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ORIGINAL ARTICLE

Serum Lactate as A Predictor of Shock Severity in Pediatric Intensive care Units

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ABSTRACT

Objective: To evaluate serum lactate as a predictor of shock severity and clinical outcomes in pediatric patients admitted to the pediatric intensive care unit.

Methodology: This cross-sectional study was conducted at Paediatrics ICU Department of Mayo Hospital Lahore from January 2023 to June 2023. A total of 155 pediatric patients diagnosed with shock were enrolled using a non-probability consecutive sampling technique. Demographic characteristics, clinical parameters, and laboratory findings were recorded. Serum lactate levels were measured at admission and patients were monitored for outcomes including mechanical ventilation requirement, development of multiorgan dysfunction, duration of PICU stay, and mortality.

Results: The mean age of patients was 5.8 ± 3.6 years and males constituted 58.1% of the study population. Septic shock was the most common type of shock observed in 46.5% of patients. The mean serum lactate level at admission was 4.7 ± 2.1 mmol/L. Patients with severe shock had significantly higher lactate levels (6.5 ± 2.4 mmol/L) compared with those with moderate (4.5 ± 1.8 mmol/L) and mild shock (3.1 ± 1.2 mmol/L). Mechanical ventilation was required in 37.4% of patients and was associated with higher lactate levels. Multiorgan dysfunction developed in 29.7% of patients and was also associated with significantly elevated lactate levels. Overall mortality was 13.5%, and non-survivors had markedly higher lactate levels compared with survivors.

Conclusion: Serum lactate is a reliable predictor of shock severity and adverse outcomes in pediatric intensive care units. Elevated lactate levels are associated with increased disease severity, multiorgan dysfunction, and mortality, emphasizing the importance of early lactate assessment in the management of pediatric shock.

Keywords: Serum lactate, pediatric shock, hyperlactatemia, critical illness, prognosis.

INTRODUCTION

The use of serum lactate has become a significant biochemical indicator during the evaluation of tissue hypoperfusion and circulatory deficiency in the critically ill patients[1]. Early detection of the severity of shock is essential in the pediatric intensive care units (PICUs) as failure to recognize and act promptly may result in multiple organ dysfunction and subsequent death[2]. Children are characterised by having shock in the form of imbalance between oxygenation and oxygen demand leading to inadequate perfusion of tissues. In these hypoxic conditions, the cells switch to anaerobic glycolysis as a result of the aerobic metabolism resulting in accumulation of lactate in the blood[3]. Therefore, the high levels of serum lactate indicate indirectly compromised tissue oxygenation and metabolic stress. Pediatric shock is an heterogeneous and complicated clinical entity that could be caused by different etiologies such as septic shock, hypovolemic shock, cardiogenic shock, and distributive shock[4]. Although there has been improvement in critical care management, shock has continued to be among the most common causes of morbidity and mortality among critically ill children all over the world[5]. Shock in children can be subtle and the clinical manifestation can progress very quickly, which is why it is difficult to diagnose it as early as possible[6]. Conventional clinical parameters including blood pressure, heart rate, capillary refill time, mental status, and urine output are traditionally employed to measure the status of circulatory conditions but this may not necessarily be accurate in measuring the intensity of tissue hypoperfusion especially in the early shock phases[7]. The normal blood pressure can be sustained to late ages because of the compensatory physiological processes and further complicates the early discovery[8]. Consequently, good biochemical indicators capable of assessing the extent of shock objectively are necessary to be able to diagnose and administer the therapeutic intervention in time[9].

