Heliyon 11 (2025) e40937

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Analysis of the accuracy of disease prediction in pediatric ward patients based on the modified early warning score for children: A randomized controlled trial

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ARTICLE INFO

Keywords:
Children
PEWS
Pediatric ward patients
Condition assessment
Randomized controlled trial

ABSTRACT

Background: Due to their young age and limited ability to communicate, pediatric patients in internal medicine wards are at risk of nursing assessment errors, which can lead to adverse events and disputes.
Objective: To explore the application effect of modified pediatric early warning score (PEWS) in the early identification of critically ill children in pediatric general wards.
Design: A single-blind, two-arm randomized controlled trial was conducted using a convenience sampling method.
Methods: A study was conducted on 300 pediatric inpatients admitted to the pediatric ward of a tertiary hospital in Guangdong Province between June 2021 and December 2023. The patients were randomly divided into an observation group (150 cases) and a control group (150 cases) using a random number table. The control group received standard treatment based on medical orders, along with routine basic and specialized nursing care. The observation group received an intervention combining the PEWS with a graded nursing management model. The PEWS scores of the observation group were analyzed upon admission, and the value of PEWS in assessing the severity of illness was evaluated using a receiver operating characteristic (ROC) curve. The study also compared treatment outcomes, complication rates, mortality, and parental satisfaction between the two groups.
Results: The observation group showed significantly lower mortality, complication rates, length of hospital stay, and hospitalization costs compared to the control group ($P < 0.05$). Additionally, parental satisfaction in the observation group was significantly higher than in the control group ($P < 0.05$). When using the need for nursing intervention in critically ill patients as a predictive indicator, a modified PEWS score of $\geq$1 point was identified as the threshold for distinguishing critically ill patients who require nursing intervention. The area under the curve (AUC) was 0.91, with a sensitivity of 92.1 %, a specificity of 75.4 %, and a Youden index of 0.675.
Conclusion: As an effective tool for assessing patient conditions, the probability of receiving nursing care significantly increases for patients with a modified PEWS score above 1. The modified PEWS is valuable for early identification of illness and assessing changes in patient conditions. It enables timely recognition of deterioration and the provision of personalized nursing interventions, thereby reducing the incidence of complications in critically ill patients, preventing further deterioration, shortening hospital stays, and lowering hospitalization costs, ultimately improving parental satisfaction. This approach is worth promoting.

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https://doi.org/10.1016/j.heliyon.2024.e40937
Received 20 August 2024; Received in revised form 17 November 2024; Accepted 3 December 2024
Available online 15 December 2024

Abbreviations

PICU	pediatric intensive care unit
PEWS	pediatric early warning score
ROC	receiver operating characteristic
AUC	area under the curve
M	Mean
SD	Standard Deviation
Q	Inter quartile Range, IQR

What is already known

- Extensive clinical studies have shown that the relationship between early identification, delayed intervention and mortality in pediatric patients remains controversial.
- On the other hand, early and effective assessment, monitoring, and subsequent timely interventions and treatments can significantly improve clinical outcomes.

What this paper adds

- Our study showed that the incidence of complications and mortality after treatment were lower in the observation group.
- Early warning scores improve the accuracy of disease assessment in pediatric patients by identifying early signs of clinical deterioration, allowing medical staff to intervene promptly. This early identification can reduce complications, shorten hospital stays, improve patient outcomes, reduce mortality, and potentially reduce the need for intensive care.

1. Introduction

Children's diseases are characterized by rapid onset, diverse condition changes, and complexity, which are significant contributors to the high incidence of pediatric doctor-patient disputes and the high risk of diagnosis and treatment [1].In pediatric wards, due to a relative shortage of nursing staff, vigilance for early signs of disease deterioration is often low, potentially leading to the oversight of changes in physiological indicators and delays in early disease identification. Numerous clinical studies have confirmed [2,3] that delays in early identification and intervention are closely related to increased mortality in children. In contrast, early and effective assessment, monitoring, and timely intervention and treatment can improve patient outcomes. Therefore, early, timely, and accurate disease assessment not only helps medical staff diagnose and treat high-risk diseases, thereby reducing the severity of the disease, reducing hospital stays and complications, but also prevents further deterioration of the disease and reduces accidents.

