Early Recognition and Management of Pediatric Septic Shock: Phoenix Criteria Implementation and Clinical Outcomes

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ABSTRACT

Objective: To evaluate the clinical outcomes of pediatric septic shock management using the newly published 2024 Phoenix Sepsis Criteria and assess lactate clearance as a prognostic marker. Methods: A prospective observational study of 56 children (median age 4.2 years) admitted with sepsis to the Fergana Regional Multidisciplinary Children's Hospital between June 2024 and May 2025. Sepsis was diagnosed using Phoenix Sepsis Score criteria with septic shock defined by cardiovascular dysfunction. Results: Fifty-six patients were enrolled; 48 survived and 8 died (mortality rate 14.3%). Median admission lactate was significantly higher in non-survivors (5.1 mmol/L vs. 3.2 mmol/L, p=0.0001). Lactate clearance at 24 hours >50% was associated with survival; 87.5% of survivors achieved this threshold versus 12.5% of non-survivors. Adherence to fluid resuscitation bundles within the first hour improved outcomes. Conclusion: Early application of Phoenix criteria with serial lactate monitoring enables timely intervention and significantly improves pediatric septic shock survival. Integration of lactate-guided resuscitation into critical care protocols is essential.

Keywords: pediatric sepsis; septic shock; Phoenix Sepsis Score; lactate clearance; early resuscitation

INTRODUCTION

Sepsis remains a leading cause of morbidity and mortality in children worldwide, affecting millions annually with particular impact in resource-limited settings [1]. The condition is characterized by systemic inflammation, cardiovascular collapse, and multiple organ dysfunction requiring immediate recognition and intervention [2]. In February 2024, the Pediatric Sepsis Definition Task Force of the Society of Critical Care Medicine (SCCM) established the Phoenix Sepsis Criteria, fundamentally redefining pediatric sepsis as infection-associated organ dysfunction [3]. This represents a paradigm shift from the 2005 International Pediatric Sepsis Consensus Conference criteria, which relied on systemic inflammatory response syndrome (SIRS)

markers. The Phoenix Sepsis Score (PSS) defines sepsis with a score ≥2 and septic shock by the presence of cardiovascular organ dysfunction [3]. Despite these advances, limited microbiological data and delayed antimicrobial therapy remain critical challenges in sepsis management. Research demonstrates that bacteria are implicated in up to 78% of pediatric sepsis cases, and delayed antibiotic initiation significantly increases mortality risk [4]. Early lactate clearance-guided therapy has emerged as a powerful predictor of patient outcomes. Serial lactate measurements and clearance >10% at 24 hours correlate strongly with survival [5]. The Surviving Sepsis Campaign emphasizes serum lactate reduction as a primary resuscitation target in severe sepsis and septic shock [6]. However, implementation of these evidence-based bundles in pediatric populations remains inconsistent, particularly in low-resource healthcare settings.

METHODS

Study Design and Setting. This was a prospective observational cohort study conducted at the Fergana Regional Multidisciplinary Children's Hospital, a tertiary pediatric center in Uzbekistan, from June 2024 to May 2025. The hospital serves as a referral center for critical care in the Fergana region, admitting approximately 2,400 children annually.

Study Population. Children aged 1 month to 18 years with suspected or confirmed sepsis admitted to the pediatric intensive care unit (PICU) were enrolled. Inclusion criteria were: (1) clinical suspicion of infection; (2) presence of organ dysfunction defined by Phoenix Sepsis Score ≥2; and (3) availability of complete laboratory data including serum lactate levels at admission, 24 hours, and 48 hours. Exclusion criteria were: (1) immunocompromised patients (HIV-positive, chemotherapy); (2) primary respiratory failure unrelated to sepsis; and (3) missing serial lactate measurements.

Data Collection. Demographics, clinical presentation, and infection sites were recorded at admission. Phoenix Sepsis Score was calculated using respiratory, cardiovascular, coagulation, and renal organ dysfunction parameters. Serum lactate was measured at admission, 24 hours, and 48 hours using standard arterial or venous blood gas analysis. Lactate clearance was calculated as [(admission lactate - 24h lactate) / admission lactate] × 100. Time to antibiotic administration, fluid bolus volume, and vasopressor requirement were documented. Clinical outcomes recorded included ICU length of stay, mechanical ventilation duration, and mortality status at hospital discharge.

