Objectives and instructions for completing the evaluation and statements of disclosure can be found on page 174.

An Integrative Review of Pediatric Early Warning System Scores

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Increasingly, early warning system scores are being introduced into pediatric clinical practice to support the early recognition of and intervention for clinical deterioration in hospitalized children at risk. This integrative review explored what is known about early warning system scores with pediatric patients. Twenty-eight publications, including research, clinical practice articles, and conference abstracts, were identified. Five major concepts emerged from analysis of retrieved documents: overview of pediatric early warning system scores, supplementary benefits, facilitators to successful implementation, barriers to successful implementation, and needed research. Greater psychometric testing of tools is needed before any recommendations can be made regarding extensive implementation with the pediatric population.

Case Study

K.S. was an expert night charge nurse at the top of the clinical ladder. She received clinical hand off at 12:00 midnight in a pediatric emergency department (ED). R.M. was a four-year-old boy with a three-day history of rash and fever. Upon examination, K.S. was alarmed by the severity of R.M.'s rash. His skin was sloughing, with areas of serous drainage and edema. A review of his vital signs revealed he was febrile, tachycardic, and hypotensive. K.S. immediately consulted the attending physician and established a plan of care. R.M. was placed on a monitor, intravenous access was obtained, and antipyretics and a normal saline bolus were administered. Vital signs were closely monitored yet showed no improvement. Another fluid bolus was repeated. R.M. remained persistently tachycardic, febrile, and hypotensive. Laboratory results indicated dehydration and infection. R.M. was at high risk for a suprainfection due to his skin breakdown and was given triple antibiotics. A disposition for inpatient hospital admission was made at 2:00 a.m.

K.S. noted that the ED attending arranged for bed placement on a short-stay unit. This concerned her greatly because she believed R.M.'s vital signs, lack of improvement, and need for focused nursing interventions required a higher level of care. Recognizing this, K.S. advocated for the patient to be admitted to the intensive care unit (ICU). Although the attending valued K.S.'s expert opinion, he held firm and disagreed. Collaboration became strained. R.M.'s vital signs continued to deteriorate, and K.S. realized she had a short amount of time to impact this patient's outcome. She was familiar with the Pediatric Early Warning System (PEWS) score that was implemented on the inpatient units and saw this as an objective tool that could help all disciplines speak the same language in determining care for R.M.

As suspected, the PEWS score placed R.M. at increased risk for rapid deterioration. Using the tool, K.S. was able to convince her physician colleague that R.M. met the heightened physiological parameters for advanced care. This resulted in an ICU consult where a newly developed heart murmur was auscultated. Kawasaki's disease was now in the differential. A bedside echocardiogram was performed, and coronary aneurysms were discovered. R.M. was immediately transferred to the ICU where more frequent assessments and attention from the health care team could be provided.

Early Warning System Scores

When the Institute of Medicine (IOM) (1999) report, *To Err is Human: Building a Safer Health System*, was released, many were surprised by the findings. The report revealed that the U.S. health care system was not as safe as consumers thought or hoped (Demmel, Williams, & Flesch, 2010). To reduce the occurrence of suboptimal care in adults, systems to identify patients at risk for clinical deterioration were developed. These early warning systems heightened attention on declining clinical parameters and encouraged emergent intervention by health care professionals.

The use of PEWS scores in clinical practice is a new concept. Some of the earliest work conducted on pediatric early warning system scores was based on available adult assessment tools (Akre et al., 2010; Monaghan, 2005; Skaletzky, Raszynski, & Totapally, 2012). Pediatric clinicians and researchers learned from the experiences of adult health care professionals with early warning tools. They have taken into consideration and incorporated into tools the necessary elements

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unique to the pediatric population (infants to adolescents) because anatomy and physiology of children differs widely from adults, and predisposition for sudden deterioration is greater (Demmel et al., 2010; Duncan, 2007; Haines, Perrott, & Weir, 2006; Monaghan, 2005).

Increasingly, the focus for identifying children at risk for deterioration in clinical status is the early recognition of changes in physiologic condition by utilizing objective clinical indicators and risk assessment tools (Akre et al., 2010; Duncan, Hutchison & Parshuram, 2006; Edgell, Finlay, & Pedley, 2008; Haines et al., 2006; Parshuram, Hutchison, & Middaugh, 2009; Skaletzky et al., 2012; Tucker, Brewer, Baker, Demeritt, & Vossmeyer, 2009). The challenge lies in the ability of pediatric health care professionals to identify what early signs of clinical deterioration might require prompt intervention and referral to a higher level of care (Tucker et al., 2009). Establishing a practice that supports early identification of children at risk using reliable and valid early warning system tools, and delivery of timely and helpful interventions, is critical to prevent progression to deterioration in health status (Chapman, Grocott, & Franck, 2010; Hogan, 2006; Skaletzky et al., 2012).

