

Identifying high risk children in the emergency department

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Abstract

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Objectives: Early warning scores reduce the occurrence of in-hospital cardiac arrest by identifying high-risk hospitalized patients prior to clinical deterioration. However, the ability of early warning scores to identify high-risk pediatric patients in the emergency department (ED) has not been evaluated. We aimed to determine the association between the modified pediatric early warning score (MPEWS) in the ED and clinical deterioration that necessitated subsequent inpatient ward-to-pediatric intensive care unit (PICU) transfer within 24 hours of admission.

Methods: This is a case-control study of 597 pediatric patients admitted from the ED to the inpatient ward at Seattle Children's Hospital between July 1, 2010 and December 31, 2011. Cases were admitted to the inpatient ward and transferred to the PICU within 24 hours, whereas controls remained hospitalized on the inpatient ward at 24 hours. The association between MPEWS in the ED and ward-to-PICU transfer was determined by chi square analysis.

Results: There were no differences in demographic characteristics between cases and controls. Children with an MPEWS of 7 or greater in the ED were relatively more likely to be transferred to the PICU within 24 hours (OR 8.36, 95% CI 2.98, 22.08). However, an MPEWS threshold of 7 yielded a sensitivity of only 18.0% and a specificity of 97.4%.

Conclusions: Elevated MPEWS in the ED is associated with increased risk of ward-to-PICU transfer within 24 hours of admission; however, an MPEWS of 7 or higher is not sufficient to identify more than a small proportion of children with subsequent clinical deterioration.

Introduction

Early identification of patients at risk for deterioration is paramount to providing high quality medical care within the hospital. Since the first report of medical emergency teams (METs) showed a decreased incidence of cardiac arrest in adult inpatients in Liverpool Hospital in Sydney, Australia,¹ hospitals throughout the world have been implementing these teams of expert providers to aid in the management of high-risk patients. Based upon these results, Tibballs *et al.* conducted a study of the incidence of cardiac arrest before and after the implementation of a MET at Royal Children's Hospital in Melbourne, Australia and observed a 42% relative risk reduction in cardiac arrest (95% CI 0.20, 1.71).² In response to these outcomes, the Institute for Healthcare Improvement recommended implementation of rapid response teams (RRTs) as one of the strategies to decrease preventable inpatient deaths.³ Prior studies in adults and children have shown that changes in patient status can be identified in the 6-8 hours preceding cardiac arrest.⁴⁻⁵ At Seattle Children's Hospital, there has been an increasing RRT activation frequency (3.36 in 2009 to 8.19 in 2012) with little change in cardiac arrest outside the ICU (0.18 to 0.28), all shown as events/1000 non-ICU patient days (unpublished data). However, pooled data and newer metrics suggest that modified pediatric early warning score (MPEWS) and RRT can be effective at recognition and response to severe clinical deterioration.^{6,7,8}

Because early warning scores have been effective in identification of high-risk inpatients, there has been interest in applying these scores to patients in the emergency department (ED), since a subset of patients initially admitted to the inpatient ward rapidly deteriorate and require transfer to the ICU. A case-control study in the UK evaluated the ability of the pediatric advanced warning system (PAWS) to distinguish ED patients requiring ICU admission from

patients requiring inpatient pediatric ward admission. A PAWS threshold of 3 yielded 70% sensitivity and 90% specificity for PICU admission,⁹ suggesting that early warning scores can identify critically ill children in the emergency department. However, of those patients deemed stable enough to admit to the general inpatient ward, a subset will clinically deteriorate and require urgent PICU admission. To date, we are unaware of any data evaluating risk factors in the ED that predict subsequent clinical deterioration. Thus, the objective of this study is to determine the association between the modified pediatric early warning score (MPEWS) in the ED and early clinical deterioration on the inpatient ward. We hypothesized that an elevated MPEWS in the ED would be associated with increased risk of ward-to-PICU transfer in the first 24 hours following admission.