The Pediatric Early Warning (PEW) tool was developed to identify children whose conditions are deteriorating as early as possible. Dr. Parshuram [4] developed and performed the initial validation of the bedside PEWS score in 2009. The PEWS is straightforward, easy to use, and not limited by time, space, or equipment. In 2018, Dr. Parshuram and colleagues [5] conducted a multi-center cluster trial with complete follow-up of clinical outcomes. The use of robust validation processes significantly enhanced the usability of the scale. In China, the scale proposed by Monaghan [6] is more commonly used. It assesses changes in a child's condition by evaluating their behavior, cardiovascular system, and respiratory system, thereby providing evidence for clinical treatment [7]. Studies abroad have highlighted the significant role of the PEWS scale in reducing hospital stays and complications in critically ill children. However, its impact on mortality remains controversial. A multi-center EPOCH Randomized Clinical Trial emphasized that [5], compared to standard care, the implementation of a bedside pediatric early warning system did not significantly reduce the all-cause mortality rate in hospitalized pediatric patients. In contrast, a multi-center cohort study found that [8] the use of the PEWS was associated with a reduction in clinical deterioration events and mortality in pediatric cancer patients. A 2024 review showed that [9] the Pediatric Early Warning Score serves as a robust determinant of mortality in critical pediatric trauma patients. Domestic studies have indicated that the application of the PEWS in general pediatric wards helps nurses quickly identify and manage critically ill children, thereby reducing complications, improving prognosis, and shortening hospital stays. This also enhances parent and doctor satisfaction with nursing care and reduces the occurrence of unplanned events[10–12].

This study preliminarily explored the effect of the modified PEWS scale on the early identification of critically ill pediatric patients. Early identification and assessment of changes in a child's condition allow for timely interventions to prevent or mitigate the deterioration of their condition, reduce complications and mortality in critically ill children, shorten hospital stays and costs, improve family satisfaction, and provide evidence-based support for clinical application and promotion.

2. Methods

2.1. Ethical considerations

The study protocol was reviewed and approved by the Institutional Review Board of the research hospital (SDFY No: B-2021-212) and met the conditions set by the research hospital's Ethics Committee. Before the survey, parents were informed about the study's purpose, procedures, and time commitment. Informed consent forms were provided to ensure voluntary participation, with assurance of their right to withdraw at any time without any consequences. It has been registered in the Chinese Clinical Trial Registry (ChiCTR2400092340).

2.2. Study design

We conducted a single-blind, two-arm randomized controlled trial using convenience sampling. The study was conducted from June 2021 to December 2023 at a tertiary general hospital in Guangdong Province, China.

2.3. Participants and randomization

A total of 300 inpatients admitted to the general pediatrics department of a Grade-III hospital in Guangdong Province from June 2021 to December 2023 were selected as study participants. They were divided into a test group and a control group using a random number table method. Randomization was performed by an independent investigator assistant who was not involved in the study. Non-duplicated random numbers were generated by a computer. The principal investigator received sequentially numbered, opaque sealed envelopes, each containing a card with either a 1 (intervention group) or a 2 (control group). Due to the nature of the study, data collectors and analysts were blinded to group assignments.

The control group consisted of 150 children, with 80 males and 70 females, and an average age of 3.77 ± 3.78 years. The observation group also included 150 children, with 81 males and 69 females, and an average age of 4.20 ± 4.04 years. The disease distribution in the observation group was as follows: 70 cases of respiratory diseases, 22 cases of central nervous system diseases, 19

Pediatric Early Warning System Assessment Form

Bed No.:__Name:___Hospital No.:___Gender:___Age:__ Diagnosis:_____

Evaluation Project / Time									
Conscious	Normal	0							
	Lethargy	1							
	Agitation; Restlessness	2							
	Lethargy / Coma; Decreased response to pain	3							
Cardiovascular system	Heart rate (times/min)								
	Color pink: CRT 1~2S	0							
	Pale skin: CRT=3S	1							
	Gray skin: CRT=4S; The heart rate was more than 20 beats/min	2							
	Color gray: CRT≥5S;	3							
	The tachycardia was more than 30 times/min; Bradycardia								
Respiratory system	Breathing (times/min)								
	Normal range; no inspiratory depression	0							
	R >10 times /min than normal; dyspnea	1							
	FiO2 >30%; O_2: 2L/min								
	R >20 times /min than normal; Concave suction	2							
	FiO2 >40%; O_2: 4L/min								
	R <5 times /min than normal with sternal indentation or moaning; FiO2 >50%; O2:8L/min	3							
Total (points)									

Fig. 1. Content and design of the improved PEWS evaluation project.
Note: CRT: Capillary Refill Time; R: Respiratory Rate; FiO2: Fraction of Inspired Oxygen; O2: Oxygen Saturation.

cases of digestive system diseases, 7 cases of blood system diseases, and 32 cases of other diseases. There were no significant differences in baseline characteristics between the two groups ($P > 0.05$), indicating comparability.

