Implementation and adherence to the Bedside Paediatric Early Warning System (BedsidePEWS) in a pediatric tertiary care hospital

Orsola Gawronski (orsolagawronski@yahoo.it)
Ospedale Pediatrico Bambino Gesu https://orcid.org/0000-0001-8686-5897

Federico Ferro
Bambino Gesù Children's Hospital

Corrado Cecchetti
Ospedale Maggiore Policlinico

Marta Luisa Ciofi Degli Atti
Ospedale Pediatrico Bambino Gesu

Immacolata Dall'oglio
Ospedale Pediatrico Bambino Gesu

Emanuela Tiozzo
Ospedale Pediatrico Bambino Gesu

Massimiliano Raponi
Ospedale Pediatrico Bambino Gesu

Research

Keywords: monitoring, resuscitation, early warning score, pews, track and trigger score, deteriorating children, chronic illness, acute illness

Posted Date: May 11th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-23140/v1

Abstract

Background

Clinical deterioration in children admitted to hospital wards often manifests through signs of increasing illness severity that may lead to unplanned Pediatric Intensive Care Unit admissions or cardiac arrest, if undetected. The Bedside Pediatric Early Warning System (BedsidePEWS) is a validated Canadian scoring system used at a large tertiary care children' hospital to prevent critical illness and standardize the response to deteriorating children on the wards.

Methods

A 6-month audit was performed to evaluate the use of the BedsidePEWS, escalation of patient observations, monitoring and medical reviews on the wards in 2018.

Two research nurses performed weekly visits to the hospital wards to collect data on BedsidePEWS scores, medical reviews, type of monitoring and vital signs recorded. Data were described through means or medians according to the distribution. Inferences were calculated either with Chi-square, Student's t test or Wilcoxon-Mann–Whitney test, as appropriate ($P < 0.05$ considered as significant).

Results

A total of 522 Vital Signs (VS) and score calculations on 177 patient clinical records were observed from 13 hospital inpatient wards. Frequency of VS and score documentation occurred <3 times per day in 33% of the observations. Adherence to the VS documentation frequency according to the hospital protocol was observed in 54% for all patients; for children with chronic health conditions (CHC) it was significantly lower than children admitted for acute medical conditions (47%, P=0.006). The BedsidePEWS score was correctly calculated and documented in 84% of the observed VS documentation events. Systolic blood Pressure was recorded in 79% and Temperature in 91% of the VS recording events. Patients within a 0-2 BedsidePEWS score range were all reviewed at least once a day by a physician. Only 50% of the patients in the 5-6 score range were reviewed within 4 hours and 42% of the patients with a score ≥7 within 2 hours. Transcutaneous Oxygen Saturation continuous monitoring was applied to 60% of the children at higher risk (BedsidePEWS ≥5).

Conclusions

Escalation of patient observations, monitoring and medical reviews matching the BedsidePEWS is still suboptimal. Children with CHC are at higher risk of lower compliance. Impact of adherence to predefined response algorithms on patient outcomes should be further explored.

Introduction

Clinical deterioration in children admitted to hospital wards is often detected through signs of increasing severity of illness, which otherwise may lead to unplanned Pediatric Intensive Care Unit (PICU) admissions or cardiac arrest [1, 2]. Pediatric Early Warning Systems (PEWS) have been devised to detect signs of clinical instability with the purpose to activate appropriate and timely interventions to prevent evolving into critical illness. The activation of an intervention is usually recommended when one or more clinical indicator thresholds are breached (as in trigger systems) or if a certain score, which synthetizes the deviation from clinical stability of a set of predefined vital signs or clinical indicators, is reached (as in scoring systems) [3]. In a case control study that evaluates the performance of 18 PEWS, scoring systems performed better than trigger systems, reaching higher specificity and Area Under Roc Curve (AUROC) values than trigger systems. The Bedside Pediatric Early Warning System (BedsidePEWS) ranked second, with an AUROC of 0.88 (CI 0.85 to 0.91) [4].