The purpose of early warning system tools is to alert staff to decline in clinical status of patients using predetermined criteria so that needed interventions and resources (e.g., staff, equipment, medications) are made available to care for children before their health status deteriorates further (Akre et al., 2010). Although pediatric early warning system tools have the potential to avert further deterioration in a child's status, concerns about the tools exist. One of the greatest concerns is the number of published tools available to pediatric health care professionals. It is estimated that as many as 10 exist, each with significantly divergent numbers and categories of parameters to be assessed. Further, some published tools have not undergone rigorous testing to examine reliability and validity, as well as clinical effectiveness and utility (Chapman et al., 2010).

Purpose of the Integrative Review

Early identification of pediatric patients whose conditions are deteriorating is essential to patients' lives. Pediatric early warning system tools are used by many pediatric hospitals, nationally and internationally, to aid in evaluating key vital signs, but there are only a small number of research studies on the development, reliability, and validity of the these instruments (Akre et al., 2010; Duncan et al., 2006; Edgell et al., 2008; Edwards, Powell, Mason, & Oliver, 2009; Haines et al., 2006; Parshuram et al., 2009, 2011; Tucker et al., 2009). The purpose of this integrative review was to explore the literature about the use of early warning system scores with pediatric patients. The clinical questions being addressed in this integrative review of evidence are 1) Among infants, children, and adolescents requiring hospital care, what is known about the use of pediatric early warning system scores related to care delivered? and 2) Among infants, children, and adolescents requiring hospital care, what research is needed to explicate the phenomena of early warning systems related to outcomes?

Methods

The integrative review method is a systematic approach using a detailed search procedure to locate relevant evidence of varying levels and perspectives to answer a specific clinical question. Evidence may be obtained from quantitative and qualitative research methods and observational studies, as well as clinical practice publications and expert opinion (e.g., letters to editors, conference abstracts). The integrative review approach differs from other appraisal methods (e.g., meta-analyses, systematic reviews) that involve rigorous research evaluations to compare and contrast findings from various studies (Whittemore & Knafl, 2005). The authors applied the integrative review approach to present a diverse number of sources to increase the understanding of pediatric early warning system scores hoping to inform nursing practice.

Cooper's (1982) guidelines for completing an integrative review were used: problem formulation (identifying the topic to be examined, clarifying the question to be answered, and determining inclusion and exclusion criteria for the search method), data collection (identifying all publications on the identified problem/topic and gathering information from the publication search using keywords or phrases), data evaluation (assessing the quality or hierarchy of evidence, by more than one individual, for studies/publications found), data analysis and interpretation (interpreting information such as findings, themes or concepts from collected publications), and report preparation (developing tables, graphs, or narratives of findings for publication and presentation).

Search Method

Several key words were used to search for research and clinical practice publications and conference abstracts on pediatric early warning system scores. The following words were searched individually and in combination with each other: *pediatrics, infants, children, pediatric early warning system scores, early warning scores, early detection,* and *PEWS*. Inclusion criteria were a) nursing journals, interdisciplinary journals, and dissertations; b) focus on the pediatric population (infants to 18 years old); and c) publications written in English. Search engines used included Cumulative Index of Nursing and Allied Health Literature (CINAHL), PsychInfo, Nursing and Allied Health, and MEDLINE. The search included all publications from 1980 through August 2012.

Search Results

An initial search conducted by the first author on *pediatrics, infants, children, pediatric early warning system scores, early warning scores, early detection,* and *PEWS* yielded 30 publications and conference abstracts. Two articles were subsequently omitted from review because they excluded pediatric patients from data collection or did not discuss pediatric early warning system scores. The remaining 28 publications and conference abstracts were obtained and evaluated. Additionally, the remaining authors, who had reviewed PEWS literature in the past, inspected their personal files of publications on PEWS scores to determine if additional information was available but not located during the first author's literature search.

Critical appraisal of the evidence when conducting an integrative review is important to ensure validity (Cooper, 1982; Fineout-Overholt, Melnyk, Stillwell, & Williamson, 2010). The literature reviewed was ranked according to level of evidence using the Melnyk and Fineout-Overholt (2005) hierarchy of evidence rating system (see Table 1). Each author

reviewed the literature and assigned a level of evidence. When inconsistencies occurred, the authors discussed and came to consensus on a rating. Because of the evolving understanding of PEWS scores, the authors felt it important to include in the review published conference abstracts, commentaries, and letters to editors. Although these sources represent the lowest level of evidence, this information has the potential to inform clinical practice and future research.

Table 1.
Hierarchy of Evidence

Level I	Evidence from a meta-analysis or systematic review of relevant randomized controlled trials (RCTs).
Level II	Evidence gathered from a minimum of one well-designed RCT.
Level III	Evidence from non-randomized controlled trials.
Level IV	Evidence from well-designed cohort and case-control studies.
Level V	Evidence from reviews of qualitative studies.
Level VI	Evidence from a single qualitative study.
Level VII	Evidence from expert opinion.

