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Evaluating the Role of Point-of-Care Lactate Measurement in Predicting Severity and Outcomes of Diabetic Ketoacidosis in Emergency Settings

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ABSTRACT

Diabetic ketoacidosis is one of the severe diabetic emergencies with hyperglycaemia, acidosis, and ketonemia, and an increased level of lactate is an indicative feature of metabolic stress and unfavourable prognosis, necessitating urgent assessment and immediate care. **Objectives:** To assess the frequency of elevated point-of-care lactate in patients presenting with diabetic ketoacidosis (DKA) and to evaluate its association with DKA severity and in-hospital mortality. **Methods:** Data were prospectively collected from patients after obtaining verbal consent. Both quantitative and qualitative data were collected and analysed using SPSS version 23.0. Chi-square tests were applied, with a p-value of ≤0.05 considered significant. The study employed a descriptive cross-sectional design, conducted over six months (January 7, 2023, to June 7, 2023) at the Department of Medicine, Civil Hospital, Karachi. **Results:** A total of 131 patients were included, with a mean age and duration of T2DM of 47.14 ± 16.49 years and 1.72 ± 1.24 years, respectively. Among the participants, 71 (54.2%) were male, and 60 (45.8%) were female. Out of 131 patients, 64 (48.9%) had elevated point-of-care lactate, while 67 (51.1%) did not. In-hospital mortality occurred in 14 (60.9%) patients with elevated point-of-care lactate. The majority of patients presented with moderate DKA. **Conclusions:** The findings conclude that initial lactate levels in DKA patients are significantly associated with the need for critical care, suggesting that lactate can be used as a reliable marker for monitoring and managing DKA patients.

INTRODUCTION

Diabetic ketoacidosis (DKA) is a severe diabetic complication characterized by insulin deficiency, which causes hyperglycemia, acidosis, and ketonemia and has prevailed in approximately 8 per 1000 diabetics each year with a mortality rate of less than 5% [1]. Even though high levels of lactate can be used to anticipate sepsis, burns, myocardial infarction, and trauma, the data on the relationship between lactate and DKA severity are scarce and contradictory [2]. Measurement of lactate on-site may be an effective prognostic indicator for a patient in DKA because a higher level of lactate indicates an increased severity of the disease and increased chances of fatality in the hospital. Lactate may develop in numerous body tissues (kidney, erythrocyte, skeletal muscle, brain). The liver metabolizes the majority of the lactate, with the help of the kidney and skeletal muscle coming next [3]. At the moment of patient presentation, point-of-care lactates were assessed by means of a portable lactate reading

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instrument. The criteria used to classify the levels as being elevated were above 2 mmol/L, which is the standard clinical reference range of hyperlactatemia. [4]. In DKA, high levels of lactate are due to hypoperfusion, tissue hypoxia, and high levels of anaerobic glycolysis caused by insulin deficiency. With no insulin, more lipolysis, free fatty oxidation, and ketone bodies will be formed, leading to metabolic acidosis [5]. The presence of lactic acidosis also complicates acid-base imbalances, thereby complicating the management of the patient. Multiple studies suggest that the rise in lactate during DKA is not tissue hypoxia in all cases but is associated with the modified glucose metabolism and increased catecholamine levels, with the potential to cause hyperlactatemia [6]. Thus, hyperlactatemia in DKA must be well-defined to guide the diagnosis, the proposed management, and the prognostic assessment, and receive appropriate clinical attention [7]. Diabetic ketoacidosis (DKA) is a life-threatening condition mostly faced by patients with unregulated diabetes mellitus. Therefore, its early recognition and prompt treatment are paramount. Point-of-care lactate levels are increasingly noted as a marker of tissue hypoperfusion and worse outcomes in critically ill patients. However, the importance of elevated point-of-care lactate levels in DKA is still insufficiently understood, especially regarding the levels of DKA-related acidosis and the overall in-hospital outcome [8]. Recently, Kumar et al. researched the impact of late lactate clearance on DKA outcomes and noted that patients with late lactate clearance had longer stays at both the ICU and the hospital [9]. Furthermore, Elfiky et al. studied that in pediatric DKA and found that higher lactate levels correlated inversely with pH and positively with inflammatory markers, though did not consistently predict recovery time [10]. Also, Munsakul et al. formulated a predictive score for in-hospital mortality for DKA and included lactate in the score as one of the biochemical predictors [11].