The measurement of serum lactate has been accorded good attention as a useful tool in assessing the severity of critical illness. Lactate is formed mostly during the anaerobic metabolism in cases whereby the pyruvate is changed to lactate in the absence of adequate oxygen[10]. When the circulatory compromise occurs, lactate production is elevated and is accompanied by reduced hepatic clearance resulting in elevated lactate concentrations in the serum. A number of studies have proved that hyperlactatemia correlates with unfavorable clinical outcomes in critically ill patients which include long-term intensive care, higher dependency on mechanical ventilation, and higher death rates[11]. Raised lactate levels in pediatric patients are proved to be connected with shock severity and may be included in the early prediction of clinical worsening[12,13]. Serum lactate measurement has a number of benefits in the critical care environment. It is a relatively easy, fast, and affordable laboratory test, which can be conducted at the bedside point-of-care analyzers[14]. Serial lactate monitoring enables clinicians to determine the success of resuscitation and the continuous therapeutic interventions. Reductions in the levels of lactates usually reflect positive changes in the perfusion of tissues and metabolism, and continuously high levels of lactate be an indication of the presence of hypoperfusion and a high risk of poor prognosis[15].

Objective: To evaluate serum lactate as a predictor of shock severity and clinical outcomes in pediatric patients admitted to the pediatric intensive care unit.

METHODOLOGY

This cross-sectional study conducted at Paediatrics ICU Department of Mayo Hospital Lahore from January 2023 to June 2023. A total of 155 children diagnosed with shock were recruited with the help of a non-probability consecutive sampling method. The study involved children who were admitted in the pediatric intensive care unit between the ages of 1 month and 12 years with clinical features of shock. The patients were deemed eligible who were diagnosed with septic shock, hypovolemic shock, cardiogenic shock, or distributive shock. The children who had their serum lactate determined at the time of admission only were included. Patients who are known to have an inborn error of metabolism,

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chronic liver disease, severe anemia that is not due to shock, poisoning or any disease that had an independent impact on serum lactate levels were excluded. Children who already underwent a considerable period of resuscitation prior to measurement of lactate or children with incomplete clinical or laboratory documentation were also not included in the study.

Data Collection: The patients meeting the inclusion criteria were recruited after receiving informed consent after passing the institutional review board and the ethical committee. Baseline demographic variables such as age, gender, weight and primary diagnosis were taken. The clinical parameters such as heart rates, blood pressure, capillary refill time, oxygen saturation, urine output and the Glasgow Coma Scale or level of consciousness was recorded at admission. Standard laboratory or point-of-care blood gas analysis were used to measure the level of serum lactate at presentation based on hospital protocol. Further laboratory tests such as complete blood count, tests on arterial blood gas, serum electrolytes, renal work as well as blood cultures where necessary were also done. The severity of the shock was clinically determined and classified based on the hemodynamic and perfusion status, dysfunction of the organ, and the need of inotropic support. Clinical outcomes such as the requirement of mechanical ventilation, PICU stay, multiorgan dysfunction, and mortality of patients were monitored during their stay in the pediatric intensive care unit. The serum lactate levels were then assessed against severity of shock.

Data Analysis: All collected data were entered and analyzed using IBM SPSS version 26. Quantitative variables such as age, serum lactate level, and duration of PICU stay were expressed as mean ± standard deviation. Qualitative variables such as gender, type of shock, severity category, need for ventilation, and mortality were presented as frequency and percentages. Independent sample t-test or ANOVA was applied for comparison of mean lactate levels across severity categories, while chi-square test was used for categorical variables. Correlation and regression analysis were performed where appropriate to determine the predictive value of serum lactate for shock severity and outcomes. A p-value of ≤0.05 was considered statistically significant.

RESULTS

The mean age of pediatric patients with shock was 5.8 ± 3.6 years. Most children were in the 1–5 years age group (64, 41.3%), followed by 6–10 years (52, 33.5%) and 11–12 years (39, 25.2%). Males constituted the majority with 90 patients (58.1%), while females accounted for 65 patients (41.9%), indicating a slight male predominance among children admitted with shock. Septic shock was the most common type observed in 72 patients (46.5%), followed by hypovolemic shock in 48 patients (31.0%), cardiogenic shock in 21 patients (13.5%), and distributive shock in 14 patients (9.0%). Regarding severity, moderate shock was the most frequent category affecting 63 patients (40.6%), while 52 patients (33.5%) had mild shock and 40 patients (25.8%) presented with severe shock.