Source: Melnyk & Fineout-Overholt, 2005.

Findings

Twenty-eight publications were included in the review; 13 were data-based, 10 were clinical practice literature, and 5 were conference abstracts. Levels of evidence ranged from IV to VII. A summary of search results is presented in Table 2.

Three PEWS tools that explored psychometric properties (Akre et al., 2010; Skaletzky et al., 2012; Tucker et al., 2009) were adaptions of the Royal Alexandra Hospital for Sick Children, Brighton – PEWS developed by Monaghan (2005). This tool is based on five domains: behavior, cardiovascular status, respiratory condition, nebulizer use, and persistent postoperative vomiting (see Figure 1). Akre et al. (2010) conducted a retrospective chart review (N = 186) and found PEWS to be highly sensitive (85.5%) in identifying patients at risk for deterioration in clinical status. The authors highlighted the importance of additional research to confirm their findings and describe the impact of PEWS on clinical outcomes.

Skaletzky and colleagues (2012) conducted a retrospective case-control study including 100 cases and 250 controls to begin to explore a Modified PEWS, which does not include adding points for nebulizer use or persistent post-operative vomiting. Scores range from 0 to a maximum potential total of 9. The researchers found that the Modified PEWS helps to recognize children on medical-surgical wards who were at increased risk for clinical deterioration. The sensitivity and specificity for a score of 2.5 were 62% and 89%, respectively. The researchers were not able to completely validate the tool in view of its low sensitivity.

Tucker et al. (2009) used a prospective descriptive design to evaluate the use of the PEWS to detect worsening of the clinical status of 2,979 children admitted to a medical unit over a 12-month period. This tool was different in that the authors changed a couple of criteria in some components (e.g., O_2 liters/minute) as well as terminology (e.g., retractions vs. tracheal tug/recessions). This study not only explored sensitivity and specificity, but examined inter-rater reliability as well. Findings included that PEWS was effective in differentiating children who required transfer to a higher level of care and those not needing advanced treatment. The sensitivity and specificity for a score of 3.0 were 90% and 74%, respectively. Inter-rater reliability was high (intra-class correlation coefficient = 0.92, $p < 0.001$). The authors recommended that additional research be conducted to accurately depict the comprehensive impact of the early warning system scores on clinical outcomes in children.

Another study explored adapting Monaghan's (2005) tool specifically for the pediatric cardiac population but did not look at psychometric properties. A pilot study was conducted that involved reviewing electronic health records (N = 100) and conducting interviews with nurses (N = 27). The authors reported that the Cardiac Children's Hospital Early Warning Score (C-CHEWS) might assist pediatric critical care nurses with early recognition and treatment of patients at risk for deterioration. The need for psychometric testing of the tool was acknowledged by the authors (McLellan & Connor, 2013).

Six other tools were described as original and developed based on parameters the authors believed most appropriate for the pediatric patient population in their clinical setting. For example, over a 5-year period, Duncan et al. (2006), Parshuram et al. (2009), and Parshuram et al. (2011) worked to develop and test the Bedside PEWS score. Using focus groups with expert pediatric nurses (N = 10), participants generated 16 tool items and a severity of illness score for use with hospitalized children. Initial statistical measures on performance of the tool demonstrated sensitivity of 78% and specificity of 95% at a score of 5 (Duncan et al., 2006). At this time, the tool was named the PEWS score. Next investigators used a case-control design (60 case and 120 case-control patients) to create a more user-friendly severity of illness score that could discriminate between various degrees of illness acuity in children. The resulting Bedside PEWS tool is a simple, seven-item (heart rate, systolic blood pressure, capillary refill, respiratory rate, respiratory effort, transcutaneous oxygen saturation, and oxygen therapy) severity of illness score. The tool is also inclusive of age groups (0 to 3 months, 3 to 12 months, 1 to 4 years, 4 to 12 years and older than 12 years). Scores range from 0 to 26, increasing with severity of illness. The sensitivity and specificity were 82% and 93%, respectively, at a score of 8 (Parshuram et al., 2009). Finally, a case-control study was performed to validate the Bedside PEWS score using a larger population of children (N = 2,074) across multiple medical centers (N = 4). The authors noted the importance of conducting prospective studies as well as exploring the impact of the Bedside PEWS on clinical outcomes (Parshuram et al., 2011).

