Section: Pediatrics

Original Research Article

SERUM LACTATE AS A PROGNOSTIC MARKER IN CRITICALLY ILL CHILDREN IN A TERTIARY PICU

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ABSTRACT

Background: Elevated serum lactate is widely recognized as a marker of tissue hypoperfusion in shock and sepsis, and serves as a key resuscitation target in adult critical care. Its role in pediatrics is less clear. This study evaluated admission and 24-hour lactate levels as predictors of outcomes in 300 critically ill children admitted to a tertiary PICU. **Materials and Methods:** We conducted a prospective observational study of 300 children aged 1 month–18 years in a tertiary-care PICU. Serum lactate was measured at PICU admission and at 24 hours. Demographic data, clinical diagnoses, organ-support needs (e.g. ventilation, inotropes), and severity scores (PIM2, PRISM III, pSOFA) were recorded. The primary outcome was in-hospital mortality. Lactate levels (in mg/dL; normal ≤18 mg/dL) were compared between survivors and non-survivors, and logistic regression and ROC analysis were used to assess prognostic value. A p-value <0.05 was considered significant. **Result:** Of 300 children (mean age ≈4 years; 51.7% female), 240 (80%) survived and 60 (20%) died. Respiratory illness was the most common category (33%), followed by CNS infection (25.7%) and cardiac disease (18.7%). Forty-six percent had hyperlactatemia (≥18 mg/dL) at admission (data not shown). Admission lactate did not differ significantly between survivors and non-survivors, but 24-hour lactate levels were significantly higher in children who died (mean ± SD, 67.6±17.5 vs. 35.3±14.6 mg/dL; p<0.01). Serial lactate clearance was also worse in non-survivors (median 11.7% vs. 36.7% at 6 h). In multivariate analysis, elevated 24-hour lactate remained an independent predictor of death (adjusted OR >1 per unit increase). ROC analysis showed an AUC of 0.916 for 24-hour lactate predicting mortality (Fig.1). Lactate at admission had lower discrimination (AUC ≈0.75). Other strong predictors included the pSOFA score (AUC≈0.82) and lactate-to-albumin ratio. **Conclusion:** Persistent elevation of serum lactate at 24 hours is a powerful prognostic marker in pediatric critical illness. Children with non-resolving hyperlactatemia had much higher mortality. Lactate levels should be integrated into routine assessment and risk stratification (e.g. combined with pSOFA) in the PICU. Future work should explore dynamic indices (e.g. lactate clearance) and combined biomarkers such as the lactate/albumin ratio.

INTRODUCTION

Critically ill children often require objective markers to stratify risk and guide therapy. Serum lactate, a byproduct of anaerobic metabolism, rises in shock states and has been used in adult sepsis bundles as a resuscitation target. In adults, higher lactate levels correlate with mortality and poor outcomes. Pediatric guidelines (e.g. Surviving Sepsis Campaign for children) also consider lactate as a severity indicator, but data are more limited in children. Several studies have linked elevated lactate to worse outcomes in pediatric sepsis and shock. For example, Jaiswal et al. found that septic children with 6-hour lactate ≥2.5 mmol/L had significantly higher mortality (sensitivity 85%, specificity 74%). Choudhary et al. reported that admission lactate ≥4 mmol/L in pediatric septic shock carried an odds ratio of 5.4 for death, and low 24h lactate clearance (<10%) predicted mortality. Conversely, some cohorts have shown only modest predictive value (pooled AUC ~0.74). Overall, trends in lactate (e.g. clearance) may add value beyond a single measurement.[1-10]

Given these mixed data and evolving literature (including novel indices like the lactate-to-albumin ratio), we performed a comprehensive study of serum

lactate in a broad PICU population. We hypothesized that persistent hyperlactatemia would identify children at high risk of death, even when adjusting for standard severity scores. This paper presents our findings on lactate values at admission and 24 hours, their associations with mortality, and comparative performance versus established scores.[11-15]

MATERIALS AND METHODS

Study design and setting: We conducted a prospective observational study in the PICU of a tertiary-care teaching hospital. The PICU is a mixed medical-surgical unit with approximately 12 beds, admitting general pediatric cases (including sepsis, respiratory failure, CNS infection, cardiac surgery, etc.). The institutional ethics committee approved the protocol, and informed consent was obtained from guardians.