Methods

Location. Seattle Children's Hospital (SCH) is a quaternary care facility that serves as the primary referral center for pediatric sub-specialty care in the five-state region that includes Washington, Wyoming, Alaska, Montana, and Idaho. The hospital has 45 ICU beds that are divided among the PICU, cardiac intensive care unit (CICU), and neonatal intensive care unit (NICU). In 2008, SCH established an RRT comprised of an experienced PICU nurse and respiratory therapist to respond to concerns for patient deterioration on the inpatient ward. The RRT activation criteria were based upon the hospital's modified pediatric early warning score (MPEWS), a numeric score calculated by assigning points for abnormal physiologic parameters and indicators of chronic illness, which was modified from the score developed by Duncan, *et al* (Table 1).¹⁰ MPEWS was recorded for every inpatient once per shift, and an increasing score was identified as a potential trigger for activation of the RRT. During the study period, SCH had approximately 200 activations per year with 40% leading to PICU transfer (unpublished data).

In June 2010, SCH began recording MPEWS on all patients in the ED being admitted to the hospital as a tool to help providers prioritize their assessments of admitted patients. Patients with MPEWS less than 7 at the time of decision to admit did not require clinical evaluation by the primary admitting service within the ED prior to transfer to the inpatient ward. For patients with MPEWS ≥ 7 at the time of decision to admit, the admitting service would evaluate the patient within the ED, but the decision regarding patient placement was not made based upon MPEWS.

Study design. This is a case-control study of patients 0-18 years of age admitted to SCH from the ED between July 1, 2010 and December 31, 2011. Cases were defined as patients initially admitted to the inpatient ward and subsequently transferred to the PICU within 24 hours. Controls were an unmatched random sample of patients, at a ratio of 5:1, who remained hospitalized on the inpatient ward 24 hours after admission from the ED. For patients with multiple admissions during the study period, only data from the first admission were included in the analysis. MPEWS was recorded at the time the ED provider made the decision to admit to the inpatient ward. From the medical record, we also determined each patient's age, sex, race, home language, insurance status, county of residence, mode of transport to the ED, admitting service, and clinical risk group (CRG), a validated tool that classifies patients based upon chronicity and severity of illness, between cases and controls.¹¹ This study was approved by the SCH institutional review board.

Statistical analysis. Descriptive statistics were performed to compare the baseline characteristics of age, sex, race, home language, insurance status, county of residence, mode of arrival to the ED, admitting service, and CRG status. A receiver-operator characteristic (ROC) curve was created to determine the sensitivity and specificity of each MPEWS threshold. Chi square analyses were used to determine the association between MPEWS ≥ 7 in the ED and ward-to-

PICU transfer in the first 24 hours of admission as well as an exploratory analysis to identify additional variables associated with ward-to-PICU transfer. Those factors associated with early clinical deterioration in univariate analysis, as well as age and race, were included in multivariate logistic regression model to determine the association between MPEWS ≥ 7 in the ED and ward-to-PICU transfer in the first 24 hours of admission. All analyses were completed using Stata12 (StataCorp, College Station, TX).

Results

There were 6643 admissions from ED to inpatient ward during the study period, and 115 individuals were transferred to the PICU in the first 24 hours of admission. A ratio of 5:1 controls was used for the analyses, so 575 individuals were randomly selected from the remaining individuals. Of the 115 cases and 575 controls who met inclusion criteria, 105 cases (91%) and 547 controls (95%) had a recorded MPEWS in the ED. Individuals admitted directly to the PICU and those taken to the operating room prior to PICU admission were excluded, leaving 50 cases and 547 controls for the analyses.

The baseline characteristics of age, sex, race, home language, county of residence (King county vs. other), and insurance status were similar between cases and controls (Table 2). Cases were more likely than controls to be transported to the ED by ambulance or air transport, to be admitted to the Medically Complex Care (MCC) or medical subspecialty services, and to have complex chronic CRG status (Table 2).

