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ORIGINAL ARTICLE

Recognizing critically ill children with a modified pediatric early warning score at the emergency department, a feasibility study

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Abstract

Pediatric Early Warning Scores were developed to monitor clinical deterioration of children admitted to the hospital. Pediatric Early Warning Scores could also be useful in the Emergency Department to quickly identify critically ill patients so treatment can be started without delay. To determine if a newly designed, fast, and easy to use Modified Pediatric Early Warning Score can identify critically ill children in the Emergency Department. We conducted a retrospective observational study in the Emergency Department of an urban district hospital in Rotterdam, the Netherlands. Patients < 16 years attending the Emergency Department with an internal medical problem were included. Immediate intensive care unit admission was used as a measure for critically ill children. During the study period 2980 children attended the Emergency Department, ten (0.4%) of them required immediate intensive care unit admission. The Modified Pediatric Early Warning Score can identify critically ill children in the general pediatric Emergency Department population (area under the ROC curve 0.82). A sensitivity of 80% and specificity of 85% show potential to rule out critical illness in children visiting the Emergency Department when these results are validated in a larger population. A model containing both the Modified Pediatric Early Warning Score and the Manchester Triage System did not perform significantly better than the Manchester Triage System alone but did show a positive tendency in favor of the model containing the Modified Pediatric Early Warning Score and Manchester Triage System, area under the ROC curve 0.89 [95% CI 0.77–1.00] versus area under the ROC curve 0.82 [95% CI 0.68–0.95].

Conclusions: In this feasibility study, the Modified Pediatric Early Warning Score could be a fast and easy to use tool to identify critically ill children in the general pediatric Emergency Department population. The effectiveness of the Modified Pediatric Early Warning Score may be optimized if combined with triage systems such as the Manchester Triage System. A larger prospective study is needed to confirm our results.

What is known:
- *Pediatric Early Warning Scores can identify children who are in need for immediate intensive care unit admission at the Emergency Department.*
- *Pediatric Early Warning Scores can be time-consuming, contain subjective parameters or parameters which are difficult to obtain in a reliable and standardized method.*

What is new:
- *We introduce a simplified, manageable and smartly designed Pediatric Early Warning Score on a pocket card based on an existing and previously investigated Pediatric Early Warning Score.*
- *In this feasibility study the diagnostic performance of the Modified Pediatric Early Warning Score to predict immediate intensive care unit admission in the Emergency Department is in line with the original Pediatric Early Warning Scores but has to be validated on a larger scale.*

Keywords Pediatric early warning scores · Triage · Emergency department · Referral and consultation · Intensive care

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Abbreviations

ED	Emergency Department
ICU	Intensive care unit
MTS	Manchester Triage System
PEWS	Pediatric Early Warning Score
MPEWS	Modified Pediatric Early Warning Score
ROC	Receiver operating curve

Introduction

Early warning scores were originally developed to monitor clinical deterioration of patients admitted to the hospital [1–5]. Early warning scores could also be useful in the Emergency Department (ED) to quickly identify critically ill patients. This makes it possible to start treatment without delay. Recent studies have shown the use of Pediatric Early Warning Scores (PEWS) in the ED to predict intensive care unit (ICU) admission [6–8]. In a previous comparative study of PEWS to predict ICU admission in the ED, the score of Parshuram scored one of the best [6]. Many PEWS are time-consuming and difficult to use in a daily clinical practice or contain parameters which are difficult to obtain in a reliable and standardized method, e.g., blood pressure [9, 10]. We modified the Parshuram PEWS to a manageable and smartly designed score on a pocket card.

The goal of this study was to prove feasibility that a Modified Pediatric Early Warning Score (MPEWS) could identify critically ill children in need of ICU admission in the ED.