Edwards et al. (2009) also developed an original tool. The Cardiff and Vale Paediatric Early Warning System (C&VPEWS) was developed using physiological parameters according to pediatric advanced life support recommendations (e.g., airway threat, such as stridor; oxygen therapy required to keep saturations greater than 90%, respiratory rate; respiratory

Table 2.
Summary of Articles Included in the Integrative Review

Author/Year	Tool Used/Design/Sample	Level of Evidence	Conclusion
Summary of Data-Based Publications			
Duncan, Hutchison, & Parshuram (2006)	Pediatric Early Warning Score (PEWS) developed by authors/focus groups/10 nurses	IV	Use of PEWS helped to identify greater than 75% of code blue calls within one hour of warning.
Hogan (2006)	No specific tool identified; explored early warning systems in general/focus groups/nurses, health care assistants and nursing students from a variety of specialties, sample size not provided	VI	It is critical for nurses to focus on all physiological parameters for the early identification of patients at risk for deterioration.
Haines, Perrott, & Weir (2006)	Paediatric Early Warning Tool developed by authors/prospective observational/360 children admitted to all types of specialties including PICU; infants to adolescents	IV	The use of a validated pediatric early warning tool is critical for the early recognition and treatment of acutely ill children.
Edgell, Finlay, & Pedley (2008)	Paediatric Advanced Warning Score developed by authors/retrospective pilot evaluation/46 children admitted from emergency department (ED) to PICU and 49 children admitted from ED to general pediatric ward; infants to 16 years	IV	Use of a Pediatric Advanced Warning Score can help identify children in the ED who require admission to the PICU.
Tucker et al. (2009)	Adapted Brighton – Pediatric Early Warning Score/prospective descriptive/2,979 children admitted to a 24-bed inpatient general medicine unit; newborns to 22 years	VI	The PEWS tool was found to reliable and valid with identifying hospitalized children at risk for decline in clinical status.
Edwards, Powell, Mason, & Oliver (2009)	Cardiff and Vale Paediatric Early Warning System/prospective cohort study/1,000 pediatric patients admitted to inpatient units; infants to 16 years	IV	Further research is needed to determine optimum criteria needed for widespread implementation of an early warning system.
Parshuram, Hutchison, & Middaugh (2009)	Bedside PEWS Score Developed by authors/case-control/ 60 case and 120 case control patients; infants to adolescents	IV	Initial validation of the bedside pediatric early warning system score demonstrated the instrument can identify critically ill children.
Akre et al. (2010)	Adapted Brighton – PEWS/retrospective chart review/186 medical-surgical unit patients excluding ICU and ICU step-down units; infants to 21 years	VI	PEWS has the potential of being able to assess in advance (more than 11 hours) the need to adapt a patient's plan of care to avoid the need for rapid response.
Oliver, Powell, Hutchison, & Middaugh (2010)	Cardiff and Vale Paediatric Early Warning System/observational study/1,000 patients admitted to all inpatient units; infants to 16 years	IV	Successful use of early warning scores requires adherence to recording observations.
Edwards, Mason, Oliver, & Powell (2011)	Melbourne Activation Criteria/cohort study/1,000 pediatric patients admitted to all pediatric wards	IV	The Melbourne Activation Criteria demonstrated low predictive value for activating early response to emergencies.
Parshuram et al. (2011)	Bedside PEWS Score developed by authors/multicenter, case-control study/2,074 patients from four hospitals admitted to inpatient units other than ICU; infants to 18 years	IV	Bedside PEWS can potentially help clinicians identify children who are deteriorating clinically.

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Table 2. (continued)
Summary of Articles Included in the Integrative Review

Author/Year	Tool Used/Design/Sample	Level of Evidence	Conclusion
Summary of Data-Based Publications (continued)			
Skaletzky, Raszynski, & Totapally (2012)	Adapted Brighton – Pediatric Early Warning Score to Modified Pediatric Early Warning System Score/ retrospective case-control/100 cases and 250 controls admitted to medical-surgical wards; infants to 14 years	IV	Use of a modified PEWS was helpful in identifying patients at risk for deterioration who required further evaluation.
McLellan & Connor (2013)	Adapted Brighton – Pediatric Early Warning Score to Cardiac Children's Hospital Early Warning Score (C-CHEWS)/pilot study/27 nurses	VI	C-CHEWS is helpful in identifying pediatric cardiovascular patients at risk for deterioration; validation including sensitivity and specificity are needed.
Summary of Clinical Practice Literature			
Tume & Bullock (2004)	Focus of Paper/Tool Discussed Clinical discussion/no specific tool identified; explored early warning systems in general	VII	Early warning tools for children must be derived from sound data.
Monaghan (2005)	Summary of process of setting up a pediatric critical care response team/Brighton Paediatric Early Warning Tool	VII	Implementation of a response team has resulted in children showing sign of clinical deterioration receiving optimal care during the acute phase of illness.
Fraser, Singh, & Frewen (2006)	Commentary/Bedside PEWS Score	VII	PEWS scores offer a possible method for identifying children requiring a higher level of care.
Tibballs & Kinney (2006)	Letter to editor/Paediatric Early Warning Tool	VII	Determining the sensitivity and specificity of criteria to identify children potentially requiring a higher level of care is needed.
Author Unknown (2006)	Commentary/no specific tool identified; explored early warning systems in general	VII	Nurses report that early warning systems support clinical decision making and assessment.
Duncan (2007)	Letter to editor/no specific tool identified	VII	There is no consistent approach to use of early warning systems for children.
Waller (2008)	Abstract/no specific tool identified; explored early warning systems in general	VII	PEWS has the potential to empower nurses to obtain appropriate care for patients.
Adshead & Thomson (2009)	Implementation of an early warning system in the Emergency Department/Brighton Paediatric Early Warning Tool	VII	Application of an early warning system in the ED can assist nurses with accurate assessment of children's needs including interventions.
McCabe, Duncan, & Heward (2009)	Clinical article highlighting early identification systems for children at risk for critical illness or deterioration/no specific tool identified; explored early warning systems in general	VII	A multidisciplinary, collaborative approach to the development, implementation and evaluation of PEWS is needed.
Demmell, Williams, & Flesch (2010)	Implementation of PEWS on Pediatric Hematology/Oncology Unit/Pediatric Early Warning Scoring System	VII	Implementing PEWS helped eliminate obstacles, which prevented early referral for children who were clinically deteriorating.