2.4. Inclusion and exclusion criteria

Eligible children were defined as follows: (1) Pediatric patients admitted to the ward; (2) Admitted through emergency or outpatient departments; (3) Age: 28 days to 14 years old; (4) Family members possess normal communication, comprehension, reading, and understanding abilities.

The exclusion criteria were as follows: (1) Incomplete registration data in the emergency room, preventing the completion of the early warning score for the child; (2) The child was deceased upon arrival at the hospital, making scoring impossible; (3) The child had received other nursing interventions recently.

2.5. Intervention

2.5.1. Control group

The control group received the prescribed treatment according to the doctor's instructions, along with standard basic nursing care and specialized nursing care.

2.5.2. Observation group

The improved PEWS evaluates project content and design: The improved PEWS (Pediatric Early Warning Score) assessment items were designed, with additional dimensions for normal heart rate and normal respiratory rate incorporated into the original PEWS. The scoring system ranged from 0 to 3 points, with higher scores indicating a more critical condition, as shown in Figs. 1 and 2.

The evaluation time and treatment measures for the improved PEWS score were as follows: (1) Evaluation Timing: Patients were assessed from the initial visit to the emergency room until transfer to the ward. Critical patients were evaluated every hour for the first 3 h and then every 4 h thereafter. Any item on the symptoms and signs review form contributes to this score.

(2) Treatment Measures:

- 0 ~ 1 points: No immediate treatment needed; continue to observe the condition.
- 2 ~ 3 points: Assess for symptoms such as pain and fever, calculate fluid balance/urine volume, and enhance inspection and observation of the child.
- 4 points: Notify the second-line doctor, who must be present within 15 min and provide appropriate medical intervention.
- Score ≥5 or within the gray zone: Immediately notify the chief resident and second-line doctor for emergency intervention, consider transferring to PICU. A higher score indicates greater severity (see Fig. 3).

The observation group received a nursing intervention based on the modified version of the PEWS: (1) Rapid Assessment: Upon the child's admission, the nursing staff promptly notified the attending physician on duty and quickly conducted a PEWS assessment. They collaborated with the physician to evaluate the child's condition based on clinical symptoms, parental reports, and basic examinations, categorizing the condition as mild or severe. Key assessments included consciousness, heart rate, respiratory rate, and extremity circulation. Concurrently, the nursing staff communicated with family members to swiftly gather the child's medical history and the onset of symptoms.

(2) Hierarchical Nursing Management:

	Score / Age	3	2	1	0	1	2
Normal heart rate for children	0~3 months	≤80	≤90	≤110	111~149	≥150	≥180
	3~12 months	≤70	≤80	≤100	101~149	≥150	≥170
	1~4 years old	≤60	≤70	≤90	91~119	≥120	≥150
	4~12 years old	≤50	≤60	≤80	81~109	≥110	≥130
	>12 years old	≤40	≤50	≤70	71~99	≥100	≥120
Normal breathing for children	0~3 months	≤15	≤19	≤29	30~60	≥61	≥81
	3~12 months	≤15	≤19	≤24	25~50	≥51	≥71
	1~4 years old	≤12	≤15	≤19	20~40	≥41	≥61
	4~12 years old	≤10	≤14	≤19	20~30	≥31	≥41
	>12 years old	≤9	≤10	≤11	12~16	≥17	≥23

Fig. 2. Detailed content design for heart rate, respiratory rate, corresponding scores.

