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Validation of the Children's Hospital Early Warning System for Critical Deterioration Recognition

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ABSTRACT

Objective: Early warning scores, such as the Children's Hospital Early Warning Score (CHEWS), are used by hospitals to identify patients at risk for critical deterioration and trigger clinicians to intervene and prevent further deterioration. This study's objectives were to validate the CHEWS and to compare the CHEWS to the previously validated Brighton Pediatric Early Warning Score (PEWS) for early detection of critical deterioration in hospitalized, non-cardiac patients at a pediatric hospital.

Design and Methods: A retrospective cohort study reviewed medical and surgical patients at a quaternary academic pediatric hospital. CHEWS scores and abstracted PEWS scores were obtained on cases (n = 360) and a randomly selected comparison sample (n = 776). Specificity, sensitivity, area under the receiver-operating characteristic curves (AUROC) and early warning times were calculated for both scoring tools.

Results: The AUROC for CHEWS was 0.902 compared to 0.798 for PEWS ($p < 0.001$). Sensitivity for scores ≥3 was 91.4% for CHEWS and 73.6% for PEWS with specificity of 67.8% for CHEWS and 88.5% for PEWS. Sensitivity for scores ≥5 was 75.6% for CHEWS and 38.9% for PEWS with specificity of 88.5% for CHEWS and 93.9% for PEWS. The early warning time from critical score (≥5) to critical deterioration was 3.8 h for CHEWS versus 0.6 h for PEWS ($p < 0.001$).

Conclusion: The CHEWS system demonstrated higher discrimination, higher sensitivity and longer early warning time than the PEWS for identifying children at risk for critical deterioration.

Introduction

Children who experience in-hospital cardiopulmonary arrest have low survival rates (25–38%)(Berg, Nadkarni, Zuercher, & Berg, 2008; López-Herce et al., 2004; Nadkarni et al., 2006; Reis, Nadkarni, Perondi, Grisi, & Berg, 2002; Samson et al., 2006; Suominen, Olkkola, Voipio, Palo, & Rasanen, 2000). Early recognition and early intervention of critical deterioration may prevent most in-hospital pediatric cardiopulmonary arrests from occurring (López-Herce et al., 2004; Nadkarni et al., 2006; Pearson, Ward-Platt, Harnden, & Kelly, 2011; Reis et al., 2002). Early warning scoring tools have been developed to detect critical deterioration in patients and to trigger an activation of resources such as a Rapid Response Team (RRT) (Bonafide et al., 2014; Brilli et al., 2007; Chan et al., 2008; Chan, Jain, Nalmothu, Berg, & Sasson, 2010; Chen et al., 2009; Hanson et al., 2009; Parshuram, Hutchison, & Middaugh, 2009; Peberdy et al., 2007; Sharek et al., 2007; J Tibballs, Kinney, Duke, Oakley, & Hennessy, 2005; Tibballs & Kinney, 2009; Tibballs & van der Jagt, 2008; Ul-Haque, Saleem, Zaidi, & Haider, 2010; Van Voorhis & Willis, 2009; Winberg, Nilsson, & Aneman, 2008).

In 2009, as part of the Child's Health Corporation of America's Collaborative to reduce cardiopulmonary arrests on inpatient units, our institution evaluated several early warning scoring tools to use for identification of deteriorating patients. Only one pediatric tool, the Brighton Pediatric Early Warning Score (PEWS) had been validated at that time; therefore it was chosen after adding two additional assessment domains (Monaghan, 2005; Tucker, Brewer, Baker, Demeritt, & Vossmeyer, 2008). The modified tool consisted of the three PEWS domains ('Behavior/Neuro', 'Cardiovascular', 'Respiratory') which are scored on a 0–3 scale with 3 being the highest severity of objective and subjective clinical symptoms. The two added domains ('Staff Concern' and 'Family Concern or Absent') are on a 0–1 scale with 1 indicating presence of concern. The domain variables can be assessed at the bedside without further patient specific information (i.e. diagnosis, lab results) or previous familiarity of the patient. Nurses complete the patients' scores, which takes ≤10 s to perform, during vital sign assessments which is typically every 4 h. A three-tiered escalation of care algorithm (Fig. 1) driven by the aggregate score was formalized to reflect existing RRT processes. On the algorithm (Fig. 1), an elevated

