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Biochemical abnormalities and its correlation with outcome of diabetic ketoacidosis in children.

Talha Ahmed Siddiqui[1], Murtaza Ali Gowa[2], Sadaf Asim[3], Syed Habib Ahmed[4], Hafsa Qazi[5], Hira Nawaz[6], Bakhtawar Chandio[7]

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ABSTRACT… Objective: To determine biochemical abnormalities and its correlation with outcome of diabetic ketoacidosis (DKA) in children requiring hospital admission. **Study Design:** Cross-sectional study. **Setting:** Department of Pediatric Intensive Care Unit and Endocrinology, National Institute of Child Health, Karachi, Pakistan. **Period:** 29th August 2024 to 30th January 2025. **Methods:** A total of 209 children of either gender, aged 1 to 16 years, diagnosed with DKA, and requiring hospital admission were analyzed. At the time of admission, domographics, along with presenting symptoms and features were noted. Necessary laboratory investigations were carried out based on the hospital protocol and common biochemical abnormalities like electrolyte abnormalities, abnormal serum creatinine, blood urea nitrogen (BUN), and osmolality level were noted. **Results:** In a total of 209 children admitted with DKA, 120 (57.4%) were female. The mean age was 10.12±3.56 years. Electrolyte abnormalities were documented in 149 (71.3%) patients. Newly diagnosed T1DM (p=0.018) was found to have significant association with electrolyte abnormality. Abnormal serum creatinine was identified in 16 (7.7%) patients, and associated with altered consciousness (p<0.001), lethargy (p=0.010), and mortality (p=0.016). Abnormal BUN was identified in 33 (15.8%) patients, and associated with abdominal pain (p<0.001), difficulty in breathing (p<0.001), fever (p=0.011), vomiting (p=0.027), DKA severity (p=0.001), and mortality (p=0.001). Abnormal osmolality level was identified in 170 (81.3%) patients, and associated with polydipsia (p=0.039), vomiting (p=0.038), and DKA severity (p=0.009). **Conclusion:** Our study highlights the high prevalence of biochemical abnormalities in children with DKA and their significant correlation with disease severity and outcomes.

Key words: Blood Urea Nitrogen, Diabetic Ketoacidosis, Electrolytes, Serum Creatinine, Vomiting.

INTRODUCTION

Diabetic ketoacidosis (DKA) is a serious and life threatening condition with mortality rates ranging between 0.2-2%.[1] The incidence rates of DKA in type-2 diabetes mellitus (T2DM) are estimated between 4.6-8 per 1,000 patients, while in type-1 diabetes mellitus (T1DM), it ranges between 50-100 episodes per 1,000 patients.[2] T1DM patients with DKA often present at the time of diagnosis, or when they are not receiving the recommended insulin dosage (either intentionally or on purpose).[3]

Dehydration, abdominal pain accompanied by nausea and emesis (which could be mistaken for gastroenteritis), the smell of acetone and other ketones on the breath, tachycardia, tachypnea, and deep, sighing Kussmaul respirations are some of the typical clinical signs and symptoms of DKA. Confusion, sleepiness, changed mental status, and loss of consciousness also ensue if untreated.[4] Biochemical changes in children with DKA include hyperglycemia, acidosis, hypocapnia, and irregular electrolytes. Children may have substantial abnormalities in various biochemical measurements, and the severity of these biochemical derangements varies greatly between patients.[5] Arrhythmia, acute kidney injury (AKI), and cardiac arrest are all risks related with the electrolyte abnormalities and hyperosmolar dehydration that DKA causes.[6] Bacha et al reported that hypoglycemia was the commonest complication in DKA (23.7%), while hypokalemia was also seen in 4.3% patients.[7]