Methods

A modified version of the Parshuram PEWS was created based on patients' age and the values of vital signs (heart rate, respiratory rate, temperature, oxygen saturation, oxygen therapy, and level of consciousness), cutoffs according to Parshuram [2, 3]. An abnormal parameter scores one to four points, higher scores correspond to an increased deviation from normal. The scores are added to one cumulative score which determines the patients' clinical condition. In contrast to other PEWS, all parameters including age-depending normal values are shown on one pocket card with a clear color scheme (Fig. 1). Missing values were assumed to be normal. Patients without any measured vital sign were excluded. This study was approved by the medical ethical committee of the

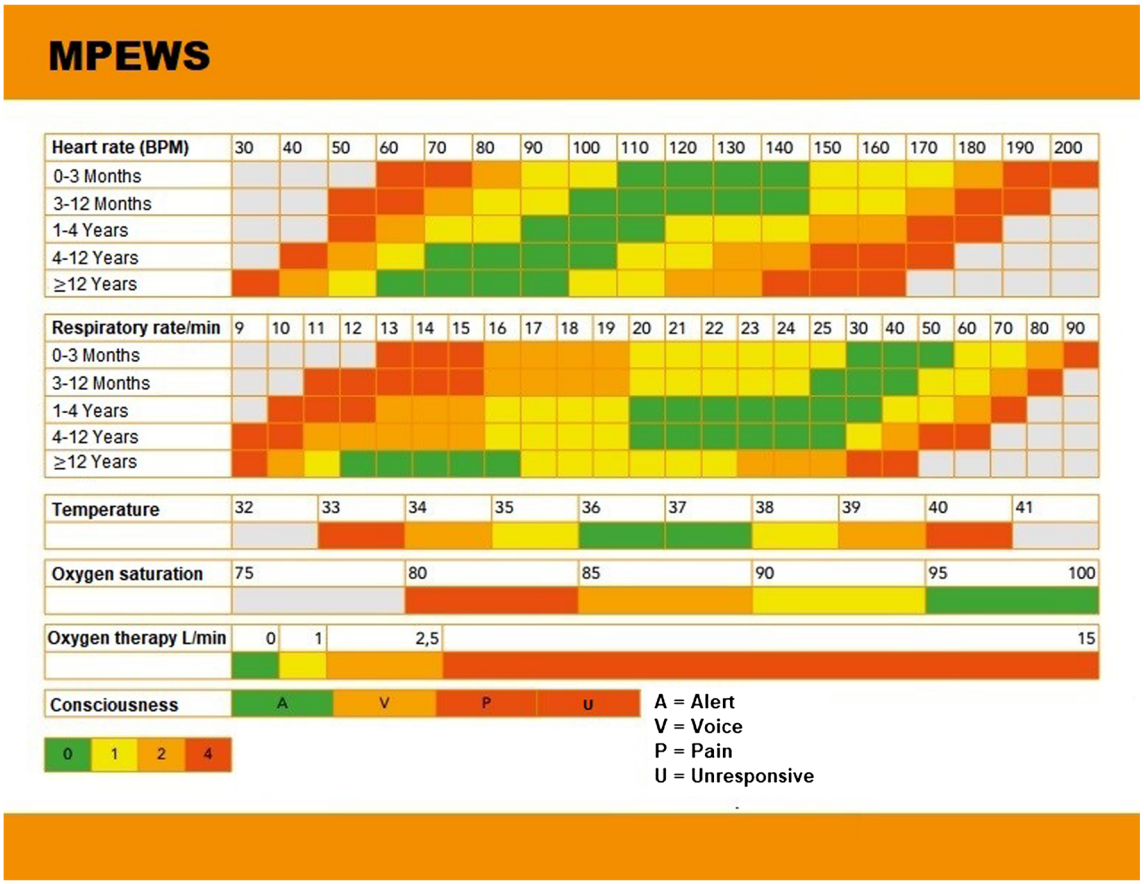

Fig. 1 The MPEWS

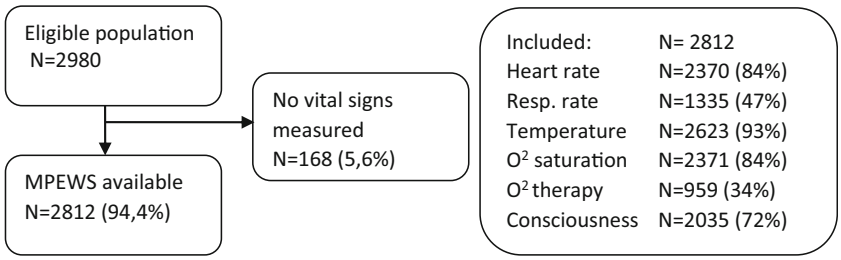

Fig. 2 Patient selection

Maasstad Hospital as part of a larger study. Informed consent was not required.

