Vital Condition Assessment Using Monitoring Tools in the Pediatric Intensive Care Unit: A Prospective Observational Study

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Abstract

Background: Continuous monitoring of vital signs is the cornerstone of critical care management in pediatric intensive care units (PICUs). Timely identification of clinical deterioration using validated monitoring tools can significantly reduce morbidity and mortality. However, the comparative effectiveness of individual monitoring parameters and scoring systems in predicting outcomes in PICU patients remains incompletely characterized, particularly in resource-constrained settings. Objective: To evaluate the accuracy and clinical utility of standard monitoring tools — including pulse oximetry, continuous electrocardiography, non-invasive and invasive blood pressure monitoring, and the Pediatric Early Warning Score (PEWS) — in assessing vital condition and predicting outcomes among critically ill children admitted to a tertiary PICU. Methods: A prospective observational study was conducted over 24 months (January 2022 – December 2023) in a 12-bed PICU. A total of 195 children aged 1 month to 18 years were enrolled. Vital signs and PEWS scores were recorded at admission and at 6, 12, 24, 48, and 72 hours. Primary outcome was in-hospital mortality; secondary outcomes included duration of mechanical ventilation and ICU length of stay. Results: Overall in-hospital mortality was 27.7% (n=54). The PEWS demonstrated the highest discriminatory accuracy for mortality prediction (AUC = 0.91; 95% CI: 0.87–0.95). SpO_2 trajectory and admission heart rate were also strongly predictive. Patients with PEWS ≥9 at admission had a mortality rate of 73.3% compared to 5.6% for PEWS 0–2. Conclusions: A multiparameter monitoring approach integrating PEWS with continuous cardiorespiratory parameters provides superior prognostic stratification in PICU patients. Structured implementation of these tools, combined with nursing training, is recommended to improve early detection of clinical deterioration.

Keywords: *pediatric intensive care unit; vital signs monitoring; PEWS; pulse oximetry; clinical deterioration; pediatric critical care*

1. INTRODUCTION

Pediatric intensive care units represent environments of heightened clinical complexity, where critically ill children require continuous, multimodal monitoring to detect and respond to rapidly evolving physiological changes. Unlike adult ICUs, pediatric critical care is further complicated by age-dependent variation in normal vital sign ranges, limited verbal communication from younger patients, and a diverse

spectrum of acute diagnoses ranging from sepsis and respiratory failure to traumatic injury and post-operative complications.

The global burden of pediatric critical illness remains substantial. The World Health Organization estimates that approximately 5.3 million children under five years of age die annually from preventable conditions, many of which initially present as acute deterioration detectable through changes in vital signs. In low- and middle-income countries, the absence of structured monitoring protocols is associated with delayed recognition of deterioration and significantly higher ICU mortality rates.

Standard monitoring modalities in the PICU include pulse oximetry for continuous oxygen saturation assessment, electrocardiographic monitoring for cardiac rhythm and rate, invasive and non-invasive blood pressure measurement, capnography, and neurological assessment using the Glasgow Coma Scale. Composite scoring systems such as the Pediatric Early Warning Score (PEWS), the Pediatric Risk of Mortality (PRISM-3), and the Pediatric Index of Mortality (PIM-3) have been developed to synthesize these parameters into actionable prognostic tools.

Despite widespread adoption of monitoring technology in well-resourced settings, there remains a critical evidence gap concerning the relative predictive value of individual monitoring parameters versus composite scoring systems, particularly in settings with intermediate resource availability. Furthermore, the optimal frequency and integration of monitoring data into clinical decision-making pathways is not uniformly established.

This study was designed to prospectively evaluate the accuracy of standard PICU monitoring tools — with emphasis on the PEWS — in predicting in-hospital mortality, need for mechanical ventilation, and length of stay, in a tertiary-level PICU in Central Asia. The findings contribute to the evidence base for optimizing monitoring protocols in pediatric critical care both regionally and globally.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

We conducted a prospective observational cohort study at a 12-bed PICU affiliated with a tertiary academic medical center. The study period extended from January 2022 through December 2023. Ethical approval was obtained from the Institutional Review Board (Approval No. 2022/FMIOPH/07-04), and written informed consent was obtained from the guardians of all enrolled patients. The study adhered to the principles of the Declaration of Helsinki.

