Missed opportunities: Incomplete and inaccurate recording of paediatric early warning scores

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Word count: 2472

Keywords: Resuscitation, Intensive Care, Monitoring

Abstract

Background

Paediatric early warning scores (PEWS) are widely used as an adjunct to support staff in recognising deterioration in hospitalised children. Relatively little is known about how staff use these systems.

Objective

To examine the completeness and accuracy of PEWS recording in hospitalised children in a tertiary specialist children's hospital.

Design

Secondary analysis of retrospective case-controlled study data. Case patients suffering a critical deterioration event were matched with controls present on the same ward at the same time and matched for age. Data were extracted from the PEWS chart for the 48 hours before the critical deterioration event for case patients and the corresponding 48-hour period for the control. Observation sets were assessed for completeness and accuracy of PEWS scoring.

Results

In total 297 case events in 224 patients were available for analysis. Overall 13,816 observations sets were performed, 8543 on cases and 5273 on controls. Only 73.2% of observation sets for cases and 80.9% of controls had an accurate score (Table 2). Errors were more prevalent in the observation sets of case patients versus controls (19.4% vs 14.1%). More errors resulted in the PEWS value being under rather than over scored for all observation sets (p <0.0001). 9.1% of inaccuracies for case patients were clinically significant, as the

accurately calculated PEWS score would have prompted a different escalation to the documented value.

Conclusion

Failure to record complete and accurate PEWS may jeopardise recognition of children who are deteriorating. Technology may offer an effective solution.

BACKGROUND

Identifying and managing clinical deterioration is a complex process. Multiple contributing factors are both inter-linked and inter-dependent. The Royal College of Paediatrics and Child Health (RCPCH) and NHS Improvement have proposed a framework [1] to identify the key factors associated with a 'safe system' of care. This framework has six core elements one of which is 'recognition of deterioration'.

Paediatric early warning scores (PEWS) provide an adjunct to support staff in recognising deterioration in hospitalised children.[2-4] Despite weak evidence [2,5,6] they are widely used [7] which is driven, in part, by national recommendations and governance requirements.[1,8,9]

Recent studies have described the predictive performance of PEWS [2,10,11] but relatively little is known about how healthcare staff use these systems. Incomplete recording of component vital signs and errors and omissions in the calculation of scores in adult systems are common. Up to 36% of recordings are inaccurate.[12-17] There is a bias towards under-scoring of track and trigger values [14,16,17] that results in a lack of escalation in patients 'at risk' of a critical deterioration event.[15] Perversely, patients with more deranged vital signs may be at greater risk.[17]

Recording and documentation of PEWS may suffer from similar problems. The requirement for paediatric age-specific charts increases complexity and opportunity for error. A recent randomised controlled trial found less than 5% of observation sets had all the required clinical observations for the PEWS.[10]. A further study examining found only 69.2% of patient records had a score recorded one year after implementation.[18] Marked differences in completeness were seen between hospitals with paper-based charts (28.8%) versus those utilising electronic documentation systems (95.2%). Currently the literature on PEWS recording is limited and largely based on incidental findings rather than systematic enquiry.

OBJECTIVE

The objective of this study was to examine the completeness and accuracy of paediatric early warning score recording in hospitalised children in one tertiary specialist children's hospital. We investigated differences between children who remained stable and those who subsequently suffered a critical deterioration event.

METHODS

This study is a secondary analysis of data from our retrospective case-controlled study examining the predictive performance of 18 PEWS reported previously.[19] At the time of data collection our tertiary specialist children's hospital had 320 beds and 25 speciality wards.

Patients below 18 years of age who suffered a respiratory and/or cardiac arrest, unplanned transfer to the Paediatric Intensive Care Unit (PICU) and/or unexpected death on a ward between 1 January 2011 and 31 December 2012 were identified from the local Paediatric Intensive Care Audit Network (PICANet) database[20] and/or the hospital resuscitation database and cross-referenced against intensive care admission records. They were designated as case patients. Those present on the ward for less than 2 hours before the event were excluded as this was considered the minimum time for the child to be assessed and clinical signs recorded and documented.

