

The application of pediatric early warning score (PEWS) in emergency observation room

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ABSTRACT

Objective: To explore the value of pediatric early warning scoring system (PEWS) in an emergency observation room in China.

Methods: The children who had been admitted consecutively to the emergency observation room from Jan, 2019 to Aug, 2020 were selected. Three most important time-points including the first value (admission value), the highest value during the observation (highest value), and final value (discharge value) of Brighton Pediatric Early Warning Score (PEWS) was evaluated in all patients.

Results: 4717 patients were included. They were categorized into 3 groups, namely, discharged group (G1, $n = 2320$), specialized ward group (G2, $n = 2128$), and ICU group (G3, $n = 269$). The different PEWS values of admission value, highest value, and discharge value were significantly different among the 3 groups ($P < 0.001$). Highest value of G1 and G2 were significantly lower than that of G3 ($P < 0.001$). AUROC curves of different PEWS values were used to predict the possibility of PICU admission and PICU mortality within 24 h of admission, and the values were 0.698, 0.878, 0.974 and 0.709, 0.883, 0.951, respectively. The cutoff values for PICU admission of 3 different PEWS values were 2.5 (sensitivity 0.635, specificity 0.699), 3.5 (sensitivity 0.817, specificity 0.9), 3.5 (sensitivity 0.837, specificity 0.985). The cutoff values for PICU mortality of 3 different PEWS values were 4 (sensitivity 0.625, specificity 0.799), 4.5 (sensitivity 0.722, specificity 0.79), 4.5 (sensitivity 0.883, specificity 0.987). The discharge value had the strongest prediction ability.

Conclusions: PEWS can be used for early identification and warning of critically ill children.

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Introduction

Most emergency departments (ED) in China are overburdened with large numbers of patients and staff shortages (Wang et al., 2021). Inpatient bed shortages result in many potentially critically ill children being housed in the emergency observation rooms for considerable periods of time. The clinical course of these children can change rapidly and lead to serious adverse events including cardiorespiratory deterioration and even death, if unrecognized. Early identification may prompt early therapy and intensive care unit (ICU) admission and may avert complications and even reduce mortality, morbidity and hospital stays. With rapid, appropriate assessment of patient status, the incidence of ED overcrowding can also be reduced, thereby reducing mortality and treatment delay (Hoot & Aronsky, 2008; Weiss et al., 2007).

However, early recognition is hampered because most staff of health care facilities in China largely on their intuitions to qualify the patients' condition, leading to delay of recognition and intervention. Thus, it is

important to use some effective and simple parameters to assist in objective evaluation of the deteriorating children.

Four systems of PEWS, including, Monaghan, Tibbals, Duncan and Haines have been developed (Duncan et al., 2006; Haines et al., 2006; Monaghan, 2005; Tibbals et al., 2005). Brighton PEWS were developed by Monaghan, which contains three parts to evaluate the function of central nervous system, respiratory system and circulatory system. The efficiency of the system has been validated and it was considered that PEWS improved the confidence of the health care staff in recognizing children at risk of deterioration in Monaghan's study (3). The other 3 systems have more scoring items, 47 (Duncan's), 9 (Tibbals's) and 5 (Haines's), respectively (Duncan et al., 2006; Haines et al., 2006; Tibbals et al., 2005), and some of the data cannot be gotten immediately and easily at bedside. Considering timeliness and maneuverability, Brighton PEWS was chosen in our emergency observation room. Besides, the deterioration of pediatric patients is mostly due to the problems of the heart, lung and brain. The study of Reis et al. (Reis et al., 2002) showed that 61% of pediatric cardiac arrests were caused by respiratory failure and 29% by shock.

Previous study on the cause of death in children demonstrated that 26–43% of 957 pediatric death were able to be avoidable or potentially

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avoidable (Pearson, 2008). The occurrence of adverse events is not totally due to the lack of knowledge and skills of the health care staff, while it is also due to the lack of adequate vigilance and cognition of critical urgency in the hours proceeding adverse events. Therefore, it is important to use those clinical physiological indicators in standardized and normalized way for early recognition of the disease risk (Adam & Odell, 2005; Tamul & Leonard, 2022).

Recent studies have been geared toward early warning scores and their ability to identify the severity of the disease (Monaghan, 2005; Oldroyd & Day, 2011; Tucker et al., 2009). For children, the original concept of a Pediatric Early Warning Score (PEWS) system was developed to provide a reproducible assessment of the pediatric patient's status based on physiologic parameters (Chapman et al., 2010; Duncan et al., 2006; Egdell et al., 2008; Haines et al., 2006; Monaghan, 2005; Oldroyd & Day, 2011; Skaletzky et al., 2012; Tucker et al., 2009). PEWS was designed for ED and has acceptable validity in predicting likelihood of admission (Egdell et al., 2008; Seiger et al., 2013). Scores consist of vital sign measurement and quick physical evaluation, which can be done quickly and easily in the busy ED setting (Duncan et al., 2006). They have never been validated in China.