1. MBBS, Postgraduate Trainee Pediatric Medicine, National Institute of Child Health, Karachi, Pakistan.
2. MBBS, FCPS (Pediatric Medicine) MRCPCH (UK), PCCM, Associate Professor Section Head Pediatric Intensive Care Unit, National Institute of Child Health, Karachi, Pakistan.
3. MBBS, MCPS, DCH, FCPS (Pediatric Medicine), FCPS (Pediatric Nephrology), Assistant Professor Pediatric Nephrology, National Institute of Child Health, Karachi, Pakistan.
4. MBBS, DCH, MCPS, FCPS (Pediatric Medicine), Assistant Professor Pediatric Oncology, National Institute of Child Health, Karachi, Pakistan.
5. MBBS, FCPS (General Surgery), Lady Medical Officer Surgery, Sheikh Khalifa bin Zayed Hospital, Quetta, Pakistan.
6. MBBS, FCPS (Pediatric Medicine), Consultant Pediatrician and Post-Fellow Critical Care Medicine, Pediatric Intensive Care Unit, National Institute of Child Health, Karachi, Pakistan.
7. MBBS, Women Medical Officer Pediatric Intensive Care Unit, National Institute of Child Health, Karachi, Pakistan.

Correspondence Address:
Dr. Talha Ahmed Siddiqui
Department of Pediatric Medicine
National Institute of Child Health, Karachi, Pakistan.
talhasiddiqui94@hotmail.com

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Rahak et al in a local study reported mortality in 3.1% T1DM patiens with DKA, and was not linked to biochemical abnormalities.[8] A mortality rate of 3.4% among DKA patients was reported in a study by Syed et al.[9]

The prevalence of T1DM is thought to be increasing in Pakistan. The International Diabetes Federation (IDF) reports that 132,600 new patients of T1DM are diagnosed each year, leaving 1,106,500 children and teenagers living with the condition.[10] The clinical characteristics and risk factors of DKA are well documented in the literature; however, there is not much data looking at the biomarker characteristics, while some studies have linked biomarker abnormalities to the outcome of DKA. To the best of our knowledge, no similar information has yet been reported from Pakistan, which is why we decided to conduct this study. The objective of this study was to determine biochemical abnormalities and its correlation with outcome of DKA in children requiring hospital admission.

METHODS

This cross-sectional study was conducted at the Pediatric Intensive Care Unit (PICU) and Endocrinology Department of National Institute of Child Health, Karachi, Pakistan, from 29th August 2024 to 30th January 2025 after obtaining approval from "Institutional Ethical Review Board" (letter: IERB-26/2024, dated: 28th August, 2024). Considering the proportion of hypokalemia as 26.7% in DKA[13], with 95% confidence interval, and 6% margin of error, the sample size was calculated to be 209 using WHO sample size calculator. Non-probability consecutive sampling technique was adopted. Inclusion criteria were patients of either gender, aged 1 to 16 years, diagnosed with DKA, and requiring hospital admission. Exclusion criteria were patients presenting with any kinds of traumatic injury. Patients or their parents/guardians unwilling to be part of this research were also excluded. Informed and written consents were sought from patients or their parents/guardians to participate in this study. DKA was diagnosed according to ISPAD 2022 guidelines as[14] hyperglycemia (blood glucose >11 mmol/L [≈200 mg/dl]), venous pH <7.3 or serum bicarbonate <18 mmol/L, ketonemia (blood ß-hydroxybuyrate ≥3 mmol/L) or moderate or large ketonuria. The severity of DKA was classified as mild, moderate, or severe on the basis of pH or serum bicarbonate according to ISPAD 2022 guideline. pH values for mild, moderate and severe DKA were <7.3, <7.2, and <7.1, respectively. Serum bicarbonate values for mild, moderate and severe DKA were <18, <10, and <5 mmol/L, respectively.

At the time of admission, gender, age, weight, socio-economic status, and clinical features were documented. Socio-economic status was labeled as low (PKR < 50,000), middle (PKR 50,000 to 100,000), and upper (PKR > 100,000). Upon hospital admission, necessary laboratory investigation were carried out based on the hospital protocol. All of the biomarkers routinely examined in DKA patients lying outside the normal reference ranges were considered abnormal. Electrolyte imbalance was defined as deviation from any of these: sodium (<135 or >145 mEq/L), potassium (<3.5 or >5.5mEq/L), and chloride (95-108 mEq/L). Serum creatinine > 1 mg/dl was considered abnormal. BUN between 5-18 mg/dL was considered normal. Normal serum osmolality was labeled as 275 to 290 mOsm/kg. All patients were treated as per institutional protocols and monitored until discharge, or death. A special proforma was designed to record study data.