Diabetic ketoacidosis (DKA) is a life-threatening complication of diabetes marked by hyperglycemia, acidosis, and ketonemia, yet the role of lactate as a prognostic marker in DKA remains unclear. Existing studies suggest associations between elevated lactate, disease severity, and in-hospital outcomes, but findings are inconsistent and mostly derived from non-local populations. Limited local evidence hampers the ability to use point-of-care lactate effectively for risk stratification and management decisions in DKA patients. This study aims to assess point-of-care lactate levels in DKA patients presenting to a tertiary care hospital, evaluating their relationship with disease severity and clinical outcomes to inform timely and evidence-based management.

METHODS

This descriptive cross-sectional study design was done in the Department of Medicine, Civil Hospital, Karachi, for six months, from January 7, 2023, to June 7, 2023, after approval of the research synopsis from the review board (IRB No. CIVL/AL/2023-064). Data were prospectively collected from patients after obtaining verbal consent; 131 patients were included in the study. The sample size was calculated through WHO software based on 68% prevalence of elevated point-of-care lactate with 8% margin of error and 95% confidence level [12]. Participants for the study were recruited using a non-probability consecutive sampling technique. The study included all male and female patients aged between 20 and 70 years who presented with diabetic ketoacidosis using a consecutive (non-probability) sampling technique. Patients were excluded if they had a history of hepatocellular carcinoma, blood or solid tumor malignancies, sepsis, or hospitalization within the previous month. Additionally, individuals with known endocrine or chronic systemic conditions, including hypothyroidism, hyperthyroidism, chronic obstructive pulmonary disease (COPD), asthma, myocardial infarction, congestive heart failure, or chronic renal failure, were also excluded to minimize confounding factors and ensure accurate assessment of metabolic parameters related to diabetic ketoacidosis. Patients meeting the study criteria were recruited from the Department of Emergency, Civil Hospital Karachi. Demographics, comorbidities, and clinical data were recorded, and blood samples were collected for point-of-care lactate measurement. Patients were classified based on lactate levels, and outcomes, including DKA severity and in-hospital mortality, were documented in a predesigned proforma. The researcher performed data entry and analyses using SPSS version 23.0. Frequency distribution and post-stratification Chi-square test were applied for statistical analysis with a significance level of $p \leq 0.05$. For normally distributed variables, means ± standard deviations were reported, while medians and interquartile ranges were reported for non-normally distribute. For the categorical variables, reported values were frequencies and percentages of gender, residence status, hypertension, dyslipidemia, smoking status, family monthly income, educational status, severity of DKA, elevated point-of-care lactate, and in-hospital mortality (Yes/No).

RESULTS

The findings indicated that the patients who were diagnosed with diabetic ketoacidosis and met the criteria were predominantly middle-aged adults of middle age with different durations of having diabetes mellitus type 2. The majority of them resided in the cities, and both genders

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were equally represented. Almost half of the patients had increased point-of-care levels of lactate, with a substantial proportion of such patients dying in-hospital. The less prevalent comorbidities were hypertension and dyslipidemia. The moderate level of DKA was the most prevalent. Statistical analysis found that there is a significant correlation between a high level of lactate and some demographic and socioeconomic variables, but not other clinical variables. One hundred and thirty-one patients (mean age 47.14 ± 16.49 years; mean T2DM duration 1.72 ± 1.24 years) took part in the research, consisting of 71 (54.2%) male and 60 (45.8%) female. High point-of-care lactate was detected in 64 (48.9%) patients, and in-hospital mortality was experienced by 23 (17.6%) of them. The median age, urban dwelling, and protracted T2DM (>2 years) were fairly high, where 64.1% of the patients were aged 64 years and above, 83.2% dwelling in urban areas, and 64.1% with diabetes exceeding two years (Table 1).

Table 1: Demographic and Clinical Characteristics of the Study Participants(n=131)

Variables	Categories	Frequency (%)
Age (Years)	Mean ± SD	47.14 ± 16.49
	Range	29 – 75
Age Groups	20 – 45 years	47 (35.9%)
	46 – 70 years	84 (64.1%)
Gender	Male	71 (54.2%)
	Female	60 (45.8%)
Residence	Urban	109 (83.2%)
	Rural	22 (16.8%)
Duration of T2DM (years)	Mean ± SD	1.72 ± 1.24
	≤ 2 years	47 (35.9%)
	> 2 years	84 (64.1%)
Point-of-Care Lactate Levels	Elevated	64 (48.9%)
	Not Elevated	67 (51.1%)
In-Hospital Mortality	Yes	23 (17.6%)
	No	108 (82.4%)