Our study objective was to explore if the PEWS score assigned in the emergency observation rooms predicts the need for ICU admission and the mortality of the patients.

Methods

Patients

This is an observational study. The children who admitted to emergency observation room in our hospital from (2019.01–2020.08) were consecutively selected.

The inclusion criteria were, 1) ill children who needed observation or hospitalization due to moderate infection, or children requiring medical intervention to support organ function, etc. but there were no beds available; 2) children should be checked by the attending doctor of emergency observation room before their admission. Patients presenting with trauma, psychiatric, dental and surgical concerns were excluded. Children were divided into three groups, including G1 (discharge group, which means children in this group recovered well without further observation), G2 (specialized ward group, which means children in this group needed specialized ward admission), and G3 (PICU group, which means children requiring PICU admission). The study protocol was not subjected to the medical ethics board because it was observational and retrospective in nature and, therefore, consent was not needed in our facility.

Table 1
The Brighton pediatric early warning score (PEWS) and Action sheet.

	0	1	2	3
Respiration	Normal respiratory rate	Respiratory rate ≥ 10 above normal parameters	Respiratory rate ≥ 20 above normal parameters	Respiratory rate ≥ 30 above normal parameters OR ≤ 5 below normal parameters
Airways	AND No retractions	Retractions	Jugular retractions	Retractions or grunting
Breathing		OR FiO2>0.30	OR FiO2>0.40	OR FiO2>0.50
Circulation	Normal skin color	OR ≥2 L/min O2	OR ≥5 L/min O2	OR ≥8 L/min O2
	OR Capillary refill time of 1–2 s	OR Pale	OR Grey or cyanotic	OR Grey or cyanotic AND mottled
		OR Capillary refill time of 3 s	OR Tachycardia, 20–30 beats/min above normal rate	OR Tachycardia, >30 beats/min above normal rate
			OR Capillary refill time of 4 s	OR Bradycardia
Disability	Alert	Voice	Pain	OR Capillary refill time of >5 s Unresponsive

Assessment

Brighton PEWS was chosen as our measuring tool (Monaghan, 2005), the detailed scoring system was shown in Table 1. PEWS was performed by the physician. The nursing staff would record the information of all the enrolled patients. General information including the gender, age, admitting diagnosis was recorded. The different values of PEWS were recorded. Values were recorded per hour in the first 4 h. After that, they could be recorded every 8 h if the values remained at 0–1, or every 4 h, if the values remained at 2–3, or still per hour, if the values ≥4 continuously. ER observation admissions at the hospital are limited to 72 h. In the study, we would record three most important time-points, which were, the first value (admission value), the highest value during the observation (highest value), and final value (discharge value). The patients were discharged, admitted to specialized wards or PICU until 72 h, were recorded. The PICU admission and PICU mortality were recorded.

Statistical analysis

The measurement data were described by mean $\bar{x} \pm SD$ or median (IQR) according to distribution characteristics of the data. Non-normal distribution measurement data were compared by Kruskal-Wallis H test among 3 different groups and Wilcoxon rank sum test. The classification data was described by n (%). Comparison between groups was performed by χ^2 test, when the frequency was less than or equal to 1, Fisher's exact probability method was used. The ROC curve was analyzed by SPSS 22.0 software.

Result

Basic characteristics

Of 4744 children admitted to the emergency observation room, 27 were excluded due to refusal to be housed in emergency observation room. Of the remaining 4717 ones, 2968 were male (62.9%). They were categorized into 3 groups, discharged group (G1, n = 2320), specialized ward group (G2, n = 2128), and ICU group (G3, n = 269). The median age of 3 groups was 12 (3, 48) months, 17 (4, 60) months, and 12 (3, 52) months, respectively. There was no significant difference in gender among 3 groups. The age of G2 was significantly higher than other two groups (P = 0.001).

According to the ICD10 standard, the primary diseases of those patients were related to the following organ system, including respiratory, blood, brain, digestive and so on. The top five diseases were pneumonia (n = 949, 19.8%, J18.900), thrombocytopenia (n = 380, 8.06%, D69.600), central nervous system infection (n = 304, 6.44%, G04.904),

gastroenteritis ($n = 247, 5.24\%, A09.901$), and epilepsy ($n = 114, 2.42\%, G40.901$). There were significant differences of the disease classification among the 3 groups. Patients who had neoplastic diseases were prone to PICU admission. The characteristics of the study population was shown in Table 2.