Data was analyzed using IBM-SPSS Statistics, version 27.0. Frequencies and percentages were shown to represent categorical variables like gender, residence, socioeconomic status, DKA severity, clinical features, comorbidity, complications, and final outcome. Numerical variables such as age, body mass index, and biochemical measures were presented as mean ± standard deviation (SD). Chi-square or Fisher exact test was applied to compare categorical variables. Numerical variables were compared using independent sample t-test P-value less than 0.05 was taken as statistically significant.

RESULTS

In a total of 209 children admitted with DKA, 120 (57.4%) were female. The mean age, and

weight were 10.12±3.56 years, and 24.88±10.52 kg, respectively. Socio-economic status of 141 (67.5%) children was lower. The mean duration of diabetes was 3.62±3.28 years, while 51 (24.4%) patient were newly diagnosed cases of T1DM. The most frequent presenting symptoms/features were difficulty in breathing, vomiting, fever, abdominal pain, noted in 87 (41.6%), 87 (41.6%), 85 (40.7%), 66 (31.6%), respectively. Celiac disease was present in 16 (7.7%) patients. DKA severity was categorized as mild, moderate, and severe in 85 (40.7%), 64 (30.6%), and 60 (28.7%) patients, respectively. The mean blood glucose level was 424.89±106.45 mg/dl.

The mean Na, K, and Cl were 135.26±5.30 mEq/L, 4.72±3.49 mEq/L, and 101.69±6.18 mEq/L, respectively. The mean serum creatinine, BUN, and osmolality were 0.70±0.45 mg/dl, 14.21±6.82 mg/dl, and 299.22±11.04 mOsm/kg, respectively.

Electrolyte abnormalities were documented in 149 (71.3%) patients. Newly diagnosed T1DM (p=0.018) was found to have significant association with electrolyte abnormality. Table-1 is showing the details about the stratification of electrolyte abnormalities with respect to various study variables.

Abnormal serum creatinine was identified in 16 (7.7%) patients. Presenting symptoms as altered consciousness (p<0.001), lethargy (p=0.010), and mortality (p=0.016) were found to have significant association with abnormal serum creatinine (Table-II).

Abnormal BUN was identified in 33 (15.8%) patients. At presentation, abdominal pain (p<0.001), difficulty in breathing (p<0.001), fever (p=0.011), and vomiting (p=0.027) were found to have significant association with abnormal BUN. DKA severity was found to have significant linkage with abnormal BUN (p=0.001). Mortality was significantly associated with abnormal BUN (p=0.001), as shown in Table-III.

Abnormal osmolality level was identified in 170 (81.3%) patients. Polydipsia (p=0.039), and vomiting (p=0.038) at presentation was found to have significant association with abnormal osmolality. DKA severity had significant association with abnormal osmolality (p=0.009), as shown in Table-IV.