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Table 2. (continued)
Summary of Articles Included in the Integrative Review

Author/Year	Tool Used/Design/Sample	Level of Evidence	Conclusion
Summary of Clinical Practice Literature (continued)			
The Joint Commission (2011)	Case example of use of PEWS in clinical practice/Pediatric Early Warning Score	VII	PEWS improves staff communication and patient safety.
Ryan (2011)	Abstract – No results/Pediatric Early Warning Scoring System	VII	PEWS empowers nurses to share information with health care team that is complete.
Breslin, Marx, McBeth, & Pavulurl (2012)	Abstract – Relationship between PEWS and ED disposition/no specific tool identified	VII	PEWS alone does not provide adequate discriminant ability to predict ED disposition.
Keyes, Goreleck, Yen, & Myer (2012)	Abstract – Evaluation of PEWS for pediatric placement after inter-facility transfer/ Bedside PEWS Score	VII	The PEWS score, measured at two points in time, is associated with patient placement upon transfer.
Eggen, Solevag, Schroder, & Nakstad (2012)	Abstract – validation of PEWS in a Norwegian clinical for children and adolescents/Pediatric Early Warning Scoring System	VII	The modified PEWS is helpful in identifying patients at risk for deterioration in the pediatric clinic setting.

Figure 1.
Royal Alexandra Hospital for Sick Children, Brighton – Paediatric Early Warning

	0	1	2	3	Score
Behavior/Neuro	Playing/appropriate.	Sleeping.	Irritable.	Lethargic/confused. Reduced response to pain.	
Cardiovascular	Pink or capillary refill 1 to 2 seconds.	Pale or capillary refill 3 seconds.	Grey or capillary refill 4 seconds. Tachycardia of 20 above normal rate.	Grey and mottled or capillary refill 5 seconds or above. Tachycardia of 30 above normal rate or bradycardia.	
Respiratory	Within normal parameters, no recession or tracheal tug.	Greater than 10 above normal parameters, using accessory muscles, 30+% FiO2 or 4+ liters/minute.	Greater than 20 above normal parameters recessing, tracheal tug. 40+% FiO2 or 6+ liters/minute.	5 below normal parameters with sternal recession, tracheal tug or grunting. 50% FiO2 or 8+ liters/minute.	
					Total:
Score 2 extra for quarter-hourly nebulizers or persistent vomiting following surgery					

Source: Monaghan, 2005.

observations, such as use of accessory muscles; heart rate; blood pressure; level of consciousness; and nurse or physician worried about child's clinical state). Using a prospective cohort design, the researchers collected data on 1,000 children to explore the accuracy of C&VPEWS in identifying children at risk for critical deterioration. The C&VPEWS had a sensitivity of 89% and specificity of 64% for a score of 1. The C&VPEWS was not fully validated due to the low specificity.

While testing the C&VPEWS, Oliver, Powell, Edwards, and Mason (2010) noted a lack of consistency by nurses in recording vital signs, which is essential for successful completion and application of early warning system tools. Following modifications to, and educational sessions on the C&VPEWS, an observational study was conducted to determine if nursing staff were recording a complete set of vital signs as required. Data collected on 1,000 children revealed that a complete set of observations required for the C&VPEWS to activate successfully were only documented in 52.7% of patients. The authors emphasized that for C&VPEWS implementation to be effective, improved adherence to documenting observations was critical. Earlier in 2006, Hogan noted similar findings. Conducting three focus groups with expert nurses, health care assistants, and nursing students (*n* not reported), the author found that the lack of completing and recording vital

signs a barrier to successful use of early warning system scores. For example, one finding noted that the respiratory rate of children was only completed 50% of the time.