Care measures (tick)								
Symptom	Whether there is pain							
	Fever (body temperature)							
	Electrolyte imbalance; dehydration							
Intervening measure	No processing required							
	Observe closely and handle if necessary							
	Notify the chief resident and the second-line physician							
Follow the doctor's advice	Do atomization							
	Dilating fluid							
	Give antipyretics							
	Sedation and analgesia							
	Others							
Responsible nurse signature								
Auditor signature								

1. Fill in the time: The patient's life is evaluated from the first visit to the ward. Critically ill patients are evaluated once every hour for the first 3 hours and once every 4 hours thereafter. Any item in the symptom and sign review form belongs to this score.
2. 0~1 points: The child does not need to be treated temporarily, and the condition continues to be observed
3. 2~3 points: Consider whether there are symptoms such as pain and fever, calculate fluid balance/urine volume, and strengthen patrols and observations of children
4. 4 points: Notify the second-line doctor, who must arrive within 15 minutes and provide corresponding medical care intervention
5. ≥5 points or gray columns: Notify the chief resident and the second-line doctor to arrive immediately for rescue, provide corresponding emergency medical intervention, and consider transfer to the intensive care unit.

Fig. 3. Personalized care based on the modified PEWS score.

- N1 Nurses: Responsible for children in the 0–1 zones. These children receive routine care according to the nursing level without special treatment and are monitored during regular rounds.
- N2 Nurses: Responsible for children in the 2–3 zones. They inform the responsible group leader for appropriate nursing guidance and visit the children every 2 h.
- N3 Nurses: Responsible for children in the 4 zone. The attending physician and the responsible nurse must check the child's condition within 15 min, provide preliminary treatment, and conduct hourly inspections.
- N4 and Above Nurses: Responsible for children with scores ≥5 or those in the gray zone. The attending physician and the team leader must check the child's condition within 5 min and visit every 30 min. If the condition does not improve upon reevaluation, the medical team will discuss revising the treatment plan or transferring the child to a PICU for further care.

(3) Personalized Care: The nursing staff collaborate with the treating physician to swiftly carry out bed allocation and initiate treatment. This includes collecting detailed information about the child, such as name, gender, age, medical history, clinical symptoms, current vital signs, and psychological status. They also promptly identify any life-threatening issues, such as dyspnea, hypoxia, or loss of consciousness. Based on the initial assessment by the attending physician, the nursing staff implement emergency rescue measures, including blood collection, infusion, and nebulization, as directed by the doctor. They also enhance close monitoring of vital signs, such as respiratory rate, heart rate, and blood oxygen saturation.

(4) Family Education: Finally, the nursing staff communicate with the families to provide health education and improve parents' understanding of their child's condition. This helps enhance the family's awareness and management of the child's health issues.

3. Measurements

The primary outcome indicator is the early warning scores, and the secondary outcome indicators include length of stay, hospitalization costs, mortality, complication rate, and parent satisfaction, all of which were evaluated using relevant tools.

3.1. Early warning scores for children in the observation group

(1) ROC Curve: Reflects the efficacy of the critical care score. (2) Sensitivity: Measures the ability of a test to correctly detect the

presence of disease. (3) Specificity: Measures the ability of a test to correctly identify individuals without the disease. (4) Best Cutoff Value (Youden Index): Calculated as Youden Index = Sensitivity + Specificity - 1. Its value ranges from −1 to 1, with values closer to 1 indicating better resolution. The highest value represents the optimal cutoff point, offering the best balance between sensitivity and specificity. (5) AUC: Evaluates how well the PEWS score differentiates between levels of disease severity requiring specialist care. The AUC interpretation is as follows: 0.5 to <0.7 indicates low accuracy, 0.7 to 0.9 signifies moderate accuracy, and 0.9 or higher reflects high accuracy [13].

3.2. The length of stay, hospitalization cost, mortality rate and complication rate were compared between the two groups

Complications [14] refer to additional health problems or adverse reactions that occur during the treatment and care of children. These may include acute respiratory dysfunction, multiple organ failure, shock, arrhythmia, cardiac and respiratory arrest, dehydration, hypoxemia, diarrhea, constipation, and other conditions. The incidence rate of complications is calculated by dividing the number of cases with complications by the total number of cases, and then multiplying by 100 to obtain the percentage of affected cases. Only the first occurrence of each complication in a given child is considered.