Study Variables		Electrolyte Abnormalities		P-Value
		Yes (n=149)	No (n=60)	
Gender	Male	63 (42.3%)	26 (43.3%)	0.889
	Female	86 (57.7%)	34 (56.7%)	
Age (years)		10.30±3.27	9.70±4.18	0.275
Weight (kg)		24.89±9.77	24.83±12.27	0.971
Socio-economic status	Lower	98 (65.8%)	43 (71.7%)	0.411
	Middle	51 (34.2%)	17 (28.3%)	
Duration of diabetes (years)		3.55±3.20	3.79±3.49	0.635
Newly diagnosed diabetes		43 (28.9%)	8 (13.3%)	0.018
Presenting symptoms/ features	Altered consciousness	8 (5.4%0	2 (3.3%)	0.533
	Abdominal pain	50 (33.6%)	16 (26.7%)	0.332
	Weight loss	10 (6.7%)	2 (3.3%)	0.342
	Polydipsia	11 (7.4%)	6 (10.0%)	0.531
	Polyurea	17 (11.4%)	4 (6.7%)	0.302
	Diarrhea	11 (7.4%)	6 (10.0%)	0.531
	Difficulty in breathing	67 (45.0%0	20 (33.3%)	0.123
	Fever	57 (38.3%)	28 (46.7%)	0.263
	Vomiting	59 (39.6%)	28 (46.7%)	0.348
	Lethargy	9 (6.0%)	8 (13.3%)	0.081
DKA severity	Mild	57 (38.3%)	28 (46.7%)	0.205
	Moderate	44 (29.5%)	20 (33.3%)	
	Severe	48 (32.2%)	12 (20.0%)	
Celiac disease		14 (9.4%)	2 (3.3%)	0.136
Final outcome	Alive	145 (97.3%)	58 (96.7%)	0.799
	Death	4 (2.7%)	2 (3.3%)	

Table-I. Association of electrolyte abnormalities with study variables

Study Variables		Abnormal Serum Creatinine		P-Value
		Yes (n=16)	No (n=193)	
Gender	Male	6 (37.5%)	83 (43.0%)	0.669
	Female	10 (62.5%)	110 (57.0%)	
Age (years)		9.63±2.06	10.17±3.65	0.560
Weight (kg)		22.50±7.04	25.07±10.74	0.348
Socio-economic status	Lower	10 (62.5%)	131 (67.9%)	0.659
	Middle	6 (37.5%)	62 (32.1%)	
Duration of diabetes (years)		2.14±2.64	3.74±3.30	0.060
Newly diagnosed diabetes		4 (25.0%)	47 (24.4%)	0.954
Presenting symptoms/ features	Altered consciousness	4 (25.0%)	6 (3.1%)	<0.001
	Abdominal pain	6 (37.5%)	60 (31.1%)	0.596
	Weight loss	-	12 (6.2%)	0.304
	Polydipsia	-	17 (8.8%)	0.215
	Polyurea	-	21 (10.9%)	0.164
	Diarrhea	-	17 (8.8%)	0.215
	Difficulty in breathing	4 (25.0%)	83 (43.0%)	0.160
	Fever	8 (50.0%)	77 (39.9%)	0.429
	Vomiting	4 (25.0%)	83 (43.0%)	0.160
	Lethargy	4 (25.0%)	13 (6.7%)	0.010
DKA severity	Mild	4 (25.0%)	81 (42.0%)	0.411
	Moderate	6 (37.5%)	58 (30.1%)	
	Severe	6 (37.5%)	54 (28.0%)	
Celiac disease		-	16 (8.3%)	0.231
Final outcome	Alive	14 (87.5%)	189 (97.9%)	0.016
	Death	2 (12.5%)	4 (2.1%)	

Table-II. Association of abnormal serum creatinine with study variables

Study Variables		Abnormal BUN		P-Value
		Yes (n=16)	No (n=193)	
Gender	Male	18 (54.5%)	71 (40.3%)	0.130
	Female	15 (45.5%)	105 (59.7%)	
Age (years)		9.73±2.73	10.20±3.69	0.486
Weight (kg)		23.91±7.29	25.06±11.02	0.566
Socio-economic status	Lower	18 (54.5%)	123 (69.9%)	0.084
	Middle	15 (45.5%)	53 (30.1%)	
Duration of diabetes (years)		3.32±2.96	3.67±3.34	0.566
Newly diagnosed diabetes		9 (27.3%)	42 (23.9%)	0.676
Presenting symptoms/ features	Altered consciousness	2 (6.1%)	8 (4.5%)	0.708
	Abdominal pain	20 (60.6%)	46 (26.1%)	<0.001
	Weight loss	-	12 (6.8%)	0.122
	Polydipsia	1 (3.0%)	16 (9.1%)	0.242
	Polyurea	1 (3.0%)	20 (11.4%)	0.144
	Diarrhea	2 (6.1%)	15 (8.5%)	0.635
	Difficulty in breathing	23 (69.7%)	64 (36.4%)	<0.001
	Fever	20 (60.6%)	65 (36.9%)	0.011
	Vomiting	8 (24.2%)	79 (44.9%)	0.027
	Lethargy	2 (6.1%)	15 (8.5%)	0.635
DKA severity	Mild	4 (12.1%)	81 (46.0%)	0.001
	Moderate	13 (39.4%)	51 (29.0%)	
	Severe	16 (48.5%)	44 (25.0%)	
Celiac disease		-	16 (9.1%)	0.071
Final outcome	Alive	29 (87.9%)	174 (98.9%)	0.001
	Death	4 (12.1%)	2 (1.1%)	