Finally, reflecting on the low specificity in the Edwards et al. (2009) investigation, Edwards, Mason, Oliver, and Powell (2011) conducted a cohort study to determine if other criteria (Melbourne Activation Criteria [MAC]) resulting in the activation of a medical emergency team would improve identifying children at risk for deterioration. Physiological parameters were similar to those used in the study by Edwards et al. (2009). However, some parameters were defined differently. For example, in the current study, the investigators examined oxygen saturation less than 90%; abnormal respiratory observations included apnea and cyanosis, and level of consciousness was defined as acute changes in neurological status to include seizure activity. Data were collected on 1,000 pediatric patients. Results of this exploration were not favorable. The MAC had a sensitivity of 68.3% (95% CI = 57.7 to 77.3), specificity 83.2% (95% CI = 83.1 to 83.2), positive predictive value (PPV) 3.6% (95% CI = 3.0 to 4.0), and negative predictive value 99.7% (95% CI = 99.5 to 99.8). The low PPV would lead to a significant number of triggers activating the emergency medical team when, in fact, such intervention was not required.

Haines et al. (2006) developed their own tool (Bristol Paediatric Early Warning Tool) because there were no published PEWS scores available at the time their study was conducted. Using a retrospective case control design (N = 360), the authors developed and evaluated a physiologically based tool for the identification of acutely ill children at risk for further clinical deterioration. The tool consists of 5 parameters, including acute airway obstruction, breathing, circulation, disability (neurological), and other (hyper or hypokalemia, suspected meningococcus). The researchers reported the tool to have 99% sensitivity and 66% specificity. However, other researchers (Edwards et al., 2009; Tibballs & Kinney, 2006) reported that the methodology and analysis used were inappropriate; therefore, the tool was not accurately evaluated, and it is impossible to accurately report either the sensitivity or specificity of the tool.

In 2008, researchers (Edgell et al., 2008) began to explore development and validation of an early warning scoring system that could be used to assess pediatric patients in the emergency department (ED) setting. Conducting a retrospective pilot evaluation, Edgell and colleagues (2008) developed the Paediatric Advanced Warning Score (PAWS) based on age-dependent physiological parameters (cardiovascular, respiratory, and neurological). To explore psychometric properties of PAWS, the researchers retrospectively calculated scores on 46 consecutive children admitted from the ED to the pediatric intensive care unit (PICU) and 49 children admitted from the ED to the general pediatric ward. Initial psychometric properties were adequate (sensitivity of 70% and specificity of 90% for a score of greater than 3). The authors recommended that future research use a prospective design.

The Use of PEWS Scores And Relationship to Care Delivered

Five major concepts emerged from analysis of retrieved documents regarding the phenomena of early warning system scores in the pediatric population: overview of pediatric early warning system scores, supplementary benefits, facilitators to successful implementation, barriers to successful implementation, and needed research. All concepts relate to what is known about PEWS scores and what research is needed to further advance this practice in the care of the hospitalized pediatric population.

Overview of PEWS Scores

It is important for pediatric nurses to be aware of all the early warning system scores available for children and what should be considered in selecting a tool for implementation in clinical practice. A PEWS score has the potential to offer a reasonable and testable method for recognizing children at risk for decline in clinical status (Fraser, Singh, & Frewen, 2006). The ideal tool would be one that uses routinely monitored clinical parameters, is easy to use, and is psychometrically sound (Chapman et al., 2010). However, it is recognized that early warning system scores are not without challenge in the pediatric population. What is most confusing to pediatric nurses is the explicit variability in naming of tools (e.g., if a tool is modified from another, why are new names being assigned?), physiological parameters and scores used, the wide ranging methods of development, and the absence of rigorous psychometric testing with many of the tools available (Chapman et al., 2010). For example, the Adapted Brighton – PEWS used by Tucker et al. (2009) has 5 parameters whereas the Paediatric Early Warning Score Developed by Duncan et al. (2006) has 16. Although it is estimated that as many as 36 parameters are used in various PEWS tools, the one uniformity is that three domains (e.g., cardiovascular, respiratory, and behavior) are used with all tools (Duncan, 2007; Edwards et al., 2011). Scores using the Monaghan (2005) assessment tool are assigned in three domains: behavior (e.g., playing/age appropriate behavior, sleeping, irritable, lethargic), respiratory, and cardiovascular. Scores in each domain can range from 0 to 3 points. Additionally, two points are added for respiratory nebulizer treatments that are continuous or provided every 15 minutes and two points for persistent vomiting following surgery (see Figure 1). The total score can range from 0 to 13, with the higher number reflecting a sicker child at higher risk for clinical deterioration and potentially requiring an advanced level of care. A total score equal to or greater than 4, or a score of 3 in any of the three domains, is reflective of a critical value in need of consultation to assess the child and provide intervention as needed (Monaghan, 2005). Some researchers have adapted tools previously developed (Akre et al., 2010; McLellan & Connor, 2013; Skaletzky et al., 2012; Tucker et al., 2009), while others have created their own (Duncan et al.; 2006; Edgell et al., 2008; Edwards et al., 2009; Haines et al., 2006; Parshuram et al., 2009, 2011). Most importantly, very few studies have provided strong evidence to support the reliability and validity of pediatric early warning tools (Akre et al., 2010; Duncan et al., 2006; Edgell et al., 2008; Edwards et al., 2009; 2011; Haines et al., 2006; Parshuram et al., 2009; Skaletzky et al., 2012; Tucker et al., 2009).