Comparison of PEWS among the 3 groups

The different PEWS values, including admission value, highest value and discharge value were significantly different among 3 different groups ($P < 0.001$) (Table 3). There were no significant differences of admission value and the highest value between G1 and G2 ($P > 0.05$), while both admission value and the highest value of G1 and G2 were significantly lower than that in G3 ($P < 0.001$). The discharge value was different between any two groups in G1, G2 and G3 (Table 3).

Predicting value of PEWS on PICU admission and PICU mortality

AUROC curves of admission value, the highest value and discharge value were used to predict the possibility of PICU admission and PICU mortality, and the values were 0.698, 0.878, 0.974 and 0.709, 0.883, 0.951, respectively. The cutoff values were determined by the area under curve. The cutoff values of 3 different PEWS values were 2.5 (sensitivity 0.635, specificity 0.699), 3.5 (sensitivity 0.817, specificity 0.9), 3.5 (sensitivity 0.837, specificity 0.985). The discharge value had the strongest prediction ability (Table 4, Fig. 1A). The cutoff values for PICU mortality of 3 different PEWS values were 4 (sensitivity 0.625, specificity 0.799), 4.5 (sensitivity 0.722, specificity 0.79), 4.5 (sensitivity 0.883, specificity 0.987) (Table 5, Fig. 1B).

Discussion

The purpose of this study is to evaluate the value of pediatric early warning score (PEWS) system in the emergency observation room in our hospital. PEWS has been validated in many countries including the United States, Britain, Ireland, and was considered as a good predictor of mortality with an AUROC for death within 24 h of admission of

Table 3
Different PEWS compared among different groups and between any two groups.

PEWS	G1	G2	G3	χ^2 value	P value
Admission value	2 (1,3)	2 (1,3)	3 (2,4)ab	125.622	$P < 0.001$
Highest value	2 (1,3)	2 (1,3)	5 (4,6)ab	465.627	$P < 0.001$
Departure value	1 (0,1)	1 (0,2)a	5 (4,5)ab	846.838	$P < 0.001$

a:compared with G1, $P < 0.01$; b: compared with G2, $P < 0.01$.

about 0.9 (Bleyer et al., 2011; Kellett et al., 2013; Otyek et al., 2013; Prytherch et al., 2010), which was consistent with our results of current study performed in China. Our study confirmed that the Brighton PEWS system had huge value to distinguish those critically ill or potentially critically ill children from general ones and was a good predictor for PICU admission and PICU death risk, which was similar with the results of previous study (Oldroyd & Day, 2011). Therefore, the EWS system might be used widely, especially in developing countries with limited health care staff and medical resources, to reduce the incidence of adverse events and medical disputes.

The state of disease in children changed fast, but there would still be a time window before adverse events in 80% patients (Bleyer et al., 2011; Prytherch et al., 2010). It showed that cardiopulmonary arrests were often caused by potential reversible causes, such as hypoxia and shock, which might proceed up to 24 h before physiological changes happened (Kellett et al., 2013). At present, most study PEWS was only to monitor the admission time-point. But for the potentially critically ill children, it was more convincing to monitor their vital signs dynamically, since the single time-point could not well reflect the real process of disease state and the possible trend. The innovative point of our study is to monitor PEWS values dynamically. The most representative three time-points, admission value, highest value and discharge value, were chosen to analyze and evaluate the efficiency of PEWS. Our study showed that there was significant difference of discharge value between any two groups, which meant that it might distinguish inpatients from outpatients, critically ill patients from general ones effectively. Furthermore, it also had the most powerful ability to predict the PICU admission and PICU mortality of those critically ill children. Thus, single time-point of EWS value, the time of entering ED or admission, which is always used as the important predictor in majority researches, is far from precise to reflect the whole process of disease state, which underestimates or overestimates the later changes of the patients. In many cases, when PEWS values were high, prompt attention and rational intervene may make PEWS values go down, and critical situation may be reversed quickly, therefore, hospitalization or even PICU admission is not needed. Our study demonstrated that for those indeed critically ill children, the discharge values are the most useful ones to predict patients' outcomes rather than the general view of the admission ones or the highest ones, reflecting a dynamic and comprehensive process of the patient. It was showed that the cutoff value of both discharge value and highest value to predict PICU admission was 3.5, which strongly suggested that great attention and early intervention should be given to such patients. However, we should still combine the PEWS system with other symptoms to avoid misdiagnosis, excessive medical treatment and resources waste.

Table 2
Basic characteristics.