Table-III. Association of abnormal BUN with study variables

Study Variables		Abnormal Osmolality		P-Value
		Yes (n=16)	No (n=193)	
Gender	Male	69 (40.6%)	20 (51.3%)	0.223
	Female	101 (59.4%)	19 (48.7%)	
Age (years)		10.02±3.66	10.54±3.09	0.421
Weight (kg)		24.57±10.73	26.21±9.57	0.383
Socio-economic status	Lower	116 (68.2%)	25 (64.1%)	0.619
	Middle	54 (31.8%)	14 (35.9%)	
Duration of diabetes (years)		3.53±3.38	4.00±2.79	0.419
Newly diagnosed diabetes		43 (25.3%)	8 (20.5%)	0.531
Presenting symptoms/ features	Altered consciousness	10 (5.9%)	-	0.121
	Abdominal pain	58 (34.1%)	8 (20.5%)	0.099
	Weight loss	10 (5.9%)	2 (5.1%)	0.855
	Polydipsia	17 (10.0%)	-	0.039
	Polyurea	19 (11.2%)	2 (5.1%)	0.257
	Diarrhea	15 (8.8%)	2 (5.1%)	0.446
	Difficulty in breathing	67 (39.4%)	20 (51.3%)	0.175
	Fever	66 (38.8%)	19 (48.7%)	0.257
	Vomiting	65 (38.2%)	22 (56.4%)	0.038
	Lethargy	17 (10.0%)	-	0.039
DKA severity	Mild	65 (38.2%)	20 (51.3%)	0.009
	Moderate	60 (35.3%)	4 (10.3%)	
	Severe	45 (26.5%)	15 (38.5%)	
Celiac disease		11 (6.5%)	5 (12.8%)	0.179
Final outcome	Alive	166 (97.6%)	37 (94.9%)	0.349
	Death	4 (2.4%)	2 (5.1%)	

Table-IV. Association of abnormal osmolality with study variables

DISCUSSION

In this study, 71.3% T1DM children admitted with DKA had electrolyte abnormalities, with newly diagnosed T1DM cases significantly associated with these derangements (p=0.018). This aligns with findings from Glaser et al.[15], who identified hyperglycemia and electrolyte imbalances, particularly altered sodium and potassium levels, as common in pediatric DKA. The mean sodium and potassium levels in our cohort were 135.26±5.30 mEq/L and 4.72±3.49 mEq/L, respectively, comparable to Isik et al.[16], who reported similar electrolyte trends in pediatric DKA. However, our study diverged from Solanki et al.[17], who observed hypokalemia as the most common abnormality. This discrepancy may stem from differences in patient demographics or timing of sample collection, as hypokalemia often manifests later in DKA management due to insulin therapy. Our results on electrolyte abnormalities are broadly consistent with previous studies, such as Liu et al.[18], and Kumar et al.[19], who noted similar trends in sodium and potassium derangements. However, the specific prevalence rates of abnormalities differ, likely due to regional variations in DKA management protocols and population characteristics. Data from resource-limited settings report higher rates of hypokalemia[19], possibly reflecting delayed presentation or limited access to appropriate insulin therapy.