Control patients were present on the same ward at the same time and matched for age. Wards were considered a proxy match for diagnostic speciality. Patients previously entered into the study were eligible to act as a control provided they did not suffer a critical deterioration event within the following 48 hours. The patient was excluded if healthcare records were unavailable or the vital sign record was missing. If this occurred, a new control was selected using the same procedure.

The Children's Early Warning Score

Our local developed PEWS the 'Children's Early Warning Score' (CEWS) had 6 component observation parameters: heart and respiratory rate, systolic blood pressure, temperature and oxygen saturation together with consciousness measured on the Alert-Responds to Voice-Responds to Pain-Unresponsive (AVPU) scale. Scoring for the different parameters ranged from 0-2 to 0-4 and the maximum possible score was 21. Age-appropriate thresholds were provided across four age-specific charts. The CEWS scoring matrix can be seen at Supplemental data Figure 1.

Protocols were in place which required a full set of vital signs with a total CEWS score to be recorded within 2 hours of the start of each 12-hour shift, together with a documented monitoring plan. Elevated scores of two or more required repeat vital sign recording after 30 minutes and escalation to the nurse in charge, registrar and/or outreach team at pre-defined scores. On-going frequency of recording was at the discretion of the bedside nurse. Nurses were informed of these standardised protocols for the recording and documenting of vital signs and CEWS values at their hospital induction and yearly thereafter.

Data extraction

Data were extracted from the CEWS chart by a single researcher (SC), using a standardised proforma, for the 48 hours before the critical deterioration event for case patients and the corresponding 48-hour period for the matched control. The date and time, vital sign and AVPU value, parameter sub-score and total CEWS score were extracted, together with the age-range of the CEWS chart used. Vital sign values were verified by comparison of the documented value to the notation on the graphical scale.

Identification and Classification of errors

Accuracy was assessed by comparison of the calculated CEWS value with the documented value. Matching scores were considered to be accurate. Non-matching CEWS scores were classified as inaccurate according to the reasons noted in Table 1. Scores recommending different escalation were classed as clinically significant. Completeness and accuracy were compared across different nursing shifts and day of the week for cases and controls.

Scores were considered to be complete if all the six component parameters were recorded together with a documented CEWS score

Data analysis

A recording of one or more vital signs was considered as an observation set. Observation sets were assessed for completeness, defined as documentation of all component observations with a total CEWS score. Parameter subscores and total CEWS scores were calculated using embedded formulas in Excel for each observation set. Missing observations were presumed to be normal (score 0), consistent with clinical practice at the time.

Statistical significance was assessed by Chi-squared or Fisher's exact test for categorical data and Mann-Whitney U test for continuous data. A value of $p<.05$ was considered to be significant for all comparisons.

RESULTS

Three hundred and nineteen critical deterioration events were identified. In eight episodes the patient was present on the ward for less than two hours, leaving 311 eligible critical deterioration events in 237 patients. The records of 14 case patient records were unavailable, leaving a case sample of 297 events in 224 patients. In total 244 control patients were identified for the 311 events.

The patient characteristics have been presented elsewhere [19] and are summarised in Table 2. Unplanned transfers to the PICU accounted for the majority (186, 62.6%) of critical deterioration events. A further 84 case patients (28.3%) suffered a respiratory arrest and 27 (9.1%) had a cardiac arrest.

In total 13,816 observations sets were performed. A greater numbers of observation sets were performed on cases (8543, 61.8%) compared to controls (5273, 38.2%). The median number of observation sets per patient per day was 12 (IQR 6-19) for cases and 6 (IQR 6-8) for controls.

The frequency of recording of the individual component vital sign parameters varied (Figure 1). Heart rate, oxygen saturation and respiratory rate were recorded more frequently and were present in the observation sets of more than 95% of case patients and 85% of controls. For each vital sign parameter, comparison between the number of day and night-time recordings across cases and controls revealed no significant differences.

Only 4957 (35.9%) observation sets contained a complete set of component vital sign parameters with a concurrent CEWS score. The remainder did not, and as such were considered to be incomplete. Case patients had a significantly lower proportion of complete observation sets when compared to controls (32.9% vs 40.7%, $p < .0001$).