		G1	G2	G3	Total (n)	P value
Gender	Male	1466	1337	165	2968	0.945
	Female	854	791	104	1749	
Age (month)		12 (3,48)	17 (4,60)	12 (3,52)		0.001
	Respiratory	936	602	128	1652	
Disease system classification	Hematologic	592	10	2	604	$P < 0.001$
	Central nervous system	295	187	10	492	
	Digestion	176	375	20	571	
	Cardiovascular	68	107	9	184	
	Inborn errors of metabolism	50	165	13	228	
	Bone	5	55	3	63	
	Myopathy	18	169	14	201	
	Urinary	29	13	5	47	
	Neoplastic disease	51	383	56	490	
	Connective tissue	3	11	5	19	
	Rash	28	16	2	46	
	Liver	30	35	2	67	
	Infection	16			16	
Others*	23			23		

G1: discharge group; G2: specialized ward group; G3: PICU group; G4: treatment abandoned group.

Others*: including contagion, self-harm and adverse effects of unspecified drugs and agents.

Table 4
ROC and 95% confidence interval to Predict the Possibility of PICU Admission.

PICU admission	ROC	95% confidence interval	
		Lower limit	Higher limit
Admission value	0.698	0.665	0.731
Highest value	0.878	0.858	0.899
Departure value	0.974	0.963	0.985

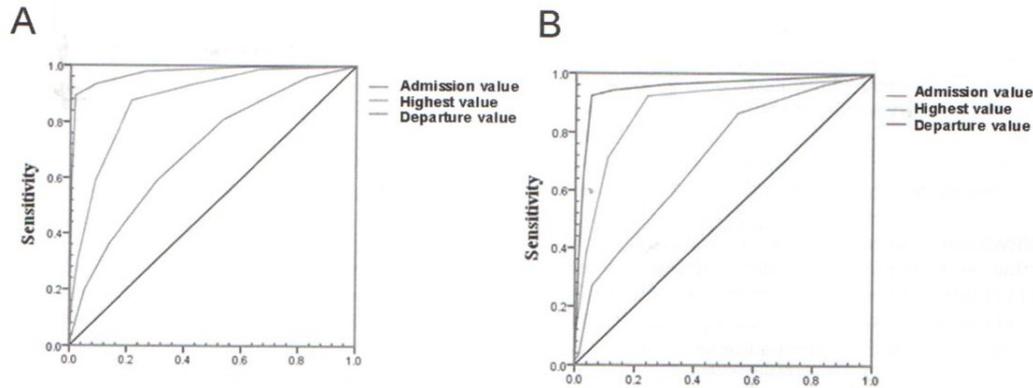


Fig. 1. AUROC Curve of Admission value, Highest value, Discharge value on PICU Admission and PICU mortality. A. AUROC Curve to Predict the Possibility of PICU Admission; B. AUROC Curve to Predict the PICU mortality within 24 h of admission.

Practice implication

In our study, many children have some specialized diseases, such as leukemia, liver failure and so on. Single organ dysfunction or failure made them need to be admitted to specialized wards for further support and treatment, such as blood products infusion. Furthermore, they were needed to be admitted to PICU to accept invasive organ support, such as blood purification. However, these children’s PEWS values might not be very high, or even normal. It may be due to that the primary disease does not affect the whole body state. But such kind of children with fragile organ function are prone to cardiopulmonary arrest. They need continuous monitoring in order to predict and prevent the occurrence of adverse events. Previous study also showed the similar problem that the sensitivity of PEWS to achieve early warning for such children was poor and limited (Bradman & Maconochie, 2008).

Limitations

There are also some limitations in this study. First, it is an observational study. Confounding factors may be unavoidable. Second, it is a single center study. The enrolled patients and result may have bias. Third, it is a retrospective study. How were children with chronic or chronic critical illness addressed and where baseline conditions represented by higher baseline scores and how did these factors into their disposition and risk were still not clear. Forth, the subgroup analysis of underlying disease was not performed in this study. Multi-center study with prospective design is still needed. Finally, the patients included in this study were young children, the application of Brighton PEWS in adolescent and young adults needs further to be evaluated.

Conclusion

PEWS can give health care staff early warning of those critically ill or potentially critically ill children. Further level, it can offer a wealth of data and possible insight into the relationship between the physiological data and adverse clinical outcomes.

Table 5
ROC and 95% confidence interval to Predict the Prognosis.

PICU admission	ROC	95% confidence interval	
		Lower limit	Higher limit
Admission value	0.709	0.642	0.777
Highest value	0.883	0.833	0.932
Departure value	0.951	0.916	0.986

Practice implication

PEWS can give health care staff early warning of those critically ill or potentially critically ill children. Further, it can offer a wealth of data and possible insight into the relationship between the physiological data and adverse clinical outcomes.

Ethical approval and consent for publication

The study protocol was not subjected to the medical ethics board because it was observational and retrospective in nature and, therefore, consent was not needed in our facility.

Availability of data and material

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

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Author contribution

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Declaration of Competing Interest

None.

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