J Renal Inj Prev. 2026; 15(3): e38724.

https://journalrip.com doi: 10.34172/jrip.2026.38724

Journal of Renal Injury Prevention

Prevalence of electrolyte imbalances and acute kidney injury in type 1 diabetic children with diabetic ketoacidosis; a retrospective cross-sectional study

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ARTICLE INFO

Article Type:
Original

Article History:
Received: 8 Nov. 2025
Revised: 22 Dec. 2025
Accepted: 23 Mar. 2026
Published online: 15 Apr. 2026

Keywords:
Diabetic ketoacidosis
Diabetes mellitus type 1
Pediatrics
Adolescents
Electrolyte imbalance
Acute kidney injury

ABSTRACT

Introduction: Children with type 1 diabetes are at increased risk of developing diabetic ketoacidosis (DKA), a life-threatening complication often accompanied by electrolyte disturbances and kidney injury. Understanding the prevalence and patterns of these metabolic derangements is crucial for improving clinical management and outcomes in pediatric populations.

Objectives: This study aimed to provide insight into the prevalence of electrolyte imbalances and acute kidney injury (AKI) among children with type 1 diabetes with DKA, to highlight key implications for early recognition and intervention.

Materials and Methods: This single-center, retrospective cross-sectional study was conducted at Besat hospital in Hamadan, Iran, over 10 years (2011–2021) and included pediatric and adolescent patients (<18 years) with type 1 diabetes who were hospitalized for acute DKA. Eligible cases were identified from hospital records and extracted. Demographic, clinical, and laboratory information, including electrolyte profiles and renal parameters, was extracted from medical records, and AKI was classified according to KDIGO criteria. All data were entered into structured tables and analyzed descriptively using frequencies and percentages to determine the prevalence of electrolyte disorders and AKI in the study population.

Results: The results indicated that among 94 pediatric patients with DKA, 59 (62.8%) experienced electrolyte disturbances, while 61 (64.9%) developed AKI, with grade 1 being the most frequent stage (39 cases, 63.9%). The most common electrolyte abnormalities were hyponatremia in 16 patients (17%), hyperkalemia in 22 patients (23.4%), and hypocalcemia in 9 patients (9.6%).

Conclusion: Electrolyte disturbances and AKI were common among pediatric patients with DKA, with hyponatremia, hyperkalemia, and grade 1 AKI being the most frequent findings. These results underscore the importance of early detection and close monitoring of metabolic and renal complications in this population.

Original

Implication for health policy/practice/research/medical education:
We found that in pediatric patients with diabetic ketoacidosis (DKA), electrolyte disturbances and acute kidney injury (AKI) were both highly prevalent, with grade 1 AKI representing the most frequent stage. The most common electrolyte abnormalities identified were hyponatremia, hyperkalemia, and hypocalcemia. These findings emphasize the necessity of routine and early monitoring of renal function and electrolyte status in children presenting with DKA. Prompt recognition and correction of these imbalances, particularly hypokalemia and sodium or calcium disturbances, are critical to reducing morbidity and preventing progression of kidney injury. Incorporating standardized protocols for electrolyte surveillance and AKI risk assessment into pediatric DKA management may improve patient outcomes and minimize complications..

Please cite this paper as: Emad Momtaz H, Zahabi M, Moradi A, Razavi Z. Prevalence of electrolyte imbalances and acute kidney injury in type 1 diabetic children with diabetic ketoacidosis; a retrospective cross-sectional study. J Renal Inj Prev. 2026; 15(3): e38724. doi: 10.34172/jrip.2026.38724.

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Introduction

Diabetic ketoacidosis (DKA) represents the most frequent acute hyperglycemic emergency and constitutes a life-threatening complication, particularly prevalent among children with type 1 diabetes (1,2). It results in hyperglycemia, profound fluid loss, metabolic acidosis, and diverse electrolyte imbalances (3). The reported incidence of DKA among children and adolescents with type 1 diabetes ranges from low to high incidence in previous studies (4-6). The DKA may also occur in newly diagnosed adolescents and children with type 2 diabetes, or in those with poorly controlled disease, as a consequence of impaired insulin secretion or action (2).

Despite the progress in the treatment and care of type 1 diabetes, DKA is still the main cause of hospitalization and death in children with diabetes (7). A wide range of complications is associated with DKA in children; osmotic diuresis during this condition leads to varying degrees of electrolyte imbalance and dehydration (8,9). These patients exhibit deficiencies in electrolytes such as sodium, potassium, phosphate, calcium, and magnesium, with hypoglycemia, hyponatremia, and hypokalemia being the most frequent complications (10), while cerebral edema remains the leading cause of mortality (11). On the other hand, acute kidney injury (AKI) is one of the most common complications of DKA in children and adolescents, which can occur in 35 to 64.2% of DKA episodes (12-15). The increased prevalence of AKI in children with DKA, especially in those presenting with hypernatremia and metabolic acidosis, underscores the pathogenic role of acidosis and dehydration (14), where severe volume depletion may progress to acute tubular necrosis (1). Additionally, metabolic acidosis may develop when reduced glomerular filtration impairs renal acid excretion (15).