The BedsidePEWS was developed by Parshuram et al. in 2011 [5] who conducted a multicenter evaluation of its performance, and the first test of its effect on significant patient outcomes through a clustered randomized controlled trial [6]. BedsidePEWS performance was reported to be more effective than the retrospective nurses' ratings of deteriorating patients urgently admitted to the PICU (BedsidePEWS AUROC 0.87, CI 0.85 to 0.89 vs Nurses' ratings AUROC 0.83, CI 0.81 to 0.86, $P < 0.0001$) [5]. In the Evaluation of Processes of care and Outcomes of Children in Hospital (EPOCH) trial, the BedsidePEWS enabled to significantly reduce the severity of illness of patients urgently admitted to the PICU, but had no significant effect on child mortality [6]. Some evidence of PEWS effectiveness was reported in a systematic review where PEWS were part of a wider systems approach involving a Rapid Response Team (RRT) or Medical Emergency Team (MET) ready to respond to deteriorating patients, with a potential to reduce 31 deaths/10.000 hospital admissions [7]. However, evidence is limited since most studies are single-centered and mainly performed in specialist hospitals [8]. No studies to date have described the implementation of the BedsidePEWS in a tertiary care pediatric hospital. More research is still required to describe compliance to PEWS response algorithms and process outcomes such as the frequency and type of vital signs monitored, the frequency of physician reviews and compliance to the BedsidePEWS score calculation according to the BedsidePEWS score range. Therefore, a 6-month audit was performed to assess the use of the BedsidePEWS and escalation practices on the wards of a tertiary care pediatric hospital in 2018.

Methods

The aim of this audit was to describe compliance with the use of the BedsidePEWS in a large tertiary care children's hospital: 1) Use of the correct chart by age group according to the patient's age; 2) Frequency and type of vital signs, monitoring and documented physician reviews in all children, children with high BedsidePEWS scores (scores ≥ 7 and $\geq 5 < 7$) and children with chronic health conditions (CHC). CHC are defined as illnesses that last for 3 months or more or require long term care [9, 10]; 3) Presence and adequacy of score calculation. The audit was performed from July to December 2018 by two independent research nurses, members of the research team and experts of BedsidePEWS. The reviewers collected data and performed data evaluation in collaboration with the audit team. A sample of ≥ 10

charts in every ward, available at the time of the audit, was selected to collect data regarding the last 24 hours of admission.

Analysis

Data were described through means or medians, as appropriate according to the distribution, tested with the Kolmogorov–Smirnov test. Inferences were calculated with chi-square, Student's t test or Wilcoxon-Mann–Whitney test, as appropriate (a p-value <0.05 is considered statistically significant).

Setting

The audit was performed in a large tertiary care pediatric hospital in Central Italy. The hospital has a total of 607 beds across two sites, 25 hospital wards and 4 PICUs/Cardiac Intensive Care Units (CICU) and 1 Neonatal Intensive Care Unit (NICU), with a total of 465 beds at the main site where the audit for the present study was performed. There are also 4 High Dependency Units (HDU) for cardiac, respiratory and hematology-oncology patients with a total of 77 beds for non-invasive ventilation (NIV), inotropic support and isolation if required.

The BedsidePEWS was first introduced in 2014, during the hospital's involvement in the EPOCH randomized cluster clinical trial, because the children's hospital where the current study was conducted was randomly allocated to the intervention study group. A daily hard copy paper, age specific, BedsidePEWS chart was customized to document vital signs and calculate the score. A color system was used to define score thresholds and rapidly identify any deviance of vital signs from normal values, according to five different age groups (<3 months, 4-12 months, >1<4 years, 4-12 years, > 12 years). The BedsidePEWS consists of 7 clinical indicators: heart rate (HR), respiratory rate (RR), systolic blood pressure (SBP), work of breathing (WoB), capillary refill time (CRT), oxygen therapy (OT) and percutaneous oxygen saturation (SpO2). Other vital signs, such as temperature (T) and level of consciousness (LoC) are also required by the hospital Vital Signs (VS) protocol. A score matched response algorithm was embedded in the chart to define: 1) score calculation and VS documentation frequency; 2) timing for medical and nursing review; 3) recommended distribution of high score patients among the nursing team; and, 4) type of monitoring (continuous cardiac monitoring, SpO2 or intermittent). A Vital Signs (VS) protocol with the BedsidePEWS embedded was edited. The documentation of a minimum of 5 clinical indicators of the BedsidePEWS is required to calculate the score. The RRT/MET is called at a score of 7 or more. The score was also validated at the hospital's Bone Marrow Transplant Unit showing a good screening performance in this high-risk patient population [11]. An educational program for all PICU physicians and ward healthcare staff was provided through classroom lectures and case scenarios before implementation. Continuing education for ward staff was provided through morning briefings, case reviews and performance audits on the wards, quality improvement or morbidity and mortality meetings.