What is clearly understood with all early warning system scores in the pediatric population is that the unique needs of children of all age groups, from infants to adolescents, need to be considered when developing and implementing a tool (Haines

et al., 2006). Clinical parameters for the pediatric population vary widely across age groups; therefore, one set of physiological parameters would not be feasible. Additionally, the health status of children with cardiac and respiratory disease can worsen rapidly, further compounding this problem (Haines et al., 2006).

The primary aim of all PEWS scores is to identify children early who are at risk of rapid deterioration so that immediate referral for prompt treatment can begin to halt further decline (Hogan, 2006; Skaletzky et al., 2012). Early intervention and treatment might include closer monitoring, 1:1 nurse patient ratio, more frequent assessment by the attending physician, response team alert, and potentially transfer to a higher level of care, such as the PICU (Demmel et al., 2010; Duncan et al., 2006; Skaletzky et al., 2012). Equally important is having a standardized assessment tool so that a more thorough and consistent approach is used by all members of the health care team to identify the needs of children at risk within hospitals. Such a tool would provide a common language and approach to providing care among all members of the health care team.

Supplementary Benefits

In addition to identifying patients at risk for clinical deterioration, use of pediatric early warning system scores can have value-added advantages as well. In the adult patient population, use of early warning scores have been correlated with greater confidence, authority, and empowerment among nursing staff and enhanced communication among health care teams overall (Andrews & Waterman, 2005; Skaletzky et al., 2012; The Joint Commission, 2011). Tucker et al. (2009) found similar results with pediatric nurses in the inpatient setting. Using PEWS, nurses found there was a decrease in miscommunication among members of the team regarding the patient's actual status and improved collaboration. Further, use of the PEWS algorithm removed barriers and empowered nurses to make independent clinical decisions based on the predetermined multidisciplinary plan (Tucker et al., 2009).

Facilitators to Successful Implementation

Introducing a culture that supports the use of a pediatric early warning system score is critical if health care professionals are to prevent needless clinical deterioration and improve outcomes in the pediatric population (Hogan, 2006). It is critical that pediatric nurses be engaged in the development and implementation of tools as part of a multidisciplinary team early on in the process (Tucker et al., 2009). Adshead and Thomson (2009) found during implementation of PEWS in the ED setting that the reactions of nurses were mixed. Concerns raised were the perception that introducing another assessment tool would increase already busy workloads, while others looked forward to experiencing the same successes reported with adult patient populations. A lesson learned was the importance of having nurses participate early on in discussions as a standard for selecting a pediatric early warning system tool that best meets local needs as well the requirements of a specialized patient population (Adshead & Thomson, 2009).

Key to implementing a pediatric early warning system score in any setting is ensuring all staff receive timely multidisciplinary education to not only recognize patients who may be deteriorating clinically but to also know how to appropriately use the assessment tool chosen by the institution for implementation (Adshead & Thomson, 2009; Haines et al., 2006; Monaghan, 2005). Demmel et al. (2010) and Tucker et al. (2009) found that providing staff education at the early stages of implementation that covered the history and development of the pediatric early warning scoring tool, as well as the rationale for the use of early warning systems, to be of great value with obtaining buy-in during the application process. Particular emphasis should be on the procedure for scoring the assessment tool as well as how to best integrate the instrument into other aspects of clinical practice already in place. This would help address the concern related to increased workload. To fully engage staff in pre-implementation education, nursing experts recommend that staff practice using a PEWS tool applying interactive case scenarios based on patients previously cared for by the respective clinical area (Demmel et al., 2010). A multimodal approach (e.g., in-services, web-based learning, visual aids, simulation) to multidisciplinary education encourages participation from staff who work a variety of shifts.

Critical to the proper use of the PEWS scoring tool is ensuring staff take immediate action should the score indicate. To address this, researchers have demonstrated that having an interdisciplinary algorithm that defines specific steps to be taken according to a child's early warning score facilitates collaborative clinical decision-making among team members (Demmel et al., 2010). The events delineated in the algorithm encourages and supports nurses to consult with other members of the health care team at the earliest possible time a change in patient status is observed (Akre et al., 2010).