This study noted abnormal serum creatinine in 7.7% of patients, with significant associations between abnormal creatinine levels and altered consciousness (p<0.001), lethargy (p=0.010), and mortality (p=0.016). These findings align with Kumar et al.[19], who reported that elevated creatinine levels indicate dehydration severity and predict adverse outcomes. In contrast, Isik et al.[16], found no significant impact of creatinine levels on clinical recovery rates, suggesting potential differences in hydration protocols or population characteristics. Abnormal BUN levels

were identified in 15.8% of patients, significantly correlating with abdominal pain ($p<0.001$), difficulty breathing ($p<0.001$), and vomiting ($p=0.027$). The association between DKA severity and abnormal BUN ($p=0.001$) parallels findings from Jansari et al.[20], who reported elevated BUN as a marker of dehydration and disease severity. Our study also observed significant links between abnormal BUN and mortality ($p=0.001$), reinforcing the prognostic value of renal biomarkers in DKA.

A particularly striking finding was the high prevalence of abnormal serum osmolality (81.3%), which was significantly associated with symptoms like polydipsia ($p=0.039$) and vomiting ($p=0.038$) and correlated with DKA severity ($p=0.009$). These results are consistent with Glaser et al.[15], who demonstrated that elevated serum osmolality and hyperosmolar states contribute to neurological complications in DKA. The mean serum osmolality in our study was 299.22 ± 11.04 mOsm/kg, higher than that reported by Weiland et al.[21], who focused primarily on mild to moderate cases, possibly explaining the differences.

Our findings underscore the importance of early identification and management of electrolyte and biochemical abnormalities in children with DKA. The significant correlation between newly diagnosed T1DM and electrolyte abnormalities suggests that clinicians should exercise heightened vigilance in first-presentation cases. Furthermore, the association between abnormal creatinine and BUN levels and poor outcomes highlights the need for aggressive hydration and monitoring of renal function in severe DKA cases. The high prevalence of abnormal osmolality and its link to severe disease warrants attention, as hyperosmolar states are risk factors for cerebral edema, a life-threatening complication of DKA. The mortality rate in this study was relatively low but significantly associated with abnormal renal biomarkers and severe DKA, echoing findings from Solanki et al.[17], and Jansari et al.[20] The differences in mortality rates across studies likely reflect variations in healthcare infrastructure, early recognition, and adherence to treatment guidelines.

This study had several limitations. First, its cross-sectional design precludes causal inferences about the relationships between biochemical abnormalities and outcomes. Second, as a single-center study conducted in a tertiary care hospital, the findings may not be generalizable to all settings, particularly primary care or resource-limited environments. Third, we relied on institutional protocols for treatment, which may differ from international guidelines, potentially introducing variability in outcomes. We did not include advanced imaging or neurobiochemical assessments to evaluate complications like cerebral edema, which may provide deeper insights into the clinical course of DKA. Long-term follow-up data, particularly on neurodevelopmental outcomes, were not available, limiting the scope of outcome analysis.

CONCLUSION

Our study highlights the high prevalence of biochemical abnormalities in children with DKA and their significant correlation with disease severity and outcomes. These findings emphasize the critical role of timely diagnosis, aggressive management, and vigilant monitoring of renal and electrolyte parameters in improving outcomes for pediatric DKA patients. Future research should explore the role of advanced biomarkers and imaging techniques in predicting complications and outcomes in pediatric DKA. Multicenter, prospective studies could enhance the generalizability of findings and identify best practices for managing this life-threatening condition in diverse healthcare settings.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORSHIP AND CONTRIBUTION DECLARATION	
1	**Talha Ahmed Siddiqui:** Data collection, drafting, responsible for data's integrity, proof reading, approved for publication.
2	**Murtaza Ali Gowa:** Study concept, design, proof reading, critical revisions, approved for publication.
3	**Sadaf Asim:** Study concept, design, proof reading, critical revisions, approved for publication.
4	**Syed Habib Ahmed:** Literature review, data analysis, proof reading, approved for publication.
5	**Hafsa Qazi:** study concept, design, proof reading, critical revisions, approved for publication.
6	**Hira Nawaz:** Data collection, data analysis, proof reading, approved for publication.
7	**Bakhtawar Chandio:** Data collection, data analysis, proof reading, approved for publication