Study population

Patients < 16 years of age attending the ED between July 2015 and July 2016 with an internal medical problem were included. The Maasstad Hospital, Rotterdam, the Netherlands, is an urban district hospital. Annually 3000 children are primarily assessed by the pediatrician in the ED.

Data collection

Physiological parameters, Manchester Triage System (MTS) urgency level (MTS version 2), and ICU or hospital admission were retrospectively derived from the electronic patient record. Data management and statistical analyses were performed using IBM SPSS version 23.0. (IBM, Armonk, NY).

Data analysis

Not critically ill children (no ICU admission) were compared to critically ill children (ICU admission) in a univariate analysis to determine differences in patient characteristics.

The diagnostic value of our MPEWS to predict ICU admission in children attending the ED was determined by logistic regression analysis and area under the receiver operating curve (ROC) analysis. To determine the most appropriate cutoff of the MPEWS, we chose the cutoff with the highest area under the ROC curve.

Diagnostic performance measures (sensitivity, specificity) of the MPEWS were calculated as well as a range of cutoff points of the MPEWS using the VassarStats website (http://vassarstats.net/clin1.html).

Table 1 General characteristics of the not critically ill (no ICU admission), critically ill (ICU admission), and the entire included population

	No ICU admission *N* = 2802 (99.6%)	ICU admission *N* = 10 (0.4%)	Total N = 2812	*P* value
Gender				
Male	1639 (58.5%)	4 (40%)	1643 (58.4%)	0.24[#1]
Age (in years)				
Median (IQR)	2.11 (0.68–5.16)	2.92 (0.83–7.60)	2.11 (0.68–5.16)	0.62[#2]
MTS classification				
Emergency	39 (1.4%)	4 (40%)	43 (1.5%)	< 0.01[#1]
Very urgent	1277 (45.6%)	5 (50%)	1282 (45.6%)	
Urgent	1141 (40.7%)	1 (10.0%)	1142 (40.6%)	
Standard/non-urgent	345 (12.3%)	0 (0%)	345 (12.3%)	
Hospitalization				
Admission to general ward	–	–	1184 (42.1%)	
MPEWS				
Median (IQR)	1.00 (0.00-3.00)	8.00 (4.25–9.25)	1 (0–3)	0.02[#2]
Low (< 5)	2371 (84.6%)	2 (20%)	2373 (84.4%)	< 0.01[#1]
High (≥ 5)	431 (15.4%)	8 (80%)	439 (15.6%)	