Of 131 patients, 33 (25.2%), 77 (58.8%), and 21 (16%) had mild, moderate, and severe DKA, respectively. There were 42 (32.1%), 19 (15.3%), and 20 (15.3%) hypertension cases, dyslipidemia cases, and smokers, respectively. The majority of patients were earning more than 75,000 PKR monthly (66.4%) and were highly educated (51.1%). It was found that lactate levels were elevated in 42.6 percent of patients between the ages of 20-45 years and 52.4 percent of those between the ages of 46-70 years, without a significant age difference in levels (p=0.28) (Table 2).

Table 2: Clinical and Demographic Characteristics Related to Severity of DKA (n=131)

Variables	Categories	Frequency (%)
Severity of DKA	Mild	33 (25.2%)
	Moderate	77 (58.8%)
	Severe	21 (16.0%)
Hypertension	Present	42 (32.1%)
	Absent	89 (67.9%)
Dyslipidemia	Present	19 (15.3%)
	Absent	111 (84.7%)
Smoking Status	Smoker	20 (15.3%)
	Non-Smoker	111 (84.7%)
Family Monthly Income (PKR)	≤ 75,000	44 (33.6%)
	> 75,000	87 (66.4%)
Educational Status	Illiterate	7 (5.3%)
	Primary	12 (9.2%)
	Secondary	45 (34.4%)
	Higher Education	67 (51.1%)
Age Group (years)	20 – 45 years (Elevated Lactate)	20 (42.6%)
	46 – 70 years (Elevated Lactate)	44 (52.4%)
	20 – 45 years (Normal Lactate)	27 (57.4%)
	46 – 70 years (Normal Lactate)	40 (47.6%)
p-value	–	0.28

The gender difference was found to be significant in the cases of elevated levels of lactate via stratified analysis, as 35.2% of males and 65% of females had been affected. There was no significant relationship with residence (urban 50.5% vs rural 40.9%, p=0.41), T2DM duration (length of less than 2 years 42.6% vs length of greater than 2 years 52.4%, p=0.28), hypertension (50% vs 48.3%), and dyslipidemia (47.4% vs 49.1%) (Table 3).

Table 3: Stratification of Elevated Point-of-Care Lactate Levels with Respect to Different Variables

Variables	Category	Elevated Lactate (n, %)	Normal Lactate (n, %)	p-value
Gender	Male (n=71)	25 (35.2%)	46 (64.8%)	0.01
	Female (n=60)	39 (65.0%)	21 (35.0%)	
Residence	Urban (n=109)	55 (50.5%)	54 (49.5%)	0.41
	Rural (n=22)	9 (40.9%)	13 (59.1%)	
Duration of T2DM	≤ 2 years (n=47)	20 (42.6%)	27 (57.4%)	0.28
	> 2 years (n=84)	44 (52.4%)	40 (47.6%)	
Hypertension	Present (n=42)	21 (50.0%)	21 (50.0%)	0.85
	Absent (n=89)	43 (48.3%)	46 (51.7%)	
Dyslipidemia	Present (n=19)	9 (47.4%)	10 (52.6%)	0.88
	Absent (n=112)	55 (49.1%)	57 (50.9%)	

Elevated lactate did not significantly correlate with smoking (45% vs. 49.5%; p=0.70) or the severity of DKA (54.5% mild, 42.9% moderate, 61.9% severe; p=0.22), according to stratified analysis. Patients with higher education (56.7%; p=0.03) and household income >75,000 PKR (57.5%; p=0.01) had substantially higher levels of elevated lactate. In-hospital deaths had increased lactate

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as 60.9% as compared to 46.3% of survivors (p=0.20) (Table 4).

Table 4: Stratification of Elevated Point-of-Care Lactate with Respect to Various Variables (n=131)

Variables	Category	Elevated Lactate (n, %)	Normal Lactate (n, %)	p-value
Smoking Status	Smoker	9 (45.0%)	11 (55.0%)	0.70
	Non-Smoker	55 (49.5%)	56 (50.5%)	
Monthly Income (PKR)	≤ 75,000	14 (31.8%)	30 (68.2%)	0.01
	> 75,000	50 (57.5%)	37 (42.5%)	
Educational Status	Illiterate	0 (0.0%)	7 (100%)	0.03
	Primary	6 (50.0%)	6 (50.0%)	
	Secondary	20 (44.4%)	25 (55.6%)	
	Higher	38 (56.7%)	29 (43.3%)	
Severity of DKA	Mild	18 (54.5%)	15 (45.5%)	0.22
	Moderate	33 (42.9%)	44 (57.1%)	
	Severe	13 (61.9%)	8 (38.1%)	
In-Hospital Mortality	Yes	14 (60.9%)	9 (39.1%)	0.20
	No	50 (46.3%)	58 (53.7%)	