The distributions of MPEWS in the ED for cases and controls are shown in Figure 1. Less than 3% of controls had MPEWS of 7 or greater in the ED, compared with 18% of cases. However, 36% of cases had MPEWS less than 3 in the ED. The sensitivities and specificities for

ward-to-PICU transfer of each MPEWS threshold (Table 3) yield an area under the ROC curve of 0.691 (Figure 2). Chi square analysis showed that cases were more likely to have MPEWS ≥ 7 (OR 8.36, 95% CI 2.98, 22.08), and this relationship remained in the multivariate logistic regression analysis adjusting for age, race, mode of transport to the ED, admitting service, and CRG category (OR 3.23, 95% CI 1.15, 9.10) (Table 4).

Discussion

Although early warning scores have been shown to decrease the incidence of inpatient cardiac arrest outside the ICU², the ability of early warning scores to identify critically ill patients in the ED has not been established. In this case-control study of 598 pediatric inpatients admitted from the ED, we sought to determine the association between MPEWS in the ED and ward-to-PICU transfer within the first 24 hours of admission. Although prior studies have established that early warning scores identify pediatric inpatients at risk of decompensation,^{2,4,12,13} to our knowledge, this is the first study evaluating the use of an early warning score in the ED to identify a subset of pediatric patients at high risk of rapid clinical deterioration requiring PICU transfer. We found that an MPEWS threshold of 7 yielded a high specificity for ward-to-PICU transfer in the first 24 hours of admission (0.974); however, this threshold was insensitive (0.180). Using an MPEWS threshold of 7 for admission to the PICU during the study period would have resulted in 256 additional admissions from the ED to the PICU, and prevented 9 ward-to-PICU transfers during the first 24 hours of admission.

There were several limitations to our study. First, not all patients meeting inclusion criteria had an MPEWS recorded in the ED. Although the reasons for this are unclear, recording MPEWS in the ED started in June 2010, only one month prior to the study period, which

potentially left inadequate time for ED providers to incorporate the recording of MPEWS into routine patient care duties. In addition, for the entirety of the study period, the MPEWS was recorded electronically while the remaining clinical information was recorded on paper documents in the medical record. This may have led to inconsistencies in recording the MPEWS, resulting in missing data or inaccurate data.

A second limitation was that the outcome of inpatient ward-to-PICU transfer does not provide a clear explanation of the specific medical necessity of PICU transfer. Due to the retrospective nature of this study, obtaining information regarding timing of mechanical ventilation and vasoactive medications proved challenging, and so this information was not included in the analysis. However, determining which ICU-level therapies these patients received could help to delineate the acuity of their condition and the risk of harm associated with their unrecognized clinical deterioration. This information would be essential for considering a hospital system change mandating PICU admission at a particular MPEWS threshold given the substantial number of unnecessary PICU admissions necessary to prevent one episode of clinical deterioration.

Another limitation is the potential influence of MPEWS on clinical decision-making by the admitting service. Although the score in the ED did not affect initial patient placement, it is possible that an elevated MPEWS in the ED created the perception that these patients were more ill, thus influencing their likelihood of early PICU consultation and transfer from the inpatient ward to the ICU. Finally, we acknowledge that the PICU admission criteria at SCH are not representative of all ICU admission criteria, making generalizability of our specific results to other institutions potentially challenging.