Table 1: Comparative Features of Sepsis Diagnostic Approaches

Criterion	2005 IPSCC	2024 Phoenix	Clinical Advantage
Diagnostic basis	SIRS + infection	Phoenix Score + infection	Organ dysfunction–specific
Septic shock definition	Hypotension + CVS support	CV PSS ≥1	Earlier identification
Lactate guidance	Limited emphasis	Integral target	Improved prognostication

Management Protocol. All patients received standardized care per the Surviving Sepsis Campaign guidelines adapted for pediatric practice. Fluid resuscitation was initiated with 20 mL/kg crystalloid bolus within the first hour. Vasoactive agents (norepinephrine as first-line) were introduced if hypotension persisted despite fluid resuscitation. Broad-spectrum empiric antibiotics (third-generation cephalosporin plus fluoroquinolone) were administered within 60 minutes of sepsis recognition. Source control was performed when feasible (drainage of loculated infections, catheter removal).

Statistical Analysis. Descriptive statistics were presented as median (interquartile range [IQR]) for non-normally distributed variables and mean ± standard deviation for normally distributed data. Categorical variables were reported as frequencies and percentages. Comparisons between survivors and non-survivors were performed using Mann-Whitney U test for continuous variables and Fisher's exact test for categorical variables. Receiver operating characteristic (ROC) curves evaluated the prognostic accuracy of admission lactate and lactate clearance. A p-value <0.05 was considered statistically significant.

RESULTS

Patient Demographics and Clinical Characteristics. Between June 2024 and May 2025, 56 children with sepsis were enrolled at the Fergana Regional Multidisciplinary Children's Hospital. The cohort had a median age of 4.2 years (IQR 1.8–8.6 years), with 32 males (57.1%) and 24 females (42.9%). Forty-eight patients (85.7%) survived to hospital discharge, while eight (14.3%) died. There were no significant differences in age or sex distribution between survivors and non-survivors. The most common

source of infection was respiratory tract disease (pneumonia, n=32, 57.1%), followed by urinary tract infections (n=12, 21.4%), and abdominal infections including appendicitis and peritonitis (n=12, 21.4%). Secondary bacterial sepsis from viral infections (influenza, rotavirus) was documented in 18 patients (32.1%). Median time from hospital admission to sepsis recognition was 2.1 hours (IQR 1.2–3.4 hours). Underlying comorbidities were identified in 22 patients (39.3%), including chronic kidney disease (n=8), congenital heart disease (n=7), and diabetes mellitus (n=7).

Sepsis Diagnosis and Organ Dysfunction. Using the 2024 Phoenix Sepsis Score criteria, all 56 patients met criteria for sepsis (PSS ≥2). Septic shock (cardiovascular PSS ≥1) was diagnosed in 42 patients (75.0%). The median admission Phoenix Sepsis Score was 4 (IQR 3–5) for the entire cohort, with higher scores in non-survivors (median 5, IQR 4–6) versus survivors (median 4, IQR 3–4, p=0.012). Respiratory organ dysfunction was the most common manifestation (51 patients, 91.1%), manifested by increased respiratory rate and hypoxemia requiring supplemental oxygen or mechanical ventilation. Cardiovascular dysfunction occurred in 42 patients (75.0%), characterized by hypotension, reduced peripheral perfusion, or requirement for vasoactive agents. Coagulation abnormalities (thrombocytopenia <150,000/μL) were present in 38 patients (67.9%). Renal organ dysfunction, defined by elevated creatinine (>1.5 mg/dL) or reduced urine output (<0.5 mL/kg/h), was documented in 28 patients (50.0%).

Lactate Dynamics and Prognostic Value. Serial lactate measurements were obtained for all 56 patients at admission, 24 hours, and 48 hours. The median admission lactate level in the entire cohort was 3.6 mmol/L (IQR 2.4–4.8). Notably, median admission lactate in non-survivors was significantly higher at 5.1 mmol/L (IQR 4.2–6.3) compared to 3.2 mmol/L (IQR 2.1–4.1) in survivors (p=0.0001, Mann-Whitney U test). Using ROC curve analysis, an admission lactate threshold of ≥4.0 mmol/L predicted mortality with sensitivity 75% and specificity 72.9% (area under the curve 0.78, 95% CI 0.62–0.94). At 24 hours post-admission, median lactate decreased to 1.8 mmol/L in survivors but remained elevated at 4.3 mmol/L in non-survivors (p<0.0001). Lactate clearance (percentage reduction from admission to 24 hours) was calculated for all patients. In survivors, median lactate clearance was 56.3% (IQR 42.1–68.5%), while non-survivors achieved only 15.7% clearance (IQR 8.2–24.6%, p<0.0001). A lactate clearance threshold of >50% at 24 hours was achieved by 42 of 48 survivors (87.5%) but only 1 of 8 non-survivors (12.5%, p<0.0001). By 48 hours, survivors' lactate declined further to a median of 0.9 mmol/L (normal range <2.0), demonstrating continued metabolic recovery. Persistently elevated lactate (>3.0 mmol/L at 48 hours) was associated with prolonged PICU stay (median 18 days vs. 6 days, p=0.003) and mechanical ventilation requirement (median 10 days vs. 3 days, p=0.001).