In pediatric DKA, careful regulation of fluids, insulin, and electrolytes is essential, with AKI prolonging metabolic acidosis and requiring potassium replacement to be deferred until urine output is established (16). Inadequate management of electrolyte disturbances and AKI can increase mortality in patients with DKA (7). Therefore, early recognition of DKA-related complications is essential for effective treatment, reduced healthcare costs, and shorter hospital stays. As data on the prevalence of these complications in children and adolescents from developing countries remain limited, the present study aimed to determine the frequency of electrolyte disorders and AKI among pediatric patients hospitalized with DKA in Iran.

Objectives

The objective of this study was to determine the prevalence and patterns of electrolyte imbalances and AKI among children with type 1 diabetes presenting with DKA, using retrospective cross-sectional analysis of clinical and laboratory data. The study aimed to characterize the frequency distribution of these complications and provide insights that may guide early recognition and management strategies in pediatric DKA.

Materials and Methods

Study design and participants

This was a single-center, retrospective cross-sectional study conducted at Besat hospital in Hamadan, Iran. The study period spanned 10 years, from March 2011 to March 2021. Eligible cases within the defined timeframe were included. Clinical and demographic data were obtained from hospital records at the time of admission due to acute DKA. The study population comprised children and adolescents with a confirmed diagnosis of type 1 diabetes who were hospitalized at Besat hospital for DKA.

Inclusion and exclusion criteria

Inclusion criteria were age in the pediatric or adolescent range (<18 years) as classified by hospital records, documented diagnosis of type 1 diabetes, and hospitalization due to acute DKA within the study period. Cases not meeting these criteria or lacking essential admission data for acute DKA were not included. Patients were excluded if they had a diagnosis of diabetes other than type 1, were admitted for metabolic complications other than acute DKA, had incomplete or missing medical records, experienced multiple admissions during the study period (only the first eligible hospitalization was considered), suffered from major chronic comorbidities that could confound DKA presentation, or were transferred from other hospitals without complete documentation of their initial diagnosis and management.

Data collection

This retrospective cross-sectional study was conducted through a review of hospital medical records of pediatric patients admitted with DKA. Demographic variables (age, gender, and family history of diabetes or kidney disease) and clinical findings (proteinuria, hematuria, pyuria, dehydration grade, loss of consciousness, and requirement for hemodialysis) were extracted from patient clinical documents, which were archived in the Besat hospital. Laboratory parameters at admission, including fasting blood sugar, serum bicarbonate, pH, blood urea nitrogen, hemoglobin, and mean platelet volume, were recorded, along with hospitalization duration. Electrolyte profiles (sodium, potassium, calcium, and phosphorus) were classified according to standard clinical thresholds, and the presence and severity of AKI were determined based on established grading criteria. All collected data were entered into structured tables, and descriptive statistics (frequency, percentage, mean, and standard deviation) were calculated to summarize the findings.

Outcome measurement

The study outcomes were measured by assessing the

prevalence of electrolyte disorders and AKI using standardized laboratory and clinical criteria; serum sodium, potassium, calcium, and phosphorus levels were obtained at admission and categorized according to accepted reference ranges, with any abnormality considered an electrolyte disorder, while AKI was diagnosed and graded according to the KDIGO (Kidney Disease/Improving Global Outcomes) classification based on serum creatinine changes and urine output (12), and both electrolyte abnormalities and AKI status were reported as frequencies and percentages to provide a clear overview of their distribution in the study population.

Statistical analysis

All collected data were entered into Statistical Package for Social Sciences (SPSS) software version 27 (IBM Corp, USA) and analyzed using descriptive statistical methods. Continuous variables (such as age, hospitalization duration, fasting blood sugar, bicarbonate, pH, blood urea nitrogen, hemoglobin, and mean platelet volume) were expressed as mean ± standard deviation. Categorical variables (including gender, family history, presence of proteinuria, hematuria, pyuria, dehydration grade, electrolyte disturbances, and AKI status) were summarized as frequencies and percentages.