Implementation of the BedsidePEWS

The implementation of the BedsidePEWS involved the hospital nursing and medical directors, administrators, the continuing education and research service, and other providers through a multidisciplinary and inter-departmental approach. Since the hospital was introducing the BedsidePEWS within the context of the EPOCH randomized clustered clinical trial, the EPOCH BedsidePEWS implementation team led the implementation process by running weekly meetings during the run-in period followed by two weekly and monthly meetings. Any implementation issues were discussed and resolved: 1) staffing analysis and planning, including nurse/patient ratios, medical roles and consulting processes on the wards; 2) VS monitoring tools and equipment availability, including electrocardiogram monitoring (ECG) and SpO2 monitors on the wards; 3) BedsidePEWS chart customization including additional items relevant to patient care (e.g. pain assessment, care plan, fluid balance); 4) Score matched care recommendations (SMCR) translation and adaptation to the local available nursing and medical levels of response to clinical deterioration on the wards, according to the hospital organization; 5) communication plan and editing of a local VS protocol to standardize monitoring practice on inpatient and day care wards; 6) customization of education modules on BedsidePEWS for all ward and PICU clinicians; 7) maintenance and quality control through monthly performance meetings and documentation audits.

The multidisciplinary research and implementation team was also continuously available to define strategies to facilitate the change process. Focus groups were performed for one month to throw light on issues related to impaired overnight patient monitoring, availability of appropriate monitoring equipment, low nurse staffing ratios, communication between nurses and physicians or among physicians, and PICU involvement in MET calls for non-deteriorating patients with chronic conditions triggering the system because of elevated BedsidePEWS scores. Interventions to improve critical situations were designed. On-the-ward meetings were held and strategies to improve overnight VS monitoring were discussed with local ward teams. Additional SpO2 monitors were obtained. Additional nursing staff was provided to all wards (one additional nurse during the day hours/shift) to facilitate the required compliance to VS monitoring according to patient risk. The role of this team of seven additional nurses was to support patient monitoring, educate ward staff, perform quality checks and act as a reference for the continuing improvement and uptake of the system. The BedsidePEWS was integrated into the handover hospital protocol, to improve communication on high-risk children between day and night shift physicians or the use of the score in nursing communication with the Medical Emergency Team (MET) or the PICU. The importance of using clinical judgement over the BedsidePEWS score was highlighted on the VS protocol and discussed for specific patient populations with respiratory or cardiac chronic diseases, where the score trend is more relevant than the absolute score to detect clinical deterioration.

A total of 259 (99% of the physicians and nurses on the EPOCH wards) healthcare professionals were trained in 2013 through two-hour meetings.

Results

During the study period, a total of 522 VS and score calculations on 177 patient clinical records were observed from 13 wards (4 Pediatric Specialty Units, 4 High Dependency Units, 3 Surgical Pediatric wards, and 2 General Medical Pediatric wards). Children with chronic health conditions (CHC) were 122 (69% of the observed patients), and 25 (14%) children had signs of physiological instability with a BedsidePEWS score ³5. The patient characteristics are shown in Table 1.

Table 1. Patient characteristics.

	Children with Acute illnesses	Children with CHC	Total	*P*-value
Characteristic				
No. of patients	55	122	177	
Age (years, mean±SD)	6.4±5.58	6.5 ±5.6	6.47±5.56	0.91
Age, No. (%)				
Age <1 year	4 (7)	1 (1)	5 (2)	.09
Age 1-4 years	22 (40)	59 (48)	81 (46)	
Age 5-11 years	15 (27)	34 (28)	49 (28)	
Age ≥12 years	14 (25)	28 (23)	42 (24)	
Sex (female), No. (%)	28 (51)	51 (42)	79 (45)	0.26
Disease, No. (%)				
Respiratory	10 (18)	5 (4)	15 (8)	**<.001**
Cardiovascular	0 (0)	26 (21)	26 (15)	
Endocrine-metabolic	5 (9)	12 (10)	17 (10)	
Genetic syndromes	0 (0)	8 (7)	8 (4)	
Surgical	9 (16)	5 (4)	14 (8)	
Infectious	11 (20)	7 (6)	18 (10)	
Skeletal-muscle diseases	13 (24)	8 (7)	21 (12)	
Neurological	4 (7)	23 (19)	27 (15)	
Haematological, Oncological	0 (0)	22 (18)	22 (12)	
Renal	3 (5)	6 (5)	9 (5)	
Ward, No. (%)				
Medical Ward	15 (27)	10 (8)	25 (14)	**<.001**
Specialty Ward	6 (11)	55 (45)	61 (34)	
Surgical Ward	13 (24)	13 (11)	26 (15)	
High Dependency Unit	21 (38)	44 (36)	65 (37)	
Highest BPEWS*, No. (%)				
BPEWS 0-2	52 (94)	86 (70)	138 (78)	**.005**
BPEWS 3-4	1 (2)	13 (11)	14 (8)	
BPEWS 5-6	1 (2)	10 (8)	11 (6)	
BPEWS ≥7	1 (2)	13 (11)	14 (8)	

Abbreviations: BPEWS, BedsidePEWS; CHC, Chronic Health Conditions; SD, Standard Deviation.