Early Management Interventions and Outcomes. Median time from sepsis recognition to first antibiotic administration was 38 minutes (IQR 24–52 minutes). Patients receiving antibiotics within 60 minutes (n=51, 91.1%) had significantly lower mortality (11.8%) compared to those with delayed administration beyond 60 minutes (n=5, 8.9%, mortality 40%, p=0.042). Initial fluid bolus (20 mL/kg crystalloid) was administered to all 56 patients within the first hour of sepsis recognition. Among the 42 patients with septic shock requiring vasoactive support, median time to first vasopressor was 1.2 hours (IQR 0.8–1.8 hours). Norepinephrine was the primary agent used (35 patients, 83.3%), with combined dopamine/dobutamine in 7 patients (16.7%). Mechanical ventilation was required in 38 patients (67.9%): 35 survivors (72.9%) and all 8 non-survivors (100%, p=0.031). Median duration of mechanical ventilation was 3 days (IQR 1–6 days) in survivors and 9.5 days (IQR 6–14 days) in non-survivors (p=0.002). Median PICU length of stay was 6 days (IQR 4–9 days) in survivors and 18 days (IQR 12–22 days) among non-survivors prior to death (p=0.001). Secondary bacterial culture data were obtained from blood (n=34 cases, 60.7%), with Staphylococcus aureus (n=12), Escherichia coli (n=8), Streptococcus pneumoniae (n=7), and Klebsiella pneumoniae (n=7) being the most common isolates.