3.3. Parent satisfaction

On the day of discharge, the CSQ-8 satisfaction scale was issued to assess parental satisfaction with the nursing care [15]. The scale includes 8 items, with total scores ranging from 8 to 32. Scores between 8 and 16 indicate unsatisfactory or low satisfaction, scores from 17 to 24 reflect medium satisfaction, and scores between 25 and 32 denote high satisfaction. A higher score signifies greater satisfaction. The total satisfaction rate for both groups was then calculated.

4. Principle of statistics

4.1. Database establishment

EpiData3.1 software was used to establish the database, and data entry was performed in duplicate to ensure accuracy.

4.2. Statistical analysis

To evaluate model performance, we used Python to plot the ROC curve. We utilized “scikit-learn” to calculate true and false positive rates at various thresholds and “matplotlib” to generate the ROC curve. This approach enabled us to compare model performance visually and compute the AUC for a quantitative assessment of accuracy.

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 27.0 (IBM Corp., Armonk, NY, USA). Measurement data that conformed to a normal distribution were expressed as mean ± standard deviation (M ± SD), while data not conforming to a normal distribution were expressed as median and inter quartile range [M (Q)], with the rank sum test applied. Counting data were expressed as frequencies or percentages and analyzed using the χ^2test. Ordinal data were analyzed using the Mann-Whitney *U* test. $P > 0.05$ was considered statistically significant.

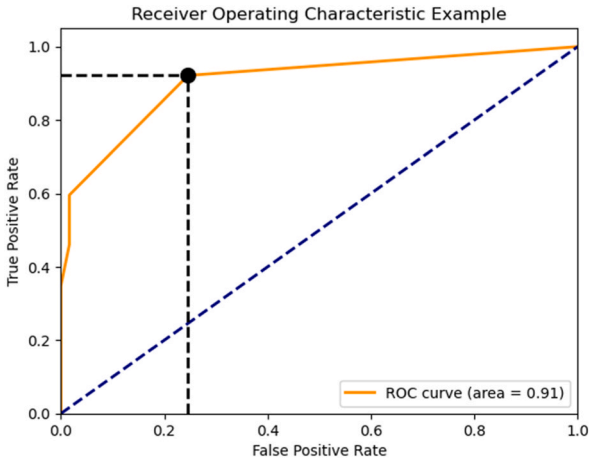

Fig. 4. The early warning score of children assessed the severity of the child’s disease.

5. Results

5.1. Observation group children early warning score

The early warning scores for 150 children in the observation group were as follows: 53 children were in the 0 zone, accounting for 35.30 %; 43 children were in the 1 zone, accounting for 28.70 %; 23 children were in the 2–3 zone, accounting for 15.30 %; 13 children were in the 4 zone, accounting for 8.70 %; and 18 children were in the ≥5 zone, accounting for 12.00 %.

5.2. The modified PEWS scoring system evaluates the severity of the disease

Using different PEWS scores as cutoff values, the ROC curve was plotted, and the AUC was calculated with the gold standard for determining whether specialized care was required based on disease severity. The AUC was 0.91. The sensitivity of the PEWS score in identifying critically ill children was 92.1 %, while the specificity was 75.4 %. The Youden index was 0.675, and the optimal cutoff value was 1 point. This indicates that a PEWS score of ≥1 provides the highest combined sensitivity and specificity for identifying critically ill children and guiding appropriate nursing measures (see Fig. 4).

5.3. Comparison of therapeutic effects between the two groups

The length of hospitalization and hospitalization costs in the observation group were significantly lower than those in the control group ($P < 0.05$). See Table 1.

5.4. Comparison of treatment and prognosis between the two groups

The incidence of complications in the observation group was significantly lower than that in the control group ($P < 0.05$). See Table 2.

5.5. Comparison of parental satisfaction between the two groups

Parental satisfaction in the observation group was significantly higher than in the control group ($P < 0.05$). See Table 3.

6. Discussion

Our study revealed that the incidence of complications was lower in the observation group following treatment which suggests that the early warning score provides a more accurate assessment of children's conditions. The observation group also had significantly shorter hospitalization days and lower costs, indicating that the early warning score helps optimize treatment timing and appropriateness. This also indirectly greatly improves our clinical work efficiency. Furthermore, the study demonstrated that a PEWS score cutoff of 1 point effectively identifies critically ill children with high sensitivity and specificity. Although there was a trend toward reduced mortality in the observation group in our study, these differences did not reach statistical significance. Because mortality is a rare outcome in pediatric patients, the small sample size of our study limits our ability to draw definitive conclusions about the effect of PEWS on mortality.