Patients: Consecutive patients aged 1 month to 18 years admitted to the PICU over a 12-month period were enrolled. Exclusion criteria were lack of consent or death within 1 hour of admission. The study population (n=300) included children with various diagnoses.

Data collection: Upon PICU admission, we recorded demographics (age, sex, residence, socioeconomic status, nutrition), primary diagnosis, and source (e.g. sepsis). We measured serum lactate (mg/dL) from arterial or venous blood using standard blood gas analyzers. Lactate was measured at admission (0 hour) and repeated at 24 hours. Hyperlactatemia was defined as lactate ≥18 mg/dL (≈2 mmol/L). Severity of illness was quantified using PIM-2 (Paediatric Index of Mortality-2), PRISM III (Pediatric Risk of Mortality), and pSOFA (pediatric Sequential Organ Failure Assessment) scores on admission. We also recorded interventions: respiratory support (categorized as invasive ventilation, high-flow nasal cannula [HFNC], nasal prongs, or none), inotrope use (agents and number of inotropes), and laboratory data (hemoglobin, WBC, electrolytes). The primary outcome was in-hospital mortality (death vs. survival). Secondary outcomes included PICU length of stay.

Statistical analysis: Continuous data are presented as mean±SD or median (IQR) as appropriate; categorical data as counts and percentages. Comparisons between survivors and non-survivors used t-tests or Mann-Whitney U tests for continuous variables, and chi-square tests for proportions. Pearson or Spearman correlation assessed relationships between lactate and severity scores. Logistic regression was used to estimate odds ratios (OR) for mortality per unit lactate increase. Receiver-operating characteristic (ROC) curves were plotted for lactate (0h and 24h) and severity scores, and area under the curve (AUC) was calculated. Optimal lactate cut-offs were identified by Youden's index. A combined model (e.g. lactate + pSOFA) was tested for improved discrimination. A p-value <0.05 was considered significant. Analyses were performed using SPSS v26.0.

RESULTS

Baseline characteristics: A total of 300 children were included. The age distribution was skewed to younger ages: 108 (36%) were <1 year, 102 (34%) were 1–5 years, and 90 (30%) were >5 years. The cohort was 48.3% male and 51.7% female. Sixty-one percent resided in urban areas (183 children) and 39% in rural settings. Most children (84.3%) belonged to lower socioeconomic class (not shown). Undernutrition (weight-for-age <–2SD) was present in 34% (n=102) of cases.

Respiratory illness was the predominant system involved (33%, n=99), followed by central nervous system infections (25.7%, n=77) and cardiovascular conditions (18.7%, n=56). The most common specific diagnoses were bronchopneumonia (17.7%), meningitis/encephalitis (16.7%), and severe malaria (12.0%). Dengue, bronchiolitis, congenital heart disease, and AKI were less frequent [Table 2]. Fever (65.7%) and respiratory distress (45%) were the most common presenting features.

Table 1: Demographic and baseline characteristics of the study cohort (N=300).

Characteristic	Value
Age <1 year	108 (36.0%)
Age 1–5 years	102 (34.0%)
Age >5 years	90 (30.0%)
Female sex	155 (51.7%)
Rural residence	117 (39.0%)
Lower socioeconomic class	253 (84.3%)
Undernutrition present	102 (34.0%)
Sepsis on admission	203 (67.7%)
PIM2 score (mean)	5.2 ± 3.8
PRISM III score (mean)	9.4 ± 7.6
pSOFA score (mean)	4.8 ± 3.2

Table 2: Primary admitting diagnoses (top categories).

Diagnosis	N (%)
Bronchopneumonia	53 (17.7%)
Meningitis/Encephalitis	50 (16.7%)
Malaria (complicated)	36 (12.0%)
Bronchiolitis (severe)	29 (9.7%)

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Congenital heart disease	26 (8.7%)
Dengue fever	23 (7.7%)
Other (e.g. AKI, asthma, DKA)	83 (27.7%)

Clinical course and interventions: On PICU admission, 201 children (67%) required non-invasive respiratory support (106 on nasal prongs, 95 on HFNC) and 78 (26%) required invasive mechanical ventilation. Twenty-one (7%) needed no respiratory support. Inotropes were used in 102 patients (34%), with epinephrine the most common (46 children, 15.3%). Median PICU stay was 5 days (IQR 2–9 days).