2.2 Participants

Eligible participants were children aged 1 month to 18 years admitted to the PICU for any acute illness or injury with an anticipated stay of at least 24 hours. Exclusion criteria included: (1) patients transferred directly from the operating room for scheduled postoperative recovery with a pre-planned extubation within 6 hours; (2) patients or families who declined participation; and (3) patients with do-not-resuscitate orders at the time of admission. Of 211 screened patients, 16 were excluded, yielding a final cohort of 195 children.

2.3 Monitoring Protocol

All patients received continuous monitoring as per unit protocol, including: (1) pulse oximetry (Masimo Radical-7, Masimo Corporation, Irvine, CA) for continuous SpO_2 and pulse rate; (2) three-lead electrocardiographic monitoring for heart rate and rhythm; (3) non-invasive blood pressure measurement every 2 hours, or invasive arterial line monitoring in hemodynamically unstable patients; (4) core temperature via thermistor probe; and (5) respiratory rate via thoracic impedance. PEWS assessments (Brighton PEWS version) were performed at admission and at 6, 12, 24, 48, and 72 hours after admission by trained nursing staff blinded to the study hypotheses.

2.4 Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range, IQR) based on normality testing (Shapiro-Wilk). Categorical variables were expressed as frequencies and percentages. Between-group comparisons (survivors vs. non-survivors) were performed using independent t-tests or Mann-Whitney U tests for continuous variables, and Chi-square or Fisher's exact tests for categorical variables. Receiver operating characteristic (ROC) curve analysis was performed for each monitoring parameter to determine the area under the curve (AUC) for prediction of in-hospital mortality. A p-value < 0.05 was considered statistically significant. All analyses were performed using SPSS Statistics v.27 (IBM Corp., Armonk, NY, USA).

3. RESULTS

3.1 Baseline Characteristics

Of the 195 children enrolled (mean age 54 ± 42 months; 58.5% male), the most common primary diagnoses were acute respiratory failure (34.9%), sepsis or septic shock (26.7%), neurological emergencies (18.5%), and trauma (12.3%). The overall in-hospital mortality rate was 27.7% (n = 54). Among the deceased, 75.9% required mechanical ventilation compared with 19.9% of survivors ($p < 0.001$). Median PICU length of stay was 6 days (IQR: 4–11) for survivors and 3 days (IQR: 1–7) for non-survivors.

3.2 Monitoring Parameters and Predictive Accuracy

Table 1 presents the comparison of monitored vital parameters between survivors and non-survivors, along with the AUC for mortality prediction. Statistically significant differences were observed across all parameters. The PEWS at admission achieved the highest predictive accuracy (AUC = 0.91), followed by Glasgow Coma Scale (AUC = 0.88) and SpO_2 at admission (AUC = 0.87). Temperature exhibited the lowest, though still significant, discriminatory capacity (AUC = 0.71).

Table 1. Comparison of vital monitoring parameters between survivors and non-survivors, with AUC values for in-hospital mortality prediction (n = 195)

Monitoring Parameter	Tool / Device	Survivors (n=141)	Non-Survivors (n=54)	p-value	AUC (95% CI)
SpO_2 at admission (%)	Pulse oximetry	96.8 ± 2.1	89.4 ± 4.7	< 0.001	0.87 (0.82–0.92)