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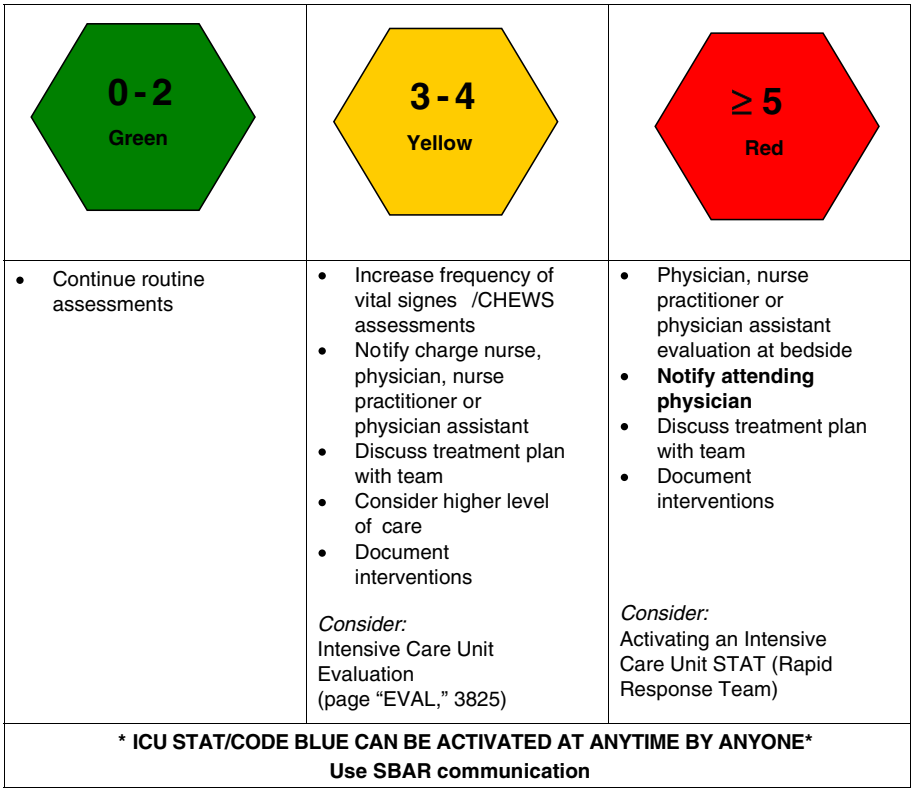

Fig. 1. Children's Hospital Early Warning System (CHEWS) escalation of care algorithm.

score (≥3) requires an escalation of resources to the patient such as increased monitoring, assessment and team communication. A critical score (≥5) requires immediate patient assessment by the clinical team, attending physician notification, and potentially RRT evaluation or activation. The scores can be trended within the patient's electronic health record and the prior 24 h of patient scores are displayed electronically on unit locator boards. After unit-based education to clinicians, the modified PEWS was implemented on medical and surgical inpatient units with a subsequent reduction of inpatient cardiopulmonary arrests and an increase in RRT evaluations (Kleinman & Romano, 2010).

When piloted on the inpatient pediatric cardiac ward, however, this modified tool failed to identify critical deterioration in one-third of deteriorating children with cardiovascular disease (McLellan & Connor, 2013). Based on data from the cardiac pilot, substantial changes (Table 1) were made to the modified tool to accommodate this high-risk patient population. The vital sign parameters were changed to be based upon percentile deviation from normal-for-age to be inclusive for all age groups (Bonafide et al., 2013). Age-based vital sign references are provided in both the electronic health record and on small posters placed in nurses' charting locations. Some components of the domains can be scored using patient specific abnormal baselines (oxygen therapy, cyanosis, heart rhythm, apnea and seizures) to prevent falsely elevated scores. If a patient's baseline is unknown, the nurse scores the patient based upon normal-for-age criteria.

Table 1
Modifications of the Brighton PEWS to create the CHEWS.

Domain added for 'staff concern'
Domain added for 'family concern or absence'
Accommodation for baseline abnormalities
Age-based variation for vital sign ranges
Increase in subjective assessment variables in each domain
Normal sleep does not increase a patient's score
Seizure added to the neuro/behavior domain
Addition of arrhythmia in cardiovascular domain
Oxygen therapy levels lowered to accommodate younger patients
Apnea added to respiratory domain
Oxygen saturation added to respiratory domain
Nebulizers incorporated into respiratory domain
Post-operative vomiting removed

The final revised tool (Fig. 2), called the Cardiac Children's Hospital Early Warning Score (c-CHEWS) and previously existing algorithm (Fig. 1) were successfully piloted, fully implemented and then formally validated (AUROC 0.917, sensitivity 95.3%, specificity 76.2%) in the pediatric cardiac population in a previous study (McLellan, Gauvreau, & Connor, 2013). In this study, the tool demonstrated excellent discrimination in identifying critical deterioration in children with cardiac disease and performed significantly better than the PEWS in identifying critical deterioration (McLellan et al., 2013). To optimize safety and to improve clarity, the hospital leadership decided to implement the cardiac tool throughout all inpatient areas rather than having similar but different tools operating in the same institution. The C-CHEWS was renamed the Children's Hospital Early Warning Score (CHEWS) and incorporated into the electronic health record (McLellan et al., 2013).

The objectives of this study were to validate and to compare the CHEWS to the Brighton PEWS for the early detection of critical deterioration in hospitalized non-cardiac patients at a pediatric hospital. Critical deterioration was defined as an unplanned ICU transfer, cardiac arrest, respiratory arrest, or cardiopulmonary arrest.

Design and Methods

A retrospective cohort design was used for this IRB-approved study. All non-cardiac patients admitted between September 2009 and September 2010 to medical and surgical inpatient units within a freestanding quaternary academic hospital were considered eligible for inclusion. Cardiac patients and the cardiovascular unit were

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