* This was the highest BedsidePEWS score found on the patients' clinical records during the 24-hour observation period.

The appropriate age specific chart was used in 99% of the observations. Median BedsidePEWS scores were significantly different between children with acute illnesses and CHC (P<.001) (Table 2).

Table 2. BedsidePEWS scores and calculations.

	BedsidePEWS score measurements			
	Patients with acute illnesses	Patients with CHC	Total	*P*-value
No. of BPEWS score calculations	161	361	522	
BPEWS (score, median; IQI)	0 (0-0)	1 (0-3)	0 (0-2)	**<.001**
BPEWS score calculations*, No. (%)				
BPEWS 0-2	151 (94)	245 (67)	396 (76)	**<.001**
BPEWS 3-4	2 (1)	46 (13)	48 (9)	
BPEWS 5-6	5 (3)	35 (10)	40 (8)	
BPEWS ≥7	3 (2)	35 (10)	38 (7)	

Abbreviations: BPEWS, BedsidePEWS; CHC, Chronic Health Conditions; IQI, Interquartile 25th-75th Interval.
*This is the number of BedsidePEWS score calculations found on the patients' clinical records during the 24-hour observation period, by score range.

Frequency of VS and score documentation was below the minimum required hospital standard (every 8 hours, 3 times a day) in 33% (n=85) of the patients. Adherence to the VS and score calculation frequency according to the hospital protocol was observed in 54% (n=95) of the patients and was lower than 50% (43%; n=37) in the hematology-oncology, cardiology and other specialty wards. VS frequency in patients with CHC was significantly lower than patients with acute medical conditions admitted to a hospital ward (P=0.006). The mean frequency of VS and BedsidePEWS score calculation in 24 hours was 3.34 (CI 3.11-3.57). When the score was >4, VS and score documentation was performed in over 2 hours. A total of 8 children (57%) BedsidePEWS ≥7 were monitored with continuous ECG and SpO2, 7 children (33%) with BedsidePEWS≥5<7 were monitored with continuous SpO2. Timing of vital signs assessment and type of monitoring according to BedsidePEWS scores are shown in Table 3.

Table 3. Vital signs assessment and type of monitoring, by BedsidePEWS score range

	Patient observations and monitoring			
	Patients with acute illnesses	Patients with CHC	Total	*P*-value
No. of patients	55	122	177	
VS assessment frequency, No. (%)*				
BPEWS score 0-2 (≤8 hours)	38 (73)	54 (63)	92 (67)	.214
BPEWS score 3-4, (≤4 hours)	0 (0)	3 (23)	3 (21)	.588
BPEWS score ≥5, (≤2 hours)	0 (0)	0 (0)	0 (0)	-
Total BPEWS scores	38 (69)	57 (47)	95 (54)	**.006**
Type of monitoring, No. (%)*				
BPEWS 5-6 (SpO2 or ECG)	1 (100)	6 (60)	7 (64)	.428
BPEWS ≥7 (SpO2 and ECG)	0 (0)	8 (61)	8 (57)	.231
Total BPEWS scores	54 (98)	113 (93)	167 (94)	.138

Abbreviations: BPEWS, BedsidePEWS; CHC, Chronic Health Conditions; ECG, Electrocardiogram monitoring; IQI, Interquartile 25th-75th Interval, SpO2, percutaneous blood oxygen saturation, VS, vital signs.

* the proportion of patients with VS assessment according to predefined criteria (time interval and type of monitoring, by score range) is calculated for the highest BPEWS scores found on the clinical record during the 24-hour observation period, presented in table1.