Our findings are consistent with findings in adult studies of early warning scores. A retrospective study of 280 adult ED encounters by Heitz, *et al* observed that the maximum modified early warning score (MEWS) in the ED was associated with increased need for higher level of care (OR 1.6, 95% CI 1.3-1.8).¹⁴ However, at a threshold of 7, where over 60% of patients required higher level of care in the first 24 hours of hospital admission, the specificity was 0.98 but the sensitivity was only 0.13, which approximate the findings in our study. A prospective study from Italy of 1107 adults admitted from the ED observed an association between $MEWS \geq 5$ and risk of death (OR 22.59, 95% CI 10.45, 49.16) and between $MEWS \geq 5$ and risk of death and/or transfer to higher level of care (OR 11.38, 95% CI 5.84, 22.19).¹⁵ However, the sensitivities of this threshold for in-hospital death and in-hospital death or transfer to higher level of care were only 0.216 and 0.170, respectively. Another prospective study of 225 consecutive ED admissions observed a similar association between early warning score (EWS) category and risk of ICU admission, CICU admission, or death (OR 2.19, 95% CI 1.41, 3.39); however, the sensitivity for $EWS > 5$ was only 0.172.¹⁶ The observed low sensitivities of early warning scores in the ED for detecting both adults and children at high risk for rapid clinical deterioration emphasize the need for developing more sensitive scoring systems so that a larger proportion of patients at high risk for rapid clinical deterioration may be detected in the ED.

Tables and Figures.

Table 1. Modified Pediatric Early Warning Score (MPEWS)

Item	Age group	Item sub-score		
		0	1	2
Heart rate	< 3mo	>110 and <150	≥ 150 or ≤ 110	≥ 180 or ≤ 90
	3 – 12mo	>100 and <150	≥ 150 or ≤ 100	≥ 170 or ≤ 80
	1-4yr	>90 and <120	≥ 120 or ≤ 90	≥ 150 or ≤ 70
	4-12yr	>70 and <110	≥ 110 or ≤ 70	≥ 130 or ≤ 60
	> 12yr	>60 and <100	≥ 100 or ≤ 60	≥ 120 or <50
Respiratory rate	< 3mo	>29 and <61	≥ 61 or ≤ 29	≥ 81 or ≤ 19
	3 – 12mo	>24 or <51	≥ 51 or ≤ 24	≥ 71 or ≤ 19
	1-4yr	>19 or <41	≥ 41 or ≤ 19	≥ 61 or ≤ 15
	4-12yr	>19 or <31	≥ 31 or ≤ 19	≥ 41 or ≤ 14
	> 12yr	>11 or <17	≥ 17 or ≤ 11	≥ 23 or ≤ 10
Oxygen saturation				
Systolic blood pressure	< 3mo	>60 and <80	≥ 80 or ≤ 60	≥ 100 or ≤ 50
	3 – 12mo	>80 and <100	≥ 100 or ≤ 80	≥ 120 or ≤ 70
	1-4yr	>90 and <110	≥ 110 or ≤ 90	≥ 125 or ≤ 75
	4-12yr	>90 and <120	≥ 120 or ≤ 90	≥ 140 or ≤ 80
	> 12yr	>100 and <130	≥ 130 or ≤ 100	≥ 150 or ≤ 85
Temperature °C		≥ 36 and ≤ 38.5	<36 or >38.5	<35 or >40
Mental status		Normal	Confused	Inconsolable
Bolus fluid		None	10mL/kg	> 10mL/kg

*One additional point was assigned for each of the following: Abnormal airway/Positive pressure ventilation, Baseline FiO₂ requirement, Previous ICU admission, Pre/post transplant admission, Acquired and/or congenital heart disease/surgery, Severe neurologic abnormality, Presence of gastrostomy tube

Table 2. Baseline characteristics of patients

		Cases (n=50)	Controls (n=547)
Age in years, mean (range)		5.3 (0.01-17.9)	6.2 (0.005-19.0)
Male sex, %		50.0	52.8
Race, %	White/Caucasian	58.0	57.0
	Asian	16.0	8.6
	African American/Black	2.0	9.0
	Other	24.0	25.4
Home language, %	English	78.0	82.1
	Spanish	12.0	9.7
	Other	10.0	8.2
Transport to hospital, %	Private vehicle	54.0	74.2
	Ambulance	40.0	23.0
	Airlift	6.0	2.2
Admitting service, %	General medicine	44.0	57.6
	Medical subspecialty	36.0	19.9
	Medically complex care	12.0	1.5
	General surgery	8.0	10.8
	Surgical subspecialty	0	8.4
	Neurosurgery	0	1.8
CRG, %	Non-chronic	24.0	43.7
	Non-complex chronic	10.0	30.0
	Complex chronic	60.0	21.0
	Malignancies	6.0	5.3
King county residence, %		56.0	53.2
Public insurance, %		46.0	43.9
ED length of stay (hrs), mean (range)		4.9 (2.1-10.5)	4.5 (0.5-14.3)