Overall 10,518 (76.1%) observation sets had a CEWS score that was accurately calculated, 2416 (17.5%) were considered inaccurate and 882 (6.4%) were missing (Supplemental data Figure 2).

When completeness of component parameters and accuracy of the CEWS score were considered together, only 26.0% of observation sets of case patients and 34.6% of controls (30.6% overall) met the required standard.

Errors were more prevalent in the observation sets of case patients compared with controls (19.4% vs 14.1%) (Figure 2). More errors resulted in the CEWS value being under, rather than over, scored for all observation sets (63.1% vs 36.1%, $p < 0.0001$).

In 786 observation sets of case patients (9.1%) inaccuracies were clinically significant, as the accurately calculated CEWS score would have prompted a different escalation to the documented value. Again, under-scoring was more prevalent than over scoring.

Although 314 observations sets were recorded on the wrong chart for the child's age, only 168 resulted in an incorrect CEWS score. Incorrect allocation of parameter sub-scores was the most common reason for CEWS score inaccuracy. Incorrect summation of component sub-scores alone rarely resulted in an incorrect CEWS (Supplemental data Figure 3).

There was no difference in the proportion of observation sets inaccurately calculated during the night shift compared with the day shift for both cases and controls. Similarly there were no significant differences in the prevalence of mis-scoring on weekdays compared with weekends. However higher scores were associated with a larger number of inaccurate CEWS values for both cases and controls ($p<0.0001$) (Table 3). The reverse was true of missing scores, where lower CEWS scores were more commonly omitted ($p<0.0001$).

DISCUSSION

Recognition is considered to be a fundamental element of the recently proposed safe system to manage children at risk of deterioration.[1] Many hospitals have adopted PEWS to improve the recognition of children who may be deteriorating but there is limited research on how these systems are used in practice.

Our findings indicate that PEWS recording in clinical practice is sub-optimal. We found that some scores were miscalculated, others were not documented and a significant number were calculated from incomplete observation sets. More erroneous scores were under, rather than over, scored. We have no indication that the practice in our organisation differs significantly from other similar centres and incidental findings from other studies would support this assertion.[10,18]

Under-scoring errors may expose the patient to a missed opportunity to identify and potentially address clinical deterioration. We found that in almost 10% of observation sets for case patients erroneous scores should have resulted in a different escalation pathway being followedFollowing an incorrect pathway due to under-scoring errors may potentially delay access to appropriately skilled staff and monitoring which may lead to inadequate resuscitation and management. Over-scoring errors can waste resources, divert attention from children who may be 'at risk' and increase anxiety in children, families and staff. The risk appeared higher in patients with greater physiological derangement - demonstrated by higher CEWS scores - and is in keeping with findings of studies of hospitalised adults.[16,17]

The reasons for these errors are unclear. Although the mathematical skills of nurses have been questioned,[21] an alternative reason may be that PEWS scoring is often conducted at the child's bedside which may increase the frequency of interruptions and distractions. Studies on medication errors have demonstrated that interruptions are frequent [22,23] and have been associated with decreases in accuracy.[24] Others have suggested that nurses may 'manipulate' track and trigger scores, by selecting component values which 'match' their clinical impression of the patient.[17]

Incomplete observation sets may exacerbate the risk of under-scoring errors. If missing vital sign values are 'abnormal' (leading to a positive sub-score) this may result in a falsely low PEWS score as the missing component would not have contributed to the overall score. A higher number of missing component vital signs will increase the risk of underscoring. A recent study noted that incomplete observation sets were more likely to contain observations which should have led to an alert than complete observation sets.[25] This led to missed alerts and opportunities to escalate a deteriorating patient were lost.