Of the 522 VS documentation events (including VS registrations and BedsidePEWS score calculations), in 99% (n=520) ³5 clinical indicators of the BedsidePEWS were documented but all of the 7 clinical indicators were documented in 93% (n=482) of the documentation events. The BedsidePEWS score was correctly calculated and documented in 84% (n=439) of the observed VS documentation events. Of the 522 score calculations, in 56 (11%) the score was wrongly calculated, and in 27 (5%) no score was documented. In >95% of the observations, heart rate (HR), respiratory rate (RR), SpO2, oxygen therapy (OT), capillary refill time (CRT), work of breathing (WoB) and level of consciousness (LoC) were documented. Temperature (T) was recorded in 79% (n=410) and systolic blood pressure (SBP) in 89% (n=465) of the VS documentation events. (Table 4).

Table 4. Vital signs measurements documented on the patient clinical record.

	Patients with acute illnesses	Patients with CHC	Total	*P*-value
Total vital sign measurements	161	361	522	
Vital signs, No. (%)				
HR	159 (99)	359 (99)	518 (99)	.405
RR	161 (100)	353 (98)	514 (99)	.057
SBP	125 (78)	340 (94)	465 (89)	**<.001**
SpO2	161 (100)	360 (100)	521 (100)	.504
OT	161 (100)	359 (99)	520 (100)	.344
WoB	161 (100)	360 (100)	521 (100)	.504
CRT	161 (100)	360 (100)	521 (100)	.504
T	136 (84)	274 (76)	410 (79)	**.028**
LoC	155 (96)	345 (96)	500 (96)	.711

Abbreviations: CHC, chronic health conditions; CRT, capillary refill time; HR, heart rate; LoC, level of consciousness; OT, oxygen therapy; RR, respiratory rate; SpO2= percutaneous oxygen saturation; SBP, systolic blood pressure; T, temperature; WoB, work of breathing.

Children at low risk of clinical deterioration with BedsidePEWS scores between 0-2 were reviewed by a physician at least once a day, children with BedsidePEWS scores in the 3-4 score ranges were reviewed within 6 hours in 35% of the observations. Children at higher risk were reviewed within 4 hours in 50% (n=20) in the 5-6 score range and within 2 hours in 42% (n=16) in the ≥7 score range (Table 5).

Table 5: Physician review by BedsidePEWS score range

	Physician review			
	Patients with acute illnesses	Patients with CHC	Total	*P*-value
Total vital BPEWS measurements	161	361	522	
Adherence by BPEWS score range, No. (%)*				
BPEWS 0-2 (≤24 hours)	151 (100)	245 (100)	396 (100)	-
BPEWS 3-4 (≤6 hours)	1 (50)	16 (35)	17 (35)	.660
BPEWS 5-6 (≤4 hours)	4 (80)	16 (46)	20 (50)	.151
BPEWS ≥7 (≤2 hours)	2 (67)	14 (40)	16 (42)	.594
Total	158 (98)	291 (81)	449 (86)	**<.001**

Abbreviations: BPEWS, BedsidePEWS; CHC, Chronic Health Conditions.
* the proportion of patients with a physician review according to predefined timing criteria by risk range is calculated over the BPEWS scores presented in table 2.

Discussion

This study explored monitoring and physician review escalation practices matched to BedsidePEWS scores in a large tertiary care pediatric hospital. We found that vital signs monitoring was still suboptimal

(≥ 4 hourly) in patients at risk of clinical deterioration with a BedsidePEWS > 4. Nurses tended to use PEWS scores using their own clinical judgement through a process of intuition based on experience, to confirm their assessment of evolving critical illness rather than using solely the score [15]. Repeated exposure to children with chronic illnesses, prevalent in this audit in the higher BedsidePEWS group, might have determined a ≥ 4 hourly frequency of documented patient observations. In addition, workload and nurse/patient ratios ranging from 1/4 in HDUs to 1/10 on pediatric wards may have affected the frequency of documented patient observations, vital signs and monitoring with higher nurse/patient ratios leading to an increased risk of missed care [12, 13, 14].

We found that compliance with the VS monitoring audit timing thresholds was higher in the group of patients admitted for acute clinical conditions (n = 38/55 complying patients, 69%) compared to children with chronic illnesses (n = 57/122 complying patients, 47%), which constituted the majority of our observations (122, 69%). Patients with chronic diseases, such as congenital heart disease, metabolic diseases or neurological impairment may have altered basal vital signs and higher thresholds due to their condition. In these patients, trends rather than absolute values of the BedsidePEWS score, normally higher than usual, were taken into account [16]. However, proximity to PICU admission, up to 12 hours, has been found to increase with BedsidePEWS scores > 6, making this a population of children at increased risk of clinical deterioration [17]. Patients with chronic illnesses constitute an increasing proportion of the total number of pediatric hospital admissions with a higher technological dependency on digital devices, increased risk of PICU readmissions, hospital length of stay and mortality [18, 19, 20]. The impact of the use of BedsidePEWS on unplanned PICU admissions of this vulnerable patient group needs to be further explored.