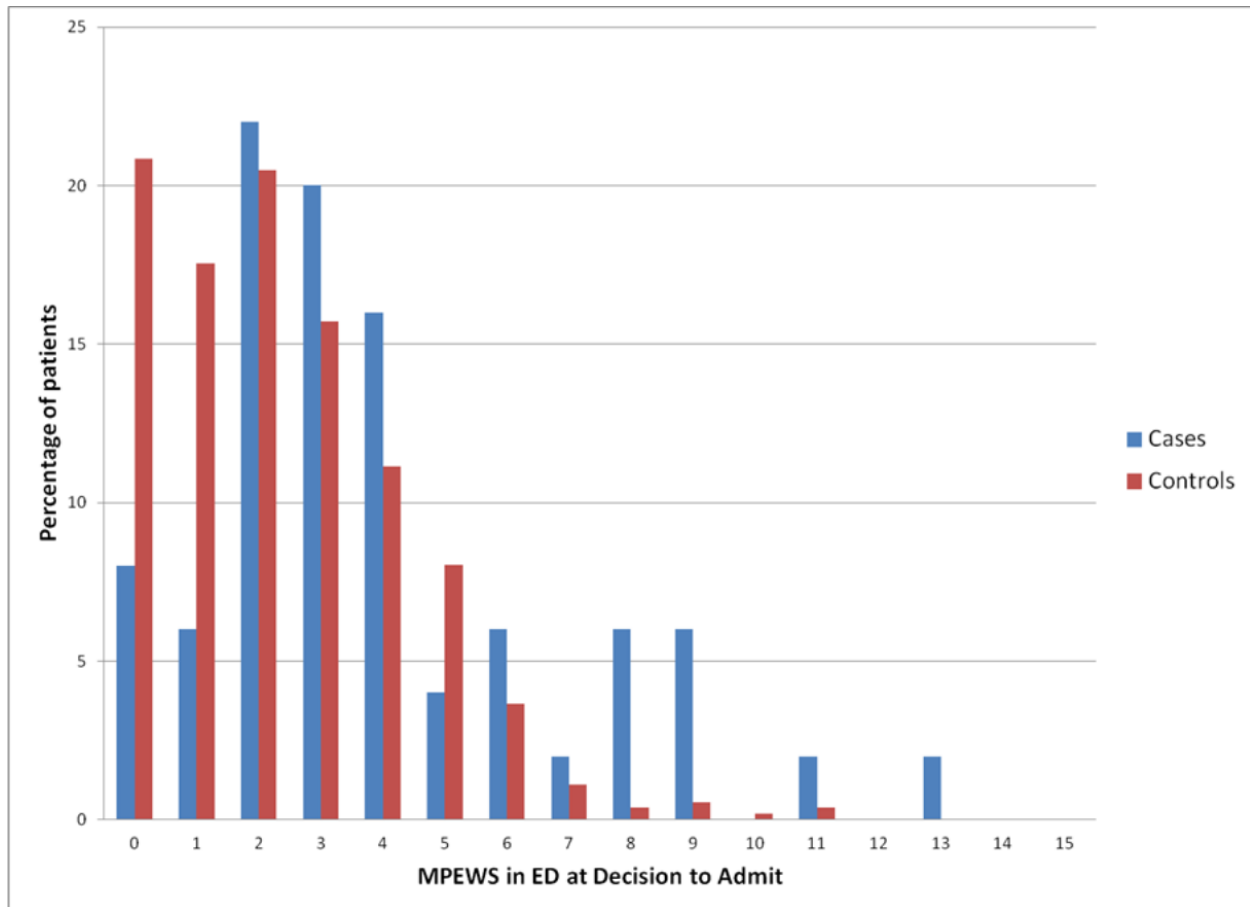


Figure 1. Distribution of MPEWS for cases and controls.