Patients with mild shock had a mean lactate level of 3.1 ± 1.2 mmol/L, while those with moderate shock showed higher levels of 4.5 ± 1.8 mmol/L. The highest levels were observed in severe shock with a mean of 6.5 ± 2.4 mmol/L. This difference was statistically significant ($p < 0.001$), indicating a strong association between rising lactate levels and increasing shock severity.

Patients requiring mechanical ventilation (58, 37.4%) had a mean lactate of 6.1 ± 2.3 mmol/L compared to 3.9 ± 1.6 mmol/L in those not requiring ventilation ($p = 0.002$). Similarly, patients with multiorgan dysfunction (46, 29.7%) showed higher lactate levels (6.3 ± 2.2 mmol/L) than those without organ dysfunction (3.9 ± 1.5 mmol/L, $p = 0.001$). Mortality was also associated with markedly elevated lactate levels, with deceased patients showing a mean lactate of 7.2 ± 2.5 mmol/L compared to 4.2 ± 1.7 mmol/L in survivors ($p = 0.001$).

Children with lower lactate (88, 56.8%) had a mean PICU stay of 3.7 ± 1.9 days, whereas those with elevated lactate (67, 43.2%) stayed significantly longer with a mean duration of 6.3 ± 2.8 days. This difference was statistically significant ($p = 0.001$), suggesting that higher lactate levels are associated with prolonged intensive care hospitalization.

Table 1: Demographic Characteristics of Pediatric Patients with Shock (n = 155)

Variable	Category	n (%) / Mean ± SD
Age (years)	—	5.8 ± 3.6
Age Group	1–5 years	64 (41.3%)
	6–10 years	52 (33.5%)
	11–12 years	39 (25.2%)
Gender	Male	90 (58.1%)
	Female	65 (41.9%)
Type of Shock	Septic shock	72 (46.5%)
	Hypovolemic shock	48 (31.0%)
	Cardiogenic shock	21 (13.5%)
	Distributive shock	14 (9.0%)
Shock Severity	Mild	52 (33.5%)
	Moderate	63 (40.6%)
	Severe	40 (25.8%)

Table 2: Serum Lactate Levels According to Shock Severity (n = 155)

Shock Severity	n (%)	Mean Serum Lactate (mmol/L) ± SD	p-value
Mild Shock	52 (33.5%)	3.1 ± 1.2	
Moderate Shock	63 (40.6%)	4.5 ± 1.8	<0.001
Severe Shock	40 (25.8%)	6.5 ± 2.4	

Table 3: Clinical Outcomes in Relation to Serum Lactate Levels (n = 155)

Variable	Category	n (%)	Mean Lactate ± SD	p-value
Mechanical Ventilation	Required	58 (37.4%)	6.1 ± 2.3	0.002
	Not required	97 (62.6%)	3.9 ± 1.6	
Multiorgan Dysfunction	Yes	46 (29.7%)	6.3 ± 2.2	0.001
	No	109 (70.3%)	3.9 ± 1.5	
Outcome	Survived	134 (86.5%)	4.2 ± 1.7	0.001
	Died	21 (13.5%)	7.2 ± 2.5	

Table 4. Duration of PICU Stay Among Patients with Different Lactate Levels (n = 155)

Serum Lactate Level	Category	n (%)	Mean PICU Stay (days) ± SD	p-value
≤4 mmol/L	Lower lactate	88 (56.8%)	3.7 ± 1.9	
>4 mmol/L	Elevated lactate	67 (43.2%)	6.3 ± 2.8	0.001