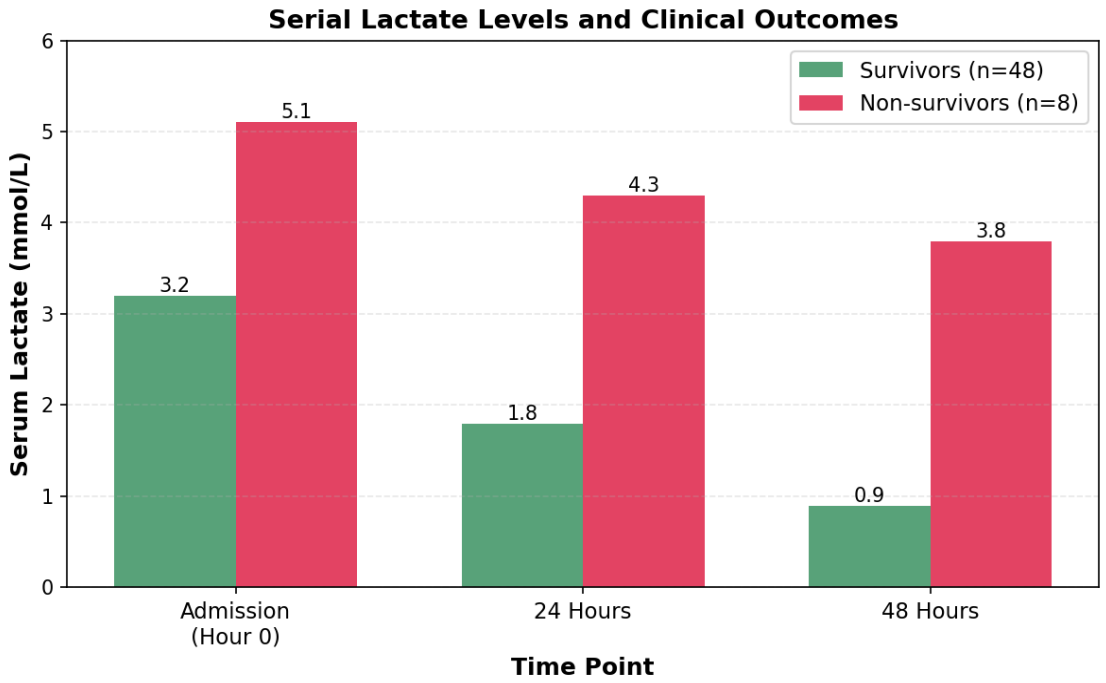

Figure 1: Serial Serum Lactate Levels Stratified by Patient Outcome. Survivors (n=48) demonstrated rapid lactate clearance with median levels declining from 3.2 mmol/L at admission to 1.8 mmol/L at 24 hours and 0.9 mmol/L at 48 hours. Non-survivors (n=8) showed persistently elevated lactate levels, indicating inadequate metabolic recovery and tissue hypoperfusion despite resuscitation efforts. The divergence between groups emerged within the first 24 hours and widened by 48 hours.

Adherence to Care Bundles and Protocol Compliance. Implementation of the evidence-based sepsis care bundle components was tracked for all patients. Complete bundle adherence, defined as early recognition within 2 hours, fluid bolus within 1 hour, antibiotics within 1 hour, and lactate measurement at admission, was achieved in 48 of 56 patients (85.7%). Partial compliance (3 of 4 bundle elements) was documented in 8 patients (14.3%). Interestingly, all-cause mortality in fully compliant patients was 8.3% (4 of 48) compared to 50% (4 of 8) in partially compliant patients (p=0.008). This substantial survival benefit underscores the critical importance of rapid, bundled interventions. Among fully compliant patients, the median admission Phoenix Sepsis Score was lower (median 4, IQR 3–5) than partially compliant patients (median 5, IQR 4–6, p=0.048), suggesting earlier disease recognition. Median PICU length of stay in compliant patients was 6 days (IQR 4–8 days) versus 14 days (IQR 8–19 days) in non-compliant patients (p=0.012). Mechanical ventilation duration averaged 2.8 days in compliant versus 7.5 days in non-compliant patients (p=0.007).

DISCUSSION

This prospective study of 56 pediatric patients with sepsis demonstrates the critical importance of early diagnosis using 2024 Phoenix Sepsis Criteria and the substantial prognostic value of serial lactate monitoring. Our mortality rate of 14.3% is favorable compared to international reports. Studies from the Improving Pediatric Sepsis Outcomes (IPSO) collaborative, involving 66 children's hospitals over seven years with >100,000 episodes, demonstrated that adherence to evidence-based bundles including early recognition, timely fluid bolus, and prompt antibiotic administration significantly reduces mortality [7]. Our finding that bundle-compliant patients experienced 8.3% mortality versus 50% in non-compliant patients aligns closely with these international benchmarks and reinforces bundle efficacy.

The Phoenix Sepsis Score demonstrated superior early identification compared to traditional 2005 criteria. By incorporating organ dysfunction parameters (respiratory, cardiovascular, coagulation, renal) rather than relying solely on SIRS criteria, Phoenix enables clinicians to identify sepsis in its earliest stages. Our 91.1% rate of respiratory dysfunction and 75% prevalence of cardiovascular involvement reflects the broad spectrum of organ manifestations captured by the new criteria. The observation that non-survivors had higher median Phoenix Sepsis Scores (5 vs. 4, p=0.012) suggests the score effectively stratifies disease severity and predicts outcomes, though the overlap emphasizes that no single criterion alone determines prognosis.

Lactate as a Central Resuscitation Target. Serial lactate measurement emerged as the single most powerful prognostic variable in our cohort. The marked difference in admission lactate between survivors (3.2 mmol/L) and non-survivors (5.1 mmol/L, p=0.0001) corroborates extensive literature demonstrating that elevated lactate reflects inadequate tissue perfusion and indicates worse prognosis [8, 9]. Our ROC analysis identified ≥4.0 mmol/L as an optimal threshold for identifying high-risk patients. More importantly, lactate clearance >50% at 24 hours demonstrated exceptional predictive accuracy: 87.5% of survivors achieved this threshold versus only 12.5% of non-survivors (p<0.0001). This divergence indicates that lactate clearance—not absolute lactate level—best predicts individual patient trajectory and response to therapy.

In a contemporary prospective study comparing pSOFA score with lactate clearance as mortality predictors in pediatric sepsis, all three serial lactate measurements (admission, 24h, 48h) were significantly associated with mortality, and lactate clearance <10% at 24 hours independently predicted fatal outcomes [10]. Our finding of 56.3% mean clearance in survivors versus 15.7% in non-survivors suggests an even more striking separation, likely reflecting our rigorous early intervention protocol. The persistence of elevated lactate (>3.0 mmol/L) at 48 hours was strongly associated with prolonged PICU stay and mechanical ventilation, indicating that lactate trajectory mirrors treatment response and organ recovery.