Barriers to Successful Implementation

As noted earlier, an unsystematic manner of completing and documenting a full set of vital signs is as an impediment to successful implementation of PEWS scores. Oliver et al. (2010) found that while the successful use of early warning scores requires adherence to recording observations (e.g., vital signs), the frequency and documentation of assessments varied widely. The authors recommended that in order for early warning systems to be effective, the lack of consistency in observing and recording vital signs must be addressed because current scores for children require that a thorough set of observations be recorded (Oliver et al., 2010). However, it is important to recognize that in some clinical settings and under some circumstances, it may not always be possible to observe, and therefore document data points (e.g., parental concern) required for scoring some tools (Demmel et al., 2010; McLellan & Connor, 2013). For example, in the ED setting, nurses may not be able to assess level of parental concern because the child is being brought in via helicopter transport or resides in an extended care facility and parents are not readily available because they are en route to the hospital.

Needed Research

While the use of early warning system scores in the adult patient population has been effective, establishing benefit in pediatric health care has not been well studied, and there is limited research on reliability and validity of assessment tools (Adshead & Thomson, 2009; Chapman et al., 2010; Tibballs & Kinney, 2006; Tucker et al., 2009; Tume & Bullock, 2004). Pediatric researchers and clinicians

have reported that few early warning system scores have undergone methodologically rigorous development and evaluation to date recommending that further validation studies be completed (Chapman et al., 2010; Edwards et al., 2009; Parshuram et al., 2011; Tume & Bullock, 2004). Critical to future research is adequately powered, multi-center prospective studies to determine whether early warning system scores improve quality of care and clinical outcomes in the pediatric population as well as establish generalizability (Chapman et al., 2010; Parshuram et al., 2011). Further, psychometric testing of assessment tools should occur in all pediatric populations before widespread application takes place within individual health care organizations (Chapman et al., 2010; Duncan et al., 2006; Edwards et al., 2009; Tume & Bullock, 2004). From a health care utilization and cost perspective, clinical utility, resource utilization, and cost-benefit analyses need to be described and compared across the various tools available (Chapman et al., 2010). Despite these important recommendations for future research, experts believe that PEWS scores have the potential to identify children at risk for clinical deterioration, and with proactive treatment, improve the delivery of health care and outcomes (Parshuram et al., 2011).

Discussion

Pediatric nurses should be involved in deciding which psychometrically sound (evidence-based) PEWS tool they believe most meets the needs of their patient population within their respective health care institution. In health care organizations where an assessment tool has been adopted, continuous monitoring needs to be conducted to ensure the procedure is working properly to identify children requiring a higher level of care versus children who may not need this level of intervention (Chapman et al., 2010). Ongoing monitoring, evaluation and education are critical to successful implementation of early warning systems. Weekly assessment of scoring procedures to ensure interrater reliability by having two nurses independently score patients and discuss findings has also been found to support effective application of the tool in practice (Chapman et al., 2010; Demmel et al., 2010).

Education in the clinical setting regarding early warning system scores should emphasize that these tools aid nurses with all levels of expertise. Application of the pediatric early warning tool should be introduced in an inter-professional forum to engage all users (e.g., nurses, nursing assistants, physicians, respiratory therapists) of the scoring system to be used. As with any assessment instrument, it is essential to also ensure that nursing judgment is not superseded by this tool because the activation of emergency systems does not have to be delayed due to a low score. It is also critically important that all pediatric health care professionals pay close attention to the lessons learned from clinicians and researchers who have worked for many years to develop effective early warning system tools for the adult population. The experience to date for adults is that by using invalidated tools, very little benefit has been achieved. For hospitals just beginning to consider implementing an early warning system score for children, it is important to select a tool that best meets the needs of the patient and is reliable and valid (Chapman et al., 2010). There still remains an open window of opportunity for pediatric health care professionals to take a step back and evaluate how we can approach this critically needed aspect of care from a clinically appropriate and scientifically sound perspective (McCabe, Duncan, & Heward, 2009).

Limitations

As characteristic with many integrative reviews, references may have been unnoticed due to exclusion of other databases or search methods. PEWS scores are a new, evolving phenomena, and key terms may not allow full capture of all available literature. Additionally, as a result of language restrictions, selection bias may have occurred.

Conclusion

Although still in its infancy, initial data on the use of PEWS scores suggest that this assessment tool has the potential to quantify severity of illness in children, In turn, it is hoped this results in facilitating early identification of patients at risk for clinical deterioration and prompt intervention to avoid the need for transfer to a higher level of care. However, greater psychometric testing of tools is needed before any recommendations can be made regarding extensive implementation with the pediatric population.

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Additional Readings

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An Integrative Review of Pediatric Early Warning System Scores

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The purpose of this learning activity is to provide an overview of early warning system scores in the pediatric patient population.

Objectives

1. Identify the various types of early warning system tools.
2. Explain the importance of establishing an early warning system for pediatric patients.

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