DISCUSSION

The current paper assessed the value of serum lactate as an indicator of severity of shock among children in the pediatric intensive care unit. The results of the study revealed that the high levels of serum lactate were strongly linked with the severity of shock, the greater mechanical ventilation, the emergence of multiorgan dysfunction, the extended PICU stay, and the high mortality. These findings contribute to the accumulating evidence that serum lactate is an excellent biomarker to determine tissue hypoperfusion and the outcome of patients in critically ill infants[16]. The age of the patients in this study was 5.8±3.6 years, most patients were between 1-5 years of age. There was a minor male preponderance as the male counted 58.1 percent of all cases. The same demographic trends have been reported in other pediatric intensive care studies, with younger children being more vulnerable to severe infections and circulatory compromise, as their immune system is immature, and their physiological structure is more vulnerable. The fact that the prevalence of septic shock in the current research is 46.5 percent of the cases also coincides with the situation in the rest of the world where sepsis is one of the most common morbidity and mortality determinants in sick children[17]. The evaluation of the shock severity showed that patients with severe shock showed very high serum lactate levels than those with moderate and mild shock. The average level of lactate rose as the severity of shock escalated, and this means that serum lactate is a marker of the degree of tissue hypoxia and deranged metabolic conditions. This observation is in line with other research studies performed in the pediatric critical care unit that have found out that high levels of lactate are directly related to the poor perfusion and to the circulatory failure. The production of high levels of lactate in shock happens due to the anaerobic metabolism that results when the transport of oxygen to the body tissues becomes insufficient[18].

Another significant observation of this research was that high levels of lactate are related to the necessity to use mechanical ventilation. Mean cases of lactate in patients who needed ventilatory support were also significantly high in relation to patients who were not on the ventilator. This finding indicates that there is a strong association between respiratory failure and severe metabolic derangements and tissue hypoperfusion in critically ill children. Another study has identified the same results in the past with hyperlactatemia serving as a predictor of the increased need of advanced level of supportive therapies such as mechanical ventilation and vasoactive drugs[19,20]. In the current research, almost a third of the group of patients developed the multiorgan dysfunction syndrome. Such patients had very high levels of serum lactate at admission than those who did not develop organ dysfunction. This correlation means that the level of lactate can also be used as a predictor of systemic decrease and organ dysfunction. Shock may cause tissue hypoperfusion which causes impaired cellular metabolism in essential organs like kidneys, liver, brain, and heart, thus, resulting in multiorgan dysfunction. Thus, the observation of serum lactate can assist clinicians in identifying the patients who are at more risk of complications and inform the aggressive management approaches[21]. The correlation of serum lactate with mortality in the present study further brings out the prognostic importance of measuring lactate in the intensive care units of the people. The death patients recorded a high level of lactate in comparison to people who survived. High levels of lactate are presumably indicators of gross circulatory insufficiency and protracted hypoxia of the tissues, both being among the major contributors of the adverse outcomes of critically ill patients. A number of studies conducted in different countries have also established that hyperlactatemia and slow lactate clearance are effective predictors of death in pediatric shock[22]. The other significant observation in this study was that there was a correlation between high levels of lactate, and the extended stay in PICU. The intensive care stay was more in patients who had higher levels of lactate than in patients with lower levels of lactate.

There are a number of limitations in this study that should be taken into consideration when interpreting the findings. To begin with, the researcher had to work in one pediatric intensive care unit, and this finding might not be applicable to other healthcare facilities with different patients and treatment regimens. Second, the sample size was relatively small and could minimize statistical power to establish some associations. Third, the serum lactate was mainly measured at the admission and serial lactate level or lactate clearance with time were not analyzed in detail, which might have given further information on patient prognosis and response to treatment. In addition, the differences in the etiology of shock in the patient group could have affected the levels of lactate and clinical outcomes. Lastly, the other possible confounding variables including variations regarding resuscitation techniques, time of interventions, and comorbid conditions were not controllable completely. Regardless of these, the research offers important data on the prognostic value of serum lactate in the measurement of the intensity of shock among children in the intensive care unit.

CONCLUSION

It is concluded that serum lactate is a valuable biomarker for assessing the severity of shock in pediatric patients admitted to intensive care units. Elevated serum lactate levels were significantly associated with increased shock severity, higher requirement for mechanical ventilation, development of multiorgan dysfunction, prolonged PICU stay, and increased mortality.

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