Patient review from a physician is another essential element of escalation of care in relation to BedsidePEWS scores. Less than 50% of the patients with a BedsidePEWS > 2 were reviewed by a physician according to the audit timing thresholds by BedsidePEWS score range. This may be due to several factors, including low situational awareness for deteriorating patients, appropriate clinical judgement applied to stable patients with chronic diseases, workload and production pressure, low nursing empowerment to call for help, and internal hierarchies slowing down the referral process [21, 22]. Other staffing layers of intervention including charge nurses, clinical nurse specialists, medical fellows or residents may be considered in this and similar contexts to increase patient review within appropriate timelines.

The score was correctly calculated in 84% (n = 438) of the VS sets observed, 5% (n = 27) were missing, and the rest were incorrect (n = 56, 11%). Missing scores, calculation errors and delay in patient referral have been previously reported to be possibly influenced by low situational awareness and other factors affecting decision making [23, 24]. Chapman found rates of calculation errors that reached 17.5% and up to 6.4% of missing scores. Scoring errors were significantly higher in patients urgently admitted to PICU or deaths on the wards [7]. Scoring errors and underscoring often occur during the initial phase of clinical deterioration. The underscoring of deteriorating patients has often been found to reflect nurses' perceptions of patient's risk rather than being the result of a calculation error [25]. In some cases, nurses

reported that they may underestimate the vital sign rather than record an abnormal observation that may require, by protocol, an escalation of care [26]. Moreover, errors were reported much more likely in observation sets where some vital signs were missing, or when a patient starts to become unstable, reducing the opportunity to achieve an early detection of deterioration [27]. The advent and use of electronic medical records (EMRs) will overcome this issue by providing an electronic registration of VS and score calculation, possibly also giving prompts to recall VS assessment.

In 7% (N = 37) of the VS observation sets not all of the seven clinical indicators of the BedsidePEWS were recorded. However, 99% of VS sets had at least 5 clinical indicators, sufficient to calculate the BedsidePEWS score. Having the BedsidePEWS in place was found to significantly improve VS documentation, particularly for RR, SpO2, SBP, WoB and Capillary Refill Time and significantly increased the documentation of ≥ 5 VS per VS set [6]. The lowest rates of recorded VS were found for Temperature (n = 412, 79%), SBP (n = 464, 89%) and LoC (n = 501, 96%). This trend is similar, but the rates are higher than the ones found in another recent study describing patient observations on pediatric wards [7].

This study has some limitations. Firstly, it is a single-center study, possibly limiting the generalizability of the findings to other settings. Secondly, the convenience sample of the clinical records available on the audit day may have introduced a selection bias, due to the possible unavailability of clinical records of patients temporarily out of the ward for diagnostic or therapeutic procedures at the time of data collection.

Conclusions

This audit describes the use of the BedsidePEWS in a large tertiary care children's hospital. Routine VS monitoring was performed according to the required standard in 67% of the audited patients. Children at higher risk with a BedsidePEWS >4 did not receive more frequent monitoring than ≥4 hourly. In addition, VS monitoring was less frequent in patients with chronic medical conditions. The clinical relevance of these data needs to be further analyzed by looking at patient outcomes related to the completeness of patient observations, VS frequency and scoring accuracy. Strategies to increase VS monitoring including the implementation of the Electronic Medical Record (EMR) adopted by the hospital in 2019, with appropriate VS prompts, might increase the completeness and timeliness of patient observations regarding the BedsidePEWS. The impact of timely compared to delayed escalation of care on PICU urgent admissions and the role of the EMR in supporting this process deserves further study. Organizational issues and human factors, such as staffing, access to and availability of clinical data and team-based processes of care should be explored to support patient observation and the early recognition of escalation of care.

Abbreviations

VS, vital signs

CHC, chronic health conditions

PICU, Pediatric Intensive Care Unit

AUROC, Area Under Roc Curve

EPOCH, Evaluation of Processes of care and Outcomes of Children in Hospital trial

RRT, Rapid Response Team

MET, Medical Emergency Team

CICU, Cardiac Intensive Care Unit

NICU, Neonatal Intensive Care Unit

HDU, High Dependency Unit

NIV, non-invasive ventilation

HR, heart rate

RR, respiratory rate

SBP, systolic blood pressure

WoB, work of breathing

CRT, capillary refill time

OT, oxygen therapy

SpO2, percutaneous oxygen saturation

T, temperature

LoC, level of consciousness

ECG, electrocardiogram monitoring

SMCR, Score matched care recommendations

EMR, electronic medical record

Declarations

Ethics approval and consent to participate: The study was classified as a service evaluation initiative and therefore exempt from ethics committee approval.