In our study, the primary purpose of the PEWS was to enable early identification of critically ill children and reduce unnecessary transfers to intensive care, ultimately enhancing nursing efficiency and improving parent satisfaction. The PEWS system, improved to align with clinical practice, now includes assessments of basic vital signs such as heart rate and respiration. This modification allows for a more comprehensive evaluation of factors that may affect disease progression and supports personalized nursing care based on the grading. These findings are consistent with Dr. Hendaus's study [16] from Qatar, which emphasized that continuous monitoring of oxygen saturation in children with bronchiolitis, followed by appropriate treatment, can provide greater reassurance to parents.

Over the past 20 years, the application of PEWS in clinical practice has produced promising results. The advantages of this scoring tool include its objectivity, simplicity, and operability, which contribute to its widespread use [17]. In the face of complex workflows, clinical care professionals need a reliable system for systematically calculating accurate scores, trusting those scores, and developing standard practices for active care. PEWS effectively identifies critically ill or potentially critically ill children and facilitates early intervention, improving prognosis and reducing mortality. This allows experienced pediatric doctors and nurses to detect early changes in a child's condition and adjust treatment accordingly.

Table 1
Comparison of treatment effects between the two groups [M (Q)].

Group	Case number	Length of stay	Hospitalization expense
Observers	150	4.59(2.73)	3838.58(2193.76)
control	150	6.81(4.98)	6451.98(6734.56)
Z-score		−4.72	−4.064
p-value		<0.001	<0.001

Table 2
Comparison of Complication Rates Between the Two Groups [n (%)].

Group	Case number	Complication	Death
Observers	150	5(3.33 %)	0(0 %)
control	150	16(10.67 %)	2(1.33 %)
χ^2		6.196	2.786
p-value		0.013	0.095

Table 3
Comparison of parental satisfaction between the two groups [n (%)].

Group	Case number	Very satisfied	Mostly satisfied	Dissatisfied
Observers	150	92(61.3 %)	48(32.00 %)	10(6.7 %)
control	150	38(25.3 %)	81(54 %)	31(20.7 %)
χ^2		41.692		
p-value		<0.001		

Scotland and Ireland have adopted a national PEWS approach to standardize practices [18,19], enhance communication, and maximize resource utilization. However, in China, numerous PEWS systems are in use, many of which lack validation through multi-center, controlled experimental studies. The primary challenge is to identify and standardize the most effective PEWS system for widespread acceptance. Additionally, effective implementation and training of healthcare workers are crucial. Accurate measurement of key vital indicators, systematic data recording, and precise score calculation is essential. With ongoing exploration and research, a unified and more effective PEWS system is expected to become widely applicable in clinical practice in the near future.

6.1. Limitations

There are several limitations to consider. First, the study included only children admitted to pediatric wards and did not involve other wards, such as the emergency department, which limits the generalizability of the findings. Additionally, the study was conducted at a Level III general hospital, the observation group showed a trend toward reduced mortality; however, the small sample size limited our ability to draw definitive conclusions about the impact of PEWS on mortality. Future research should employ stratified random sampling to include various types of hospitalized children from multiple research centers, which would enhance the representativeness of the sample.

Moreover, while most of the children in this study had respiratory diseases, these conditions were not specifically categorized. Future studies should focus on targeted sampling of children with specific respiratory conditions, such as pneumonia, respiratory infections, and suppurative tonsillitis. Accurate triage and individualized assessments based on specific diseases can lead to more effective planned interventions. Finally, the study design involved scoring conducted by nurses, which may introduce bias into the implementation process.

7. Conclusions

This study highlights the effectiveness of the modified PEWS scale in the early identification of critically ill children and in improving diagnostic and treatment outcomes. Additionally, the use of nurse grading management based on this scale offers a novel approach for future research. The high satisfaction reported by parents underscores the feasibility and effectiveness of the modified PEWS scale. This suggests that the modified PEWS scale provides a valuable and practical option for enhancing therapeutic outcomes and parental satisfaction, from rapid disease identification to symptomatic management in pediatric patients.

Data availability

The data that support the findings of this study are available from the authors upon reasonable request.

Funding

The authors declared that this study has received no financial support.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e40937.

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