Table 3. Sensitivities and specificities for each MPEWS threshold.

MPEWS threshold	Sensitivity	Specificity
1	0.920	0.208
2	0.860	0.384
3	0.640	0.589
4	0.440	0.746
5	0.280	0.857
6	0.240	0.938
7	0.180	0.974
8	0.160	0.985
9	0.100	0.989
10	0.040	0.996
11	0.040	0.996
12	0.020	1.000

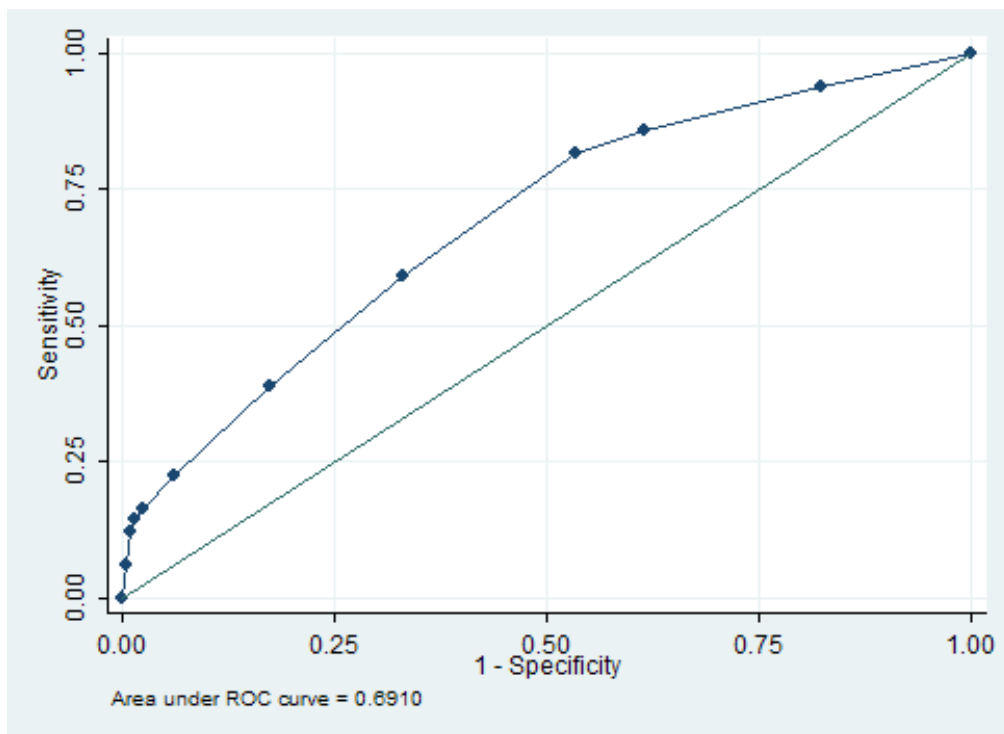


Figure 2. Receiver operating characteristic of the ability of MPEWS in the ED to identify children at risk of rapid clinical deterioration.

Table 4. Association between MPEWS and ward-to-PICU transfer

	OR (95% CI)	p
MPEWS ≥ 7 [*]	8.36 (2.98, 22.08)	<0.0001
MPEWS ≥ 7 [†]	3.64 (1.32, 10.03)	0.012
MPEWS ≥ 7 [‡]	3.23 (1.15, 9.10)	0.027

^{*}Unadjusted; [†]Adjusted for mode of transport, admitting service, CRG; [‡]Adjusted for age, race, mode of transport, admitting service, CRG

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