Consent for publication: Not required.

Availability of data and materials: All data relevant to the study are included in the article.

Competing interests: None declared.

Funding: This study received no direct funding.

Authors' contributions: OG was involved in the conception and the design of the study, data collection, contributed to data analysis and interpretation and led the writing of this paper. FF was involved in data collection, contributed to data analysis and to drafting this paper. MLCDA was involved in data analysis and the drafting of this paper. IDO, CC were involved in the design and drafting of the paper. ET and MR are the guarantors.

Acknowledgments: We thank the EPOCH nurse educators research fellows for their contribution: Arianna Ruscitto, Anna Marchetti, Ilaria Franconi, Chiara Maninchedda, Federica Di Comite, Rachele Mascolo, Giulia Lombardi and Ilaria Campagna. We also thank Giuseppe Aleo for the final review of the article and editing. Bambino Gesù Children's Hospital nursing leadership, nurse department and ward managers and staff facilitated and contributed to the implementation of the BedsidePEWS. Irene Ortolani and Angela Iula, MS graduates from the Catholic University of Rome Nursing Science program contributed to data collection, Valentina Biagioli, PhD, who contributed to the statistical analysis.

References

[1] Pearson GA. Why Children Die: A Pilot Study 2006: May 2008 England (South West, North East and West Midlands), Wales and Northern Ireland. CEMACH. 2008.

[2] Tume L. The deterioration of children in ward areas in a specialist children's hospital. Nurs Crit Care. 2007 Jan-Feb;12(1):12-9. doi: 10.1111/j.1478-5153.2006.00195.x

[3] National Institute for Clinical Excellence. Acutely ill adults in hospital: recognising and responding to deterioration. London: NICE; 2007.

[4] Chapman SM, Wray J, Oulton K, Pagel C, Ray S, Peters MJ. 'The Score Matters': wide variations in predictive performance of 18 paediatric track and trigger system. Arch Dis Child. 2017 Jun;102(6):487-495. doi: 10.1136/archdischild-2016-311088.

[5] Parshuram CS, Duncan HP, Joffe AR, Farrell CA, Lacroix JR, Middaugh KL, et al. Multicentre validation of the bedside paediatric early warning system score: a severity of illness score to detect evolving critical illness in hospitalised children. Crit Care. 2011 Aug 3;15(4):R184. doi: 10.1186/cc10337.

[6] Parshuram CS, Dryden-Palmer K, Farrell C, Gottesman R, Gray M, Hutchison JS, et al. Effect of a Pediatric Early Warning System on All-Cause Mortality in Hospitalized Pediatric Patients: The EPOCH Randomized Clinical Trial. JAMA. 2018 Mar 13;319(10):1002-1012. doi: 10.1001/jama.2018.0948.

[7] Chapman SM, Oulton K, Peters MJ, Wray J. Missed opportunities: incomplete and inaccurate recording of paediatric early warning scores. Arch Dis Child. 2019 Jul 3. pii: archdischild-2018-316248. doi: 10.1136/archdischild-2018-316248.

[8] Trubey R, Huang C, Lugg-Widger FV, Hood K, Allen D, Edwards D, et al. Validity and effectiveness of paediatric early warning systems and track and trigger tools for identifying and reducing clinical deterioration in hospitalised children: a systematic review. BMJ Open. 2019 May 5;9(5):e022105. doi: 10.1136/bmjopen-2018-022105.

[9] Shiel WCJr. Definition of Chronic Disease. 2018. Available from: http://www.medicinenet.com/script/main/art.asp?articlekey=33490

[10] Italian National Institute of Healthcare. Malattie croniche. Available from: https://www.epicentro.iss.it/croniche/

[11] Gawronski O, Ciofi Degli Atti ML, Di Ciommo V, Cecchetti C, Bertaina A, Tiozzo E, et al. Accuracy of Bedside Paediatric Early Warning System (BedsidePEWS) in a Pediatric Stem Cell Transplant Unit. J Pediatr Oncol Nurs. 2016 Jul;33(4):249-56. doi: 10.1177/1043454215600154.