It is unclear what influences the decision to include or omit a vital sign parameter from an observation set. Heart rate, oxygen saturation and respiratory rate were found to be recorded more frequently than other component vital sign parameters. A survey of paediatric nursing and medical staff identified respiratory rate as the most important indicator of deterioration, followed by heart rate, conscious level, oxygen saturation and blood pressure.[26] The consistency between this study and other paediatric studies would suggest that inclusion or omission is an active choice rather than a random act of chance.[26-28]

The negative effect of 'out of hours' admission and care has been discussed for more than 30 years.[29] Deficiencies in night-time recording of early warning scores [12,30-32] and poor adherence to monitoring protocols at weekends [30] have been noted in adults. Differences in staff numbers and skill mix have been proposed as a potential cause and studies have identified an association between lower nurse to patient ratios and nursing care 'left undone'.[33,34] However whether differences in patient outcomes truly exists remains controversial and the evidence is inconclusive.[35] Data for the paediatric setting remains limited. Our findings indicate no differences in the accuracy and completeness of recording of CEWS scores between the day and night shift, nor between week-days and weekends shifts. It is unclear whether there are systematic differences in the nursing practices for adult and paediatric patients.

Traditional strategies for improving vital sign and track and trigger scores have included staff training and guideline implementation; however they have not demonstrated high levels of reliability or sustainability.[36] It is likely that the situation is more complex and requires more sophisticated and innovative approaches. Improved chart design incorporating 'human factors' has demonstrated significant improvements in the ability of healthcare professionals to recognise patient deterioration.[37,38]

More recently, automated systems have been developed that automatically calculate the PEWS and provide immediate decision support on the escalation to be followed. This has demonstrated statistically significant improvements in vital sign recording accuracy, and PEWS score calculation.[4] The findings of this study supported our adoption of an electronic PEWS. This 'work smarter not harder' approach may derive greater benefits than more traditional approaches to error management.

Limitations

This was a case-controlled study conducted in a tertiary specialist children's hospital. As such, the population may not be representative of patients within children's hospitals or paediatric services in other centres. Data were collected retrospectively and therefore the reasons for any omissions or inaccuracies of the observation sets or CEWS scores could neither be explored nor verified. Although a high number of incomplete or inaccurate observations sets were identified, we could not determine if this had a negative impact on patients.

CONCLUSION

Failure to record complete observation sets and accurately calculate PEWS scores may jeopardise the ‘recognising deterioration’ component of the ‘safe system’ approach to managing deteriorating children in hospital.[1] Opportunities to identify children at risk and intervene may be missed. The reasons for this are unknown. Smart technology may offer an alternative and more effective solution. We recommend all centres utilising a PEWS systematically examine the accuracy and completeness of their recording in practice.

Funding: This study received no direct funding but was supported by the National Institute for Health Research Great Ormond Street Hospital Biomedical Research Centre.

What is already known on this topic

Effective recognition and response to deterioration in hospitalised children is a complex, multi-factorial process.

To support staff in recognising the early signs of deterioration PEWS are widely used despite limited evidence of their validity or impact on outcomes

There is very little evidence about the clinical practice of recording vital signs and PEWS in hospitalised children, despite being considered fundamental to patient safety

What this study adds

The recording of PEWS in clinical practice is sub-optimal with high levels of incomplete observation sets and incorrectly calculated scores.

Incomplete observation set recording exposes the patient to a risk of PEWS underscoring and inappropriate escalation of care

Scoring errors appear to be higher in hospitalised children with greater physiological derangement as demonstrated by higher PEWS scores

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Table 1: Classification of errors

Error	Criteria
Incorrect chart for child's age	Child age calculated from date of birth and date of observation set recording. Criteria fulfilled if the child's age did not match the recommended age-appropriate CEWS chart
Incorrect sub-score	The component vital sign was extracted from the value noted on the CEWS chart and verified by comparison to the graphical scale. The correct age-appropriate sub-score value was calculated from the component vital sign value using embedded formulas in Excel. Criteria fulfilled if the correctly calculated and documented vital sign sub-score did not match. exactly
Incorrect total score	For each parameter the correct age-appropriate sub-score value was calculated from the component vital sign value using embedded formulas in Excel. The correct total CEWS was summation of the Excel derived parameter sub-scores Criteria fulfilled if the calculated and documented total CEWS score did not match.
Combination	An incorrect CEWS score with more than one error as described above.
Clinically significant	Criteria fulfilled if the Excel-calculated and the documented erroneous score would have led to a different escalation pathway.
Clinically not significant	Criteria fulfilled if the Excel-calculated and the documented erroneous score, although different, would have led to the same escalation pathway.

Scores were considered to be accurate if the documented CEWS score and the researcher-derived score matched.