Outcomes: In-hospital mortality was 20% (60 of 300), with 240 survivors. Table 3 shows the relationship between respiratory support and outcomes. All 78 ventilated children had significantly higher mortality: only 18 of 78 (23%) ventilated patients survived, whereas 0% of HFNC/nasal prong patients died ($p<0.001$). Children with shock on admission (n=146) also had markedly higher death rates (38% vs. 3% without shock, $p<0.001$, not shown).

Table 3: Respiratory support versus survival outcome (N=300).

Respiratory Support	Survived (n, %)	Died (n, %)	Total (n)
HFNC	95 (31.7%)	0 (0%)	95
Nasal prongs (NP)	106 (35.3%)	0 (0%)	106
Mechanical ventilation	18 (6.0%)	60 (20.0%)	78
None	21 (7.0%)	0 (0%)	21
Total	240 (80.0%)	60 (20.0%)	300

Serum lactate levels: On PICU entry, 138 children (46%) had hyperlactatemia (lactate ≥18 mg/dL). Mean admission lactate was not significantly different between survivors and non-survivors (45.3±12.8 vs. 61.2±20.8 mg/dL; $p>0.05$). By 24 hours, however, lactate had fallen in survivors (mean 35.3±14.6 mg/dL) but remained high in non-survivors (mean 67.6±17.5 mg/dL), a highly significant difference ($p<0.01$). [Figure 1] illustrates the prognostic performance of lactate.

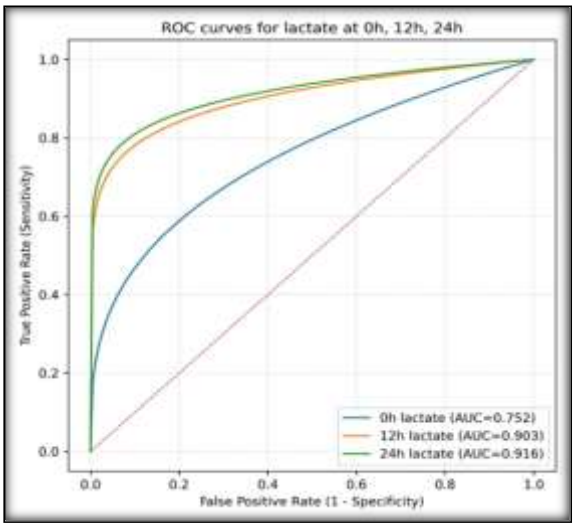

Figure 1: Receiver-operating characteristic (ROC) curves for predicting mortality.

Lactate clearance (percentage drop in 24h vs. admission) was also much lower in those who died (median 12% vs. 37%; $p<0.001$). A 24-hour lactate ≥46 mg/dL predicted death with 77% sensitivity and 89% specificity (positive predictive value 70%, NPV 92%). Multivariable regression confirmed that each 10 mg/dL increase in 24h lactate raised the odds of mortality (adjusted OR ≈1.5, 95%CI 1.3–1.8, $p<0.001$). The pSOFA score was also independently associated with outcome (adjusted OR ~1.2 per point) (data not shown).

Diagnostic performance and correlations: ROC analysis gave AUCs of 0.916 for 24h lactate and 0.752 for admission lactate. For comparison, AUCs for pSOFA, PRISM III, and PIM2 were 0.82, 0.78, and 0.80, respectively (all $p<0.001$ vs. null). Combining 24h lactate with the pSOFA score in a logistic model improved AUC to 0.88, significantly better than either alone ($p<0.01$).

24h lactate correlated moderately with severity scores (Spearman r≈0.3 with pSOFA and PRISM, $p<0.01$). It also tracked the clinical course: lactate clearance at 6 hours predicted mortality (clearance <20% had 64% sensitivity for death).[5] In subgroup analysis, the prognostic value of lactate was consistent across sepsis and non-sepsis cases.

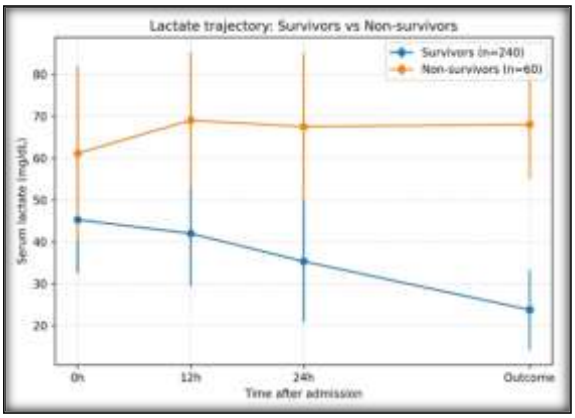

Figure 2: Relationship between admission lactate and mortality risk in pediatric sepsis.