[#1] Pearson chi-square

[#2] Mann-Whitney *U* test

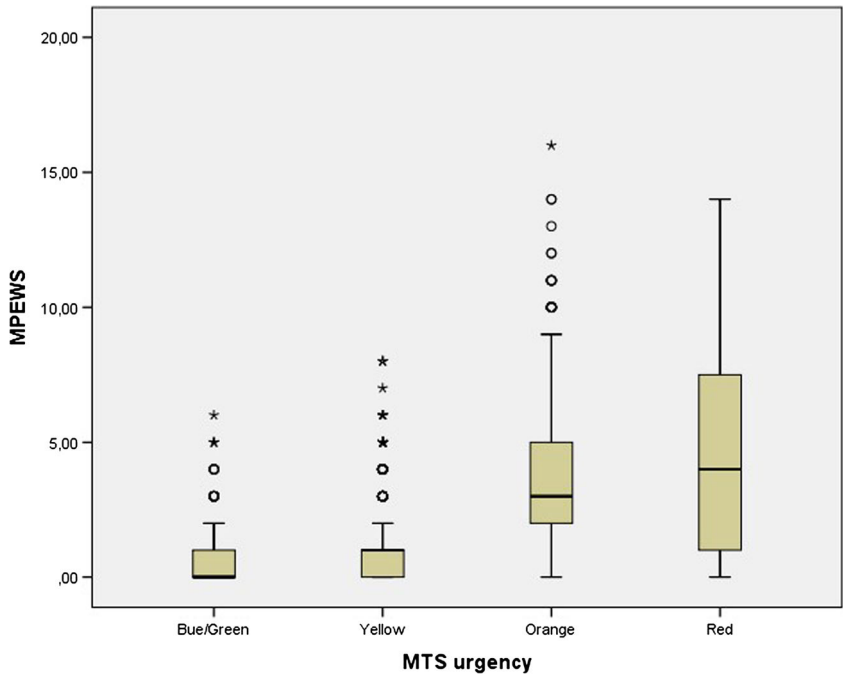

Fig. 3 Boxplot of MPEWS per MTS class

Results

A total of 2980 children attended the ED during the study period. One hundred sixty-eight (5.6%) patients were excluded due to missing data of all vital signs. In 2812 patients, at least one vital sign was measured, making it possible to calculate the MPEWS. The heart rate was available in 2370 children (84%), respiratory rate in 1335 (47%), temperature in 2623 (93%), oxygen saturation in 2371 (84%), oxygen therapy in 959 (34%), and level of consciousness in 2035 (72%) (Fig. 2). Forty-two percent of the included children ($N = 1184$) were admitted to the hospital and 0.4% ($N = 10$) transferred to the ICU. Patient characteristics are shown in Table 1. Excluded patients had a significantly lower MTS urgency level ($P < 0.01$) and were less frequently admitted to the hospital (general ward) ($P < 0.01$) in comparison to the included patients. An increased MPEWS corresponded to a high MTS classification as can be seen in the box plot Fig. 3/Table 2.

Table 2 Median MPEWS per MTS class

MTS classification	MPEWS median (IQR)
Emergency ($N = 43$)	4 (1–8)
Very urgent ($N = 1282$)	3 (2–5)
Urgent ($N = 1142$)	1 (0–1)
Standard/not urgent ($N = 345$)	0 (0–1)

There was no difference in age and sex between critically and not critically ill children (Table 1). Critically ill children had a significantly higher MTS urgency: of the critically ill children 40% ($N = 4$) had MTS urgency level "emergency" versus 1.4% ($N = 39$) of the not critically ill children. Fifty percent of the critically ill children ($N = 5$) had the MTS urgency "very urgent." Eighty percent of the critically ill children had a MPEWS ≥ 5 compared to 15.4% of the not critically ill children ($< P = 0.01$ $N = 2812$) (Table 1).

The area under the ROC curve was calculated and showed that the MPEWS is a significant discriminator for ICU admission. The area under the ROC curve suggested an optimal cutoff for the modified PEWS at ≥ 5: 0.82 [95% CI 0.68–0.97], with a sensitivity of 80% and specificity of 85%. A model containing both the MPEWS and the MTS did not perform significantly better than the MTS alone, area under the ROC curve 0.89 [95% CI 0.77–1.00] versus area under the ROC curve 0.82 [95% CI 0.68–0.95]. An overview of the diagnostic performance measures of the MPEWS, MTS, and a model combining the MPEWS are shown in Table 3.

The MPEWS could not predict hospitalization as no cutsoff point was found to have high sensitivity and high specificity. The maximum area under the ROC was 0.57 [95% CI 0.55–0.59].

Discussion

In this pilot study, we show the MPEWS has potential to be a useful tool to identify critically ill children in the general

Table 3 Diagnostic performance measures MPEWS and MTS to identify critically ill children (95% CI)