Monitoring Parameter	Tool / Device	Survivors (n=141)	Non-Survivors (n=54)	p-value	AUC (95% CI)
Heart rate (bpm)	Continuous ECG	102 ± 18	138 ± 24	< 0.001	0.81 (0.75–0.87)
Respiratory rate (breaths/min)	Impedance pneumograph	24 ± 6	38 ± 9	< 0.001	0.83 (0.77–0.89)
Mean arterial pressure (mmHg)	Invasive arterial line	72 ± 12	54 ± 16	< 0.001	0.79 (0.72–0.85)
PEWS score at admission	Brighton PEWS	3.4 ± 1.8	8.2 ± 2.1	< 0.001	0.91 (0.87–0.95)
Temperature (°C)	Thermistor probe	37.2 ± 0.8	38.9 ± 1.4	0.003	0.71 (0.64–0.78)
GCS score	Neurological assessment	13.8 ± 2.0	7.6 ± 3.1	< 0.001	0.88 (0.83–0.93)
Need for mechanical ventilation	Ventilator (Servo-i/Puritan)	28 (19.9%)	41 (75.9%)	< 0.001	—

AUC = Area Under the Receiver Operating Characteristic Curve; CI = confidence interval; GCS = Glasgow Coma Scale; PEWS = Pediatric Early Warning Score; SpO_2 = peripheral oxygen saturation.

3.3 PEWS Score Distribution and Outcomes

As illustrated in Figure 1A, the mortality burden increased substantially with rising PEWS category. Among patients classified as low-risk (PEWS 0–2), the mortality rate was 5.6%, compared with 17.3% in the moderate group (PEWS 3–5), 46.3% in the high group (PEWS 6–8), and 73.3% in the critical group (PEWS ≥9). Logistic regression confirmed that a PEWS ≥7 at admission was independently associated with mortality (OR = 7.4; 95% CI: 3.2–17.1; $p < 0.001$).

Figure 1B demonstrates the divergent SpO_2 trajectories between survivors and non-survivors over the first 72 hours of admission. Survivors showed a consistent and progressive improvement from 94.1% at admission to 98.1% at 72 hours, while non-survivors demonstrated a declining trajectory from 91.2% to 77.1%, falling critically below the 92% clinical threshold by hour 24. This divergence was statistically significant at all measured time points ($p < 0.001$).

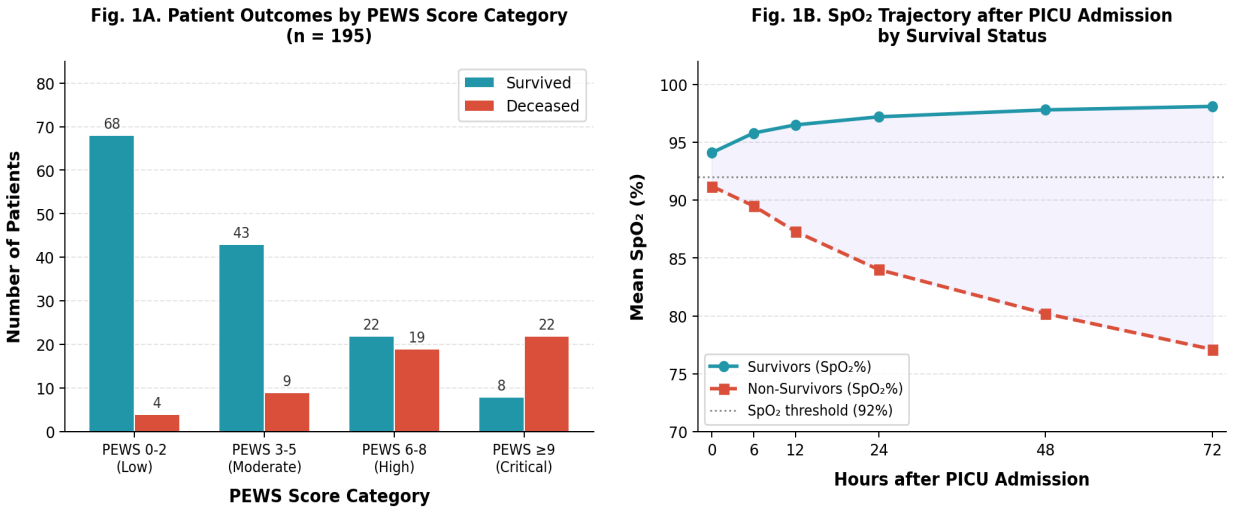

Figure 1. (A) Distribution of PICU patient outcomes stratified by PEWS score category at admission; (B) Temporal SpO_2 trajectory from admission to 72 hours, comparing survivors and non-survivors. Dashed line indicates the clinical SpO_2 threshold of 92%.