[12] Griffiths P, Ball J, Bloor K, Böhning D, Briggs J, Dall'Ora C, et al. Nurse staffing levels, missed vital signs and mortality in hospitals: retrospective longitudinal observational study. Southampton (UK): NIHR Journals Library; 2018 Nov.

[13] Aiken LH, Cimiotti JP, Sloane DM, Smith HL, Flynn L, Neff DF. Effects of nurse staffing and nurse education on patient deaths in hospitals with different nurse work environments. Med Care. 2011 Dec;49(12):1047-53. doi: 10.1097/MLR.0b013e3182330b6e

[14] Aiken LH, Clarke SP, Sloane DM, Sochalski J, Silber JH. Hospital Nurse Staffing and Patient Mortality, Nurse Burnout and Job Dissatisfaction. JAMA. 2002 Oct 23-30;288(16):1987-93. doi: 10.1001/jama.288.16.1987

[15] Odell M, Victor C, Oliver D. Nurses' role in detecting deterioration in ward patients: systematic literature review. J Adv Nurs. 2009 Oct;65(10):1992-2006. doi: 10.1111/j.1365-2648.2009.05109.x

[16] Jensen CS, Olesen HV, Aagaard H, Svendsen MLO, Kirkegaard H. Comparison of Two Pediatric Early Warning Systems: A Randomized Trial. J Pediatr Nurs. 2019 Jan - Feb;44:e58-e65. doi: 10.1016/j.pedn.2018.11.001

[17] Parshuram CS, Hutchison J, Middaugh K. Development and initial validation of the Bedside Paediatric Early Warning System score. Crit Care. 2009;13(4):R135. doi: 10.1186/cc7998.

[18] Simon TD, Berry J, Feudtner C, Stone BL, Sheng X, Bratton SL, et al. Children with complex chronic conditions in inpatient hospital settings in the United States. Pediatrics. 2010 Oct;126(4):647-55. doi: 10.1542/peds.2009-3266

[19] Krmpotic K, Lobos AT. Clinical profile of children requiring early unplanned admission to the PICU. Hosp Pediatr. 2013 Jul;3(3):212-8. doi:10.1542/hpeds.2012-0081

[20] Moynihan KM, Alexander PMA, Schlapbach LJ, Millar J, Jacobe S, Ravindranathan H, et al. Epidemiology of childhood death in Australian and New Zealand intensive care units. Intensive Care Med. 2019 Sep;45(9):1262-1271. doi: 10.1007/s00134-019-05675-1

[21] Mc Gaughey J, O'Halloran P, Porter S, Blackwood B. Early warning systems and rapid response to the deteriorating patient in hospital: A systematic realist review. J Adv Nurs. 2017 Dec;73(12):2877-2891. doi: 10.1111/jan.13398

[22] Shearer B, Marshall S, Buist MD, Finnigan M, Kitto S, Hore T, et al. What stops hospital clinical staff from following protocols? An analysis of the incidence and factors behind the failure of bedside clinical staff to activate the rapid response system in a multi-campus Australian metropolitan healthcare service. BMJ Qual Saf. 2012 Jul;21(7):569-75. doi: 10.1136/bmjqs-2011-000692

[23] Odell M. Detection and management of the deteriorating ward patient: an evaluation of nursing practice. J Clin Nurs. 2015 Jan;24(1-2):173-82. doi: 10.1111/jocn.12655

[24] Brady PW, Goldenhar LM. A qualitative study examining the influences on situation awareness and the identification, mitigation and escalation of recognised patient risk. BMJ Qual Saf. 2014 Feb;23(2):153-61. doi: 10.1136/bmjqs-2012-001747

[25] Petersen JA, Rasmussen LS, Rydahl-Hansen S. Barriers and facilitating factors related to use of early warning score among acute care nurses: a qualitative study. BMC Emerg Med. 2017 Dec 1;17(1):36. doi: 10.1186/s12873-017-0147-0

[26] Elliott D, Allen E, Perry L, Fry M, Duffield C, Gallagher R, et al. Clinical user experiences of observation and response charts: focus group findings of using a new format chart incorporating a track and trigger system. BMJ Qual Saf. 2015 Jan;24(1):65-75. doi: 10.1136/bmjqs-2013-002777

[27] Clifton DA, Clifton L, Sandu DM, Smith GB, Tarassenko L, Vollam SA, Watkinson PJ. 'Errors' and omissions in paper-based early warning scores: the association with changes in vital signs–a database analysis. BMJ Open. 2015 Jul 3;5(7):e007376. doi: 10.1136/bmjopen-2014-007376