	Sensitivity	Specificity	PPV	NPV	ROC	P value ROC
MPEWS (no cutoff)	–	–	–	–	0.85 (0.68–1.00)	< 0.001
MPEWS ≥ 4	80% (44–96%)	77% (75–78%)	1.2% (0.5–2.4%)	100% (99.6–100%)	0.78 (0.64–0.93)	0.002
MPEWS ≥ 5	80% (44–96%)	85% (83–86%)	1.8% (0.8–3.7%)	100% (99.7–100%)	0.82 (0.68–097)	< 0.001
MPEWS ≥ 6	70% (35–92%)	90% (88–91%)	2.3% (1.0–5.0%)	100% (99.6–100%)	0.80 (0.63–0.97)	0.001
MPEWS ≥ 7	60% (27–86%)	94% (93–95%)	3.5% (1.4–7.9%)	99.8% (99.6–100%)	0.77 (0.59–0.96)	0.003
MTS (categorical)	–	–	–	–	0.82 (0.68–0.95)	< 0.001
Model with:						
MPEWS (no cutoff) + MTS	–	–	–	–	0.92 (0.84–1.00)	< 0.001
MPEWS ≥ 5 + MTS	–	–	–	–	0.89 (0.77–1.00)	< 0.001

pediatric ED population (area under the ROC curve 0.82 [95% CI 0.68–0.97]) but further study is needed to confirm this.

Previous studies have evaluated the use of PEWS in ED settings with promising results [6, 7, 11]. In addition, Seiger et al. have compared the performance of different PEWS in an ED population [6]. The diagnostic performance of the MPEWS to predict ICU admission is in line with the results of Seiger et al. using the PEWS by Parshuram, area under the ROC curve 0.82 [95% CI 0.79–0.85], with a sensitivity of 78% and specificity of 72% [2, 6].

Many PEWS currently used at EDs are time-consuming and contain subjective parameters or parameters which are difficult to obtain in a reliable and standardized method, e.g., work of breathing and blood pressure [1–3, 9, 10, 12, 13]. The MPEWS is fast, easy to use, and manageable for medical and support staff. The MPEWS could be integrated in the electronical patient record and would not require extra time.

Most PEWS are created and evaluated in tertiary centers [2, 3, 6, 8, 13]. The MPEWS is modified to suit the situation in a busy district hospital and has been evaluated in a general Dutch pediatric population.

One limitation of this study is that in this retrospective study, the MPEWS was not yet integrated in daily practice in the ED. However, this has prevented bias from clinicians as the knowledge about the MPEWS in the clinical assessment could have influenced the outcome measures. This study contains only 10 cases (0.4%) of children in need of ICU admission, therefore our results in terms of sensitivity and area under the ROC curve have wide confidence intervals. Future prospective research should be done to validate the MPEWS in larger populations. Missing values for vital signs is a limitation of this retrospective study, missing values were assumed to be normal which could underestimate the severity of MPEWS for some patients. The low PPV stated in Table 3 suggests a high rate of false positive results, the practical implications in our hospital would be manageable, with on average once daily a MPEWS score of ≥ 5 in the ED. Nonetheless, the low PPV could lead to responder fatigue; this has to be evaluated when the MPEWS is integrated in daily practice. A model containing both MTS and the MPEWS might perform better than the MTS alone. We could not find significant improvement of a combined triage with MTS and MPEWS, although the area under the ROC curve and narrower 95% CI show a positive tendency in favor of the model containing MPEWS and MTS. Adding PEWS to some specific flowcharts needs to be evaluated in future studies.

As in many other studies, we have used immediate ICU admission as a measure for critically ill children and as outcome measure [1–4, 6, 13]. The use of this outcome measure for critically ill children could lead to missed critically ill children who deteriorated soon after they were admitted to the general ward or children who died before ICU admission. In this study no children died between ED and ICU admission.

In conclusion, the MPEWS could be a fast and easy to use tool to identify critically ill children in the general pediatric ED population. Due to a low incidence of children in need of ICU admission a larger prospective study is needed to validate the MPEWS.

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Authors' Contributions S.J. Vredebregt has conceptualized and designed this study, carried out the analyses, and drafted the manuscript.

H.A. Moll has designed the initial study, supervised analyses, and reviewed and revised the manuscript.

F.J. Smit has supervised the data collection and reviewed and revised the manuscript.

J.J. Verhoeven has conceptualized and designed the study, designed the Modified Pediatric Early Warning Score, and reviewed and revised the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest

Financial disclosure No relevant relationships to this article

Informed consent This study was approved by the medical ethical committee of the Maasstad Hospital as part of a larger study, the requirement for informed consent was waived.

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