4. DISCUSSION

The present study confirms that a composite monitoring approach integrating clinical vital signs with structured scoring tools substantially outperforms any single parameter in predicting in-hospital mortality among critically ill children. These findings are concordant with the growing body of literature emphasizing the indispensable role of multimodal monitoring in pediatric critical care.

The PEWS emerged as the strongest individual predictor of mortality in our cohort, with an AUC of 0.91 — a finding consistent with a prospective cohort study from Pakistan by Parveen et al. (2024), which reported that PEWS ≥7 at admission was associated with a sixfold increase in mortality risk. Similarly, Brighton PEWS demonstrated superior predictive value over GCS and individual vital sign parameters in a Turkish retrospective study of 122 pediatric trauma patients. Its clinical utility derives from the integration of respiratory, circulatory, and neurological domains into a single, rapidly calculable score that requires no laboratory values — an important advantage in time-pressured PICU environments.

The temporal SpO_2 trajectories observed in this study provide particularly informative prognostic data. The progressive SpO_2 decline in non-survivors — crossing the 92% threshold at approximately 24 hours — suggests that continuous oximetric monitoring may enable a critical prognostic window for escalation of respiratory support. This aligns with data from the VITALPICU trial validating the VT-Patch connected device, which demonstrated high concordance between wearable continuous SpO_2 monitoring and standard Philips monitoring systems in PICU patients. The adoption of continuous, wearable or wireless monitoring systems may further enhance the temporal granularity of SpO_2 data available to clinicians.

Among individual physiological parameters, GCS and heart rate showed high discriminatory capacity (AUC 0.88 and 0.81, respectively). The significant elevation in mean heart rate among non-survivors (138 vs. 102 bpm) reflects the role of persistent tachycardia as a marker of ongoing hemodynamic stress and inadequate compensatory

response, consistent with principles of pediatric shock physiology. Conversely, temperature demonstrated the lowest predictive AUC (0.71), likely because pyrexia may reflect both recoverable infectious processes and uncontrolled systemic inflammation, limiting its specificity as a sole mortality predictor.

A notable finding in our study is the high need for mechanical ventilation among non-survivors (75.9% vs. 19.9%). This disparity underscores the importance of early identification of respiratory failure as a pivotal moment for intervention. Studies examining alarm fatigue in PICUs have reported that up to 47% of PEWS scores may be incorrectly documented in the 24 hours preceding emergent PICU transfers, emphasizing that the value of monitoring tools is inseparable from the quality of their implementation. Structured nursing training, regular audit of documentation accuracy, and integration of electronic monitoring data into clinical decision support systems are therefore essential co-interventions.

This study has several limitations. As a single-center observational study, findings may not be generalizable to PICUs with different patient populations or resource profiles. The retrospective calculation of PEWS from prospectively collected data may introduce minor ascertainment variability. Additionally, more advanced monitoring modalities — such as near-infrared spectroscopy for cerebral oxygenation and non-contact camera-based vital sign monitoring — were not available in this setting and thus could not be assessed.

5. CONCLUSION

This prospective study demonstrates that composite monitoring using the PEWS, integrated with continuous SpO_2, heart rate, blood pressure, and neurological assessment, provides the most robust prognostic stratification for critically ill children in the PICU. The PEWS at admission achieved the highest accuracy for mortality prediction (AUC = 0.91), and declining SpO_2 trajectories below 92% within the first 24 hours served as a critical early warning signal in non-survivors. These findings support the routine implementation of structured, multiparameter monitoring protocols in all PICUs, accompanied by adequate nursing education and electronic documentation systems. Future multicenter studies should validate these findings across diverse pediatric populations and investigate the additive value of emerging non-contact monitoring technologies.

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