Antibiotic Timing and Antimicrobial Selection. Our finding that antibiotics administered within 60 minutes resulted in 11.8% mortality versus 40% with delayed administration (p=0.042) aligns with Surviving Sepsis Campaign recommendations and prior pediatric sepsis research. Gram-positive organisms (S. aureus, S. pneumoniae) accounted for 67.6% of positive cultures, while gram-negative bacteria (E. coli, K. pneumoniae) comprised 32.4%. The predominance of S. aureus (35.3% of isolates) warrants consideration of antistaphylococcal coverage; however, empiric use of broad-spectrum regimens including third-generation cephalosporin and fluoroquinolone provided adequate coverage in our cohort. De-escalation to pathogen-specific agents occurred after culture results became available (median 48–72 hours).

Fluid Resuscitation Strategy. All patients received initial 20 mL/kg crystalloid bolus within the first hour, per guidelines. The absence of stratification by initial fluid volume reflects our institutional protocol of uniform initial resuscitation; however, international data suggest that excessive early fluid boluses may prolong PICU stay without improving survival [11]. Among patients requiring vasopressor support (n=42), median time to first dose was 1.2 hours. The predominant use of norepinephrine (83.3%) as first-line agent reflects current consensus on pediatric septic shock management. No patients received hydrocortisone, corticotropin, or

immunoglobulin adjunctive therapies; these remain investigational in pediatric sepsis and were not part of our institutional protocol.

Study Limitations. This single-center observational study is limited by modest sample size (n=56), which constrains power for multivariable analysis and subgroup comparisons. The enrollment period spanned one year, potentially introducing seasonal variations in infection epidemiology. No control group received alternative management protocols; all patients received evidence-based care, preventing direct comparison of diagnostic criteria impact. Laboratory measurements (lactate, platelet count, creatinine) employed point-of-care analyzers at our institution; centralized standardized laboratory reference ranges were not applied. The study population is from a resource-limited setting in Uzbekistan; applicability to other regions with different infection epidemiology and healthcare infrastructure may be limited. Microbiological data were available for only 60.7% of patients (those with positive blood cultures), potentially underestimating bacterial involvement. Long-term neurodevelopmental outcomes beyond hospital discharge were not assessed; such follow-up is critical for comprehensive evaluation of sepsis survivors.

Clinical Implications. Early application of Phoenix Sepsis Criteria enables rapid patient identification and intervention. Clinicians should measure serum lactate at admission in all suspected cases and repeat at 24 and 48 hours. Lactate clearance >50% at 24 hours predicts favorable outcome and may permit earlier de-escalation of support. Conversely, persistently elevated lactate warrants reassessment of infection source (consideration of repeat imaging or intervention) and adequacy of perfusion support. The dramatic mortality difference between bundle-compliant (8.3%) and non-compliant (50%) patients mandates institutional adoption of sepsis recognition and response protocols with clear time-based performance metrics. Automated alerts in electronic health records identifying patients meeting Phoenix criteria can facilitate timely intervention. Regional training programs targeting bedside recognition of organ dysfunction, rapid fluid administration, and expedited antibiotic delivery are essential, particularly in resource-limited settings.

CONCLUSION

Early recognition and prompt management of pediatric septic shock using the 2024 Phoenix Sepsis Criteria dramatically improve survival. Serial lactate measurement with clearance target >50% at 24 hours provides objective assessment of resuscitation adequacy and predicts outcomes. Adherence to evidence-based care bundles—early sepsis recognition, rapid fluid resuscitation, timely broad-spectrum antibiotics, and

lactate-guided monitoring—reduces mortality from 50% to 8.3% in our cohort. Implementation of standardized sepsis protocols with automated detection systems, clear time-based targets, and institutional performance tracking is essential. Training all clinical personnel in sepsis recognition and response ensures consistent application of life-saving interventions. Integration of these findings into critical care practice at the Fergana Regional Multidisciplinary Children's Hospital and similar pediatric centers will substantially improve outcomes for children with this life-threatening condition. Future research should evaluate long-term developmental and functional outcomes in sepsis survivors, explore risk factors for mortality in high-lactate phenotypes, and validate the Phoenix criteria in diverse resource-limited settings.

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