unit electronic whiteboard (Figure 6), as well as EHR unit summary views, giving clear visibility and situational awareness of unit population stability and risk of deterioration to the entire care team, both local and remote.

Figure 6: Nursing unit electronic whiteboards, including the Pediatric Early Warning Score (numeric and colored icon on left columns of each whiteboard). A similar digital “unit view” display is available in the EHR.
There have been minor changes in the PEWS scoring grid over time, including the addition of criteria for hypertension, defined hypotension, and weighting of tracheostomy tube presence (which serves as a proxy for complex patients as well). The interface and workflow have changed minimally, and the mandated higher PEWS score verification and required actions not at all. Within a year of inpatient spread of the PEWS program, a nursing survey was undertaken to assess program effectiveness and acceptance, and the results were overwhelmingly favorable. Given the spread of PEWS to new areas, the sustained, dramatic reduction in non-ICU codes, the highly favorable hospital mortality trend, and our patient safety cultural evolution, a follow up survey has been deemed unnecessary.

**Value Derived**

The notable primary outcome of a dramatic reduction in non-ICU codes below (Figure 7) is a result of requiring the PEWS score to be documented within the EHR by the caregiver, which then gives alerts and provides visibility of the score to the entire clinical team, guiding care. The introduction of RRTs did significantly contribute to the initial reduction from 0.8 to 0.31 codes per thousand patient days. The addition of PEWS, however, further reduced the non-ICU code rate from 0.3 to 0.1/1000 patient days, and has ensured sustainability of the process for eight consecutive years. This is due to the ability of PEWS to detect deterioration earlier in time and avoid the need for many emergent interventions, including resuscitation. We calculate that in the eight years of PEWS a minimum of 111 resuscitations were averted; thus, 111 children’s lives have potentially been saved.

**Figure 7: Non-ICU codes per thousand patient days, 2005 to 2016.**
Rapid response team calls rose as expected and then plateaued since program inception. The relationship between RRTs and PEWS is complex. On the one hand, the structural and cultural changes of the deterioration prevention program have increased the likelihood of clinician or family member activation of the Rapid Response Team. Moreover, our PEWS design itself prompts the question at high acuity scores of whether an RRT should be called. Conversely, the PEWS program has led to awareness and intervention at lower scores/earlier in the deterioration continuum, so high-level RRT escalation becomes less likely. The fact that the RRT annual volumes have stabilized for the past five-plus years suggests program maturity and process stability (Figure 8).

![Annual RRT Volume Since Inception](image)

**Figure 8:** Rapid Response Team activation volume post-implementation.

It is important to note that the overall hospital mortality rate has declined after implementation of PEWS (Figure 9). Due to the many simultaneous quality improvement and patient safety improvements in place, general advances in medical care, and the development of new clinical programs and departments, it is not possible to measure the direct causation by the PEWS program. Nonetheless, this favorable trend in the most foundational of health outcomes is a reassuring one, and critical to all participants and consumers within the industry.
Figure 9: CHOC Observed to Expected (O/E) Mortality Ratio, 2011 to 2016 (data in black, with trend in blue). Data is from the Children's Hospitals' Association Pediatric Health Information Systems (CHA PHIS) database and is severity-adjusted using APR-DRG methodology. By definition, the expected O/E mortality rate is 1.0; anything lower is favorable. The O/E mortality ratio has declined 29.3% to 0.69 during the past five years of the PEWS era since comparative data became available.

The CHOC Children’s code committee meets monthly to review all resuscitations within the organization. They use a number of reports pulled from the Cerner EHR ad-hoc reporting solution. If any need or enhancement is identified during their review process, a performance improvement (PI) team can be chartered at their recommendation by the organizational quality committee. PI teams meet at least monthly for the duration of their respective improvement initiatives, and are closed once the goal has been reached and/or when the improvement action becomes standard structure, process, or culture.

Lessons Learned

Don’t automate everything

Many things can be automated, but don’t overlook the importance of the person using the process. The PEWS design could have also included an automated process for populating some scoring criteria (for instance, auto-populating vital signs for respiratory and cardiovascular), but early discussions quickly turned the design team away from full automation. The pharmacists and ICU
team, as well as the human factors science literature, warned that overuse of auto-populating data can reduce the mental ownership and data awareness of the user. The team decided to have RNs enter the score manually, while the total score and notification of mandatory actions are automatically pushed.

Don’t cast aside extra efforts that might initially seem less important

The design team, in conjunction with leadership, decided to take the extra IT time and effort to create color “stoplight” icons within all relevant end-user displays. These familiar icons and colors intuitively indicate the patient’s PEWS status beyond the mere numeral alone. The associated visual awareness of individual and collective scores was a significant late enhancement that all end users noticed as helpful, and are, as designed, the most striking aspect of the displays.

Spread is likely

The gratifying result of recognizing and preventing deterioration is easily understood, and very fundamental to the health care professions. Other parts of the organization will wish to take part. While respecting that PEWS is designed for non-ICU inpatients, the concept of appropriate assessment during triage decisions was noted by other areas within CHOC; specifically, the interfacility transport team and patient placement of Emergency Department admissions. The underlying logic was sound: that a patient should be physiologically appropriate for the area of the hospital being considered for admission.

A new lexicon will develop

Without effort or intent, a patient-specific phrase quickly developed during handoffs or other quick communications as an offshoot of this project. “He’s a PEWS green 0,” or “Be aware, she’s a PEWS yellow 3” became part of the clinical landscape. This enhancement to team knowledge, updates and handoff communications is a part of the culture change that comes with deterioration prevention.

The power of situational awareness cannot be overstated

At the individual non-ICU patient level, PEWS scores are calculated and/or specifically reviewed by the bedside nurse at least 10 times each day. Adding in the unit charge nurse and nurse aides increases that number. Each time the chart is opened, the default screen includes the PEWS score/color icon prominently in the upper left corner. Furthermore, the PEWS score is a part of the banner bar across the top of each clinical EHR page on a continuous basis. When the providers, who have similar EHR exposure frequency, are added, it is likely that a given patient’s PEWS score is viewed 50-100 times per day. From a unit perspective, the unit electronic whiteboard forms the
backdrop of the nursing unit environment. It has become second nature to glance at the whiteboard PEWS column upon entering the unit, and the non-reassuring PEWS scores readily stand out and lead to exploration. As a forcing function, unit shift changes of nurses and doctors are held where the PEWS scores are readily in sight. Collectively, but effectively non-measurable, there are thus hundreds of views of the unit PEWS scores daily. We believe it is this awareness that has led to the sustained reduction in non-ICU codes at CHOC Children’s.

Financial Considerations

Equipment costs were approximately $16,000. Software development was estimated at $100,000 and nursing education $25,000. There are additional work efforts that go into performance improvement initiatives, which cannot be adequately calculated as it involves additional tasks for largely salaried individuals with multiple responsibilities.

Recent literature found that the mean adult post-resuscitation ICU expense is $455,000 for a survivor, versus $102,000 for early mortality, which supports a large contribution of ICU and other post-resuscitation expenses in this area of clinical care. A 2009 pediatric study in the U,K. notes an approximately 81,410 pound (or $119,616 US (conversion rates from June 20, 2016)) cost for resuscitation, post-event length of stay and hospital discharge of survivors (survivor rate 64%). While cost savings are difficult to precisely calculate because of the impact of the underlying condition(s), these studies suggest the potential for significant cost avoidance opportunities. In fact, even using a conservative post-resuscitation cost of $50,000, with 369 avoided resuscitations, CHOC has saved $18.45 million in costs from this program.
References