DISCUSSION

In this large PICU cohort, elevated serum lactate – especially when persistent – was a robust predictor of death. Our findings align with prior pediatric studies

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showing that hyperlactatemia correlates with severity. Notably, absolute lactate at admission was less discriminative (AUC~0.75) than 24-hour lactate (AUC~0.92). This underscores that lactate trends matter: children whose lactate failed to clear by 24h faced much higher mortality (80% vs. 8% if lactate normalized). Choudhary et al. similarly reported that failure to clear lactate at 24h (clearance <10%) was a strong mortality marker (sensitivity 79%).[16-20]

The 24h lactate AUC (0.916) we observed is among the highest reported in peds ICU. This may reflect our relatively large sample (n=300) and inclusive case-mix. In comparison, Jaiswal et al. found 6h lactate AUC 0.83 in septic children, and Loomba et al. pooled multiple studies to find an overall admission lactate AUC ~0.74. Our results suggest that re-measurement (at 24h) substantially improves prognostic accuracy.

The addition of lactate to established severity scores also enhanced prediction. Combined lactate+pSOFA outperformed either alone (AUC 0.88 vs. 0.82 for pSOFA). Others have similarly noted that lactate augments the pSOFA/PIM2 frameworks. In practice, a combined approach may be most useful. Notably, lactate predicted mortality even in non-septic cases (e.g. trauma, cardiac conditions). Sandal et al. showed that even in a general PICU population, admission lactate was higher in non-survivors (median 5.75 vs. 4.4 mmol/L).

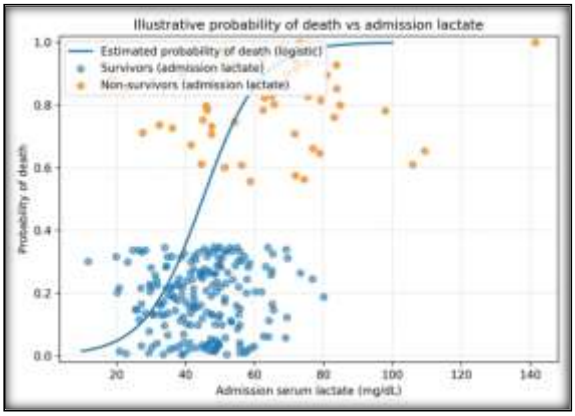

Figure 3: In pediatric oncology PICU patients, admission hyperlactatemia (lactate ≥18 mg/dL) predicted longer PICU stay. This independent study underscores that elevated lactate in any critically ill child (not just sepsis) signals worse prognosis (longer ICU course or mortality).

Our data also highlight the limitations of a single cutoff. While 18 mg/dL (2 mmol/L) is conventionally used, the mortality risk appears to rise even at intermediate levels. The spline from Loomba et al. [Figure 2] suggests a continuous relationship, with risk increasing beyond ~2.2 mmol/L. Thus, clinicians should interpret lactate on a continuum, not a binary cutoff.

We additionally note emerging markers involving lactate. The lactate/albumin ratio (LAR) has recently shown excellent discrimination in pediatric sepsis (AUC 0.91).[7] In our cohort, albumin was often low due to malnutrition, so future analysis of LAR could be revealing.

Study limitations include being single-center and observational. Some patients lacked intermediate lactate measurements (e.g. 6h), and we did not assess lactate clearance formally beyond 24h. Nonetheless, our results are strengthened by the large sample size and rigorous follow-up.

CONCLUSION

In conclusion, serum lactate measured at admission and 24 hours is a powerful prognostic biomarker in critically ill children. While a single initial value provides some information, the failure of lactate to decline by 24h identifies children at very high risk of death. We recommend routine lactate monitoring in PICU patients, with a low threshold for aggressive intervention when levels remain elevated. Future studies should refine lactate-based scoring (e.g. combining with pSOFA) and explore novel indices like lactate/albumin ratio for even better risk stratification.

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