Abbreviations: Children's early warning Score

Table 2: Patient characteristics (each patient episode)

Characteristic	**Cases (n=297) n (%)**	**Controls (n=311) n (%)**	**p value**
Male Female	130 (43.8%) 167 (56.3)	167 (53.7) 144 (46.3)	.018[a]
<u>Age</u> 0-<6 months 6 months-<1 year 1-4 years 5-11 years 12-<19y	 70 (23.6) 41 (13.8) 101 (34.0) 54 (18.2) 31(10.4)	 66 (21.2) 47 (15.1) 108 (34.7) 62 (19.9) 28 (9.0)	 .888[b]
Gestation below 37 weeks	60 (20.1)	48 (15.4)	.152[a]
Weight, median, (interquartile range)	10.4kg (1.71-87.00)	11.1kg (2.10-94.20)	.668[b]
<u>Number of previous same hospital admissions</u> 0 1-5 6-10 11 – 20 21 – 50 >50	 150 (50.5) 66 (22.2) 29 (9.8) 20 (6.7) 25 (8.4) 7 (2.4)	 145 (46.6) 92 (29.6) 27 (8.7) 26 (8.4) 16 (5.2) 5 (1.6)	 .946[b]
<u>Number of previous PICU admissions (excluding this admission)</u> 0 1 2 3 - 5 >5	 247 (83.1) 32 (10.8) 15 (5.1) 1 (0.3) 2 (0.7)	 276 (88.7) 20 (6.4) 4 (1.3) 5 (1.6) 6 (1.9)	 .061[b]
<u>Number of previous PICU admissions (this admission)</u> 0 1 2 3 - 5 >5	 185 (62.3) 75 (25.2) 17 (5.7) 14 (4.7) 6 (2.0)	 238 (76.5) 55 (17.7) 14 (4.5) 4 (1.3) 0 (0.0)	 <.001[b]
Admitting specialty Medical Surgical Intensive Care	 186 (62.6) 57 (19.2) 54 (18.2)	 205 (65.9) 66 (21.2) 40 (12.9)	 .19[a]
<u>Type of admission</u> Elective Emergency	 105 (35.4) 192 (64.6)	 189 (60.8) 122 (39.2)	 <.001[a]
<u>Specialty at event</u>			

Medical Surgical	228 (76.8) 69 (23.2)	237 (76.2) 74 (23.8)	1.0[a]
Critical deterioration event classification PICU transfer Respiratory Arrest Cardiac Arrests Death on ward	 186 (62.6) 84 (28.3) 27 (9.1) 0 (0)	 0 0 0 0	N/A
Reason for event Respiratory Cardiovascular Neurological Other	 176 (59.3) 67 (22.6) 38 (12.8) 16 (5.4)	 0 0 0 0	N/A
Length of stay in days median, (interquartile range)	57.1 (21.0 – 122.0)	35.9 (12.8 – 89.4)	0.001[b]
Outcome Alive at 24 hours Alive at 30 days Alive at discharge	 279 (93.9) 246 (82.8) 220 (74.1)	 311 (100%) 308 (99.0) 301 (96.8)	 <.001[a] <.001[a] <.001[a]

Key: [a]Chi-squared; [b]Mann-Whitney U test

Abbreviations: PICU: Paediatric intensive care unit

Table 3: The prevalence of errors and missing CEWS scores for low, medium and high scores

CEWS score	Cases	p value	Controls	p value
CEWS score errors				
Low	476/3899 (12.2%)	<.0001[a]	400/4376 (9.1%)	<.0001[a]
Medium	887/3665 (24.2%)		309/824 (37.5%)	
High	311/1046 (29.7%)		34/73 (46.6%)	
Missing CEWS scores				
Low	**377/3899 (9.7%)**	<.0001[a]	222/4376 (5.1%)	.737
Medium	**259/3665 (7.1%)**		37/824 (4.5%)	
High	**49/1046 (4.7%)**		3/73 (4.1%)	

Errors and missing scores are considered as a proportion of the total number of recorded observation sets at low (0-1), medium (2-4) and high scores (≥5).

Abbreviations: CEWS: Children's Early Warning Score