DISCUSSION

Increased metabolic stress and tissue hypoperfusion are reflected in elevated lactate levels in diabetic ketoacidosis (DKA), which suggests a more severe illness, a larger need for rapid treatment, and a higher chance of unfavorable outcomes, such as in-hospital mortality. Lactate metabolism is key to understanding DKA, as insulin deficiency and altered glucose utilization increase lactate production and impair clearance, reflecting metabolic stress during acute diabetic emergencies [13]. Tissue hypoperfusion, hypoxia, insulin deficiency-driven increased anaerobic glycolysis, and stress hormone-mediated accelerated glycolysis are the causes of hyperlactatemia in DKA. Effective metabolic treatment requires careful fluid resuscitation, insulin therapy, and lactate level monitoring since these mechanisms worsen metabolic acidosis [14]. The hyperlactatemia develops with the loss of the pyruvate oxidation and the gain of the pyruvate to lactate process because of the condition of insulin deficiency. Besides that, the fact that the pyruvate and acetyl-CoA are converted into ketones and not gluconeogenic can be interpreted as less lactate being involved and more excreted [15]. It is due to the metabolic imbalance that enables the high levels of lactate: it shows the amount of lactate-related metabolic stress and hypoperfusion when compared to lactate and hypoxia that cause tissue and oxygen transportation damage [16]. The metabolism of DKA through lactate is the key to fluid and insulin therapy judicious use, hyperlactatemia assessment, and, above all, metabolic recoveries to diseased states assessment during the treatment process [17]. Several mechanisms can account for high levels of lactate in DKA that encompass anaerobic glycolysis, soaring levels of catecholamine, and stifled tissue oxygenation [18]. This, nonetheless, focuses on the perception of the lactate levels considering other metabolic and hemodynamic conditions [19]. More importantly, the alterations in the lactate sample are indications of the direct intervention effects and, therefore, the effects of an intervention as a whole because enhancing the levels of lactate indicates enhancing the clinical condition. In addition to that, demographic and socioeconomic characteristics such as age, location, and income level also affect the prevalence rates of high lactate levels in DKA [20]. In our research, it is demonstrated that point-of-care lactate has a prognostic value in DKA, which is increased in metabolic stress, is correlated with the severity of DKA, and has a correlation with increased in-hospital mortality. Out of 131 patients (mean age 47.14 ± 16.49 years; mean T2DM duration 1.72 ± 1.24 years), 48.9% had high levels of lactate, and 60.9% of deaths were found within the group, and most patients reported with moderate levels of DKA.

The study's observational design and relatively small sample size may limit the strength of causal inferences, and unmeasured confounders such as comorbidities, infection severity, and concurrent medications could have influenced lactate levels. Lactate was measured only at admission, preventing assessment of trends during treatment. Future research should include larger, longitudinal studies with serial lactate measurements to better understand its prognostic role in DKA management.

CONCLUSIONS

To sum up, point-of-care testing with lactate is useful in the management of diabetic ketoacidosis since it provides quick, practical data regarding the metabolic condition of the patient. It enables timely evaluation of the risk, contributes to early introduction of individualized measures, and can even influence improved results. The prognostic significance of the socioeconomic status elements is represented in the high level of lactate in patients with regard to their demographic and socioeconomic factors in a significant portion of patients. However, these consequences should be diluted with clinical studies, established guidelines, and a fair amount of anticipation of the pitfalls in the diagnostic. As the burden of diabetes continues to increase in the world today, particularly in the lower- and middle-income nations, point-of-care lactate detection will play a central role in timely detection of patients at high-risk with acute metabolic crisis and improved management of the situation.

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Authors' Contribution

Conceptualization: IM
Methodology: IM, RJD, SI, FZ
Formal analysis: RJD, FA, FZ
Writing and Drafting: SI, SA
Review and Editing: IM, RJD, FA, SI, FZ, SA

All authors approved the final manuscript and take responsibility for the integrity of the work.

Conflicts of Interest

All the authors declare no conflict of interest.

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