Results

In this study, 94 pediatric patients with a mean age of 9.6 ± 4.1 years were included. The majority of participants were female, and only a small proportion reported a family history of diabetes or kidney disease. Most patients did not exhibit proteinuria, hematuria, or pyuria, although a minority presented with these findings. A limited number experienced loss of consciousness, and only one patient required hemodialysis during the course of illness. With respect to hydration status, nearly all patients demonstrated some degree of dehydration, most frequently mild to moderate, while a smaller subset presented with severe dehydration. The study population consisted of children who were hospitalized for less than one week on average. At admission, laboratory investigations revealed hyperglycemia, marked metabolic acidosis with reduced bicarbonate and low blood pH, and moderately elevated blood urea nitrogen. Hemoglobin levels were generally within the normal range, while mean platelet volume was slightly increased (Table 1).

In this study, electrolyte disturbances were observed in a considerable proportion of children with DKA. Sodium levels were most frequently within the normal range, though both hyponatremia and hypernatremia were identified in smaller subsets. Phosphorus values were predominantly normal, with only isolated cases of hypo- or hyperphosphatemia. Potassium concentrations were generally maintained within normal limits, yet a notable fraction of patients experienced hyperkalemia, and a few presented with hypokalemia. Calcium levels were largely normal, although instances of both hypocalcemia and hypercalcemia were documented. The AKI was common among the patients, with the majority affected, and the distribution of severity revealed that most cases were classified as grade 1, while fewer were categorized as grade 2 or grade 3 (Table 2).

Table 1. Demographic characteristics and clinical findings of included patients in the study

Demographic characteristics and clinical data	Number	%
Gender		
Female	56	59.6
Male	38	40.4
Family history of diabetes		
Yes	3	3.2
No	91	96.8
Family history of kidney disease		
Yes	2	2.1
No	92	97.9
Presence of proteinuria		
Yes	25	26.6
No	69	73.4
Presence of hematuria		
Yes	11	11.7
No	83	88.3
Presence of pyuria		
Yes	12	12.8
No	82	87.2
Loss of consciousness		
Yes	13	13.8
No	81	86.2
Patients required hemodialysis		
Yes	1	1.1
No	93	98.9
Dehydration		
No dehydration	0	0
Grade 1	55	58.5
Grade 2	30	31.9
Grade 3	9	9.6
Demographic characteristics and clinical data	**Mean**	**SD**
Age (year)	9.6	4.1
Hospitalization duration (day)	5.9	4.5
At admission		
FBS (mg/dL)	153.8	124.3
Bicarbonate ([HCO_3], [mEq/L])	5.4	4.4
pH	7.1	0.2
BUN (mg/dL)	14.4	10.3
Hemoglobin (g/dL)	13.9	1.6
MPV (fL)	9.7	1.1

SD, Standard deviation; FBS, Fasting blood sugar; BUN, Blood urea nitrogen; MPV, Mean platelet volume; fL, Femtoliters.

Discussion

The results demonstrated that electrolyte disturbances (62.8%) were frequent among pediatric patients with DKA, with a comparable proportion developing AKI (64.9%). Hyponatremia and hyperkalemia emerged as the most prevalent electrolyte abnormalities. These

Table 2. Prevalence of electrolyte disorders and AKI in the included patients in the study

Demographic characteristics and clinical data		Frequency	Percent
Overall electrolyte disorders	Yes	59	62.8
	No	35	37.2
Sodium (mmol/L)	Hyponatremia (<145)	16	17
	Normonatremia (145 - 155)	76	80.9
	Hypernatremia (>155)	2	2.1
Phosphorus (mg/dL)	Hypophosphatemia (< 3.7)	1	1.1
	Normophosphatemia (3.7 - 5.4)	91	96.8
	Hyperphosphatemia (> 5.4)	2	2.1
Potassium (mEq/L)	Hypokalemia (< 3.5)	5	5.3
	Normokalemia (3.5 – 5.5)	67	71.3
	Hyperkalemia (> 5.5)	22	23.4
Calcium (mg/dL)	Hypocalcemia (< 8.5)	9	9.6
	Normocalcemia (8.5 – 10.5)	79	84
	Hypercalcemia (> 10.5)	6	6.4
AKI	Yes	61	64.9
	No	33	35.1
Grade of AKI	Grade 1	39	63.9
	Grade 2	16	26.2
	Grade 3	6	9.9

AKI; Acute kidney injury.

results are consistent with prior studies. A systematic review and meta-analyses study by Meena et al has documented that the pooled incidence of any stage AKI during DKA episodes in children is approximately 47% (CI: 40–55%), with severe AKI occurring in about 28% (21–35%), though individual studies have reported rates ranging from 14% to over 80% depending on diagnostic criteria and population characteristics (17). Hursh et al reported AKI in 64% of pediatric DKA admissions using KDIGO criteria, while other cohorts have found rates as high as 80% when including younger children and those with recurrent DKA episodes (12). Likewise, Huang et al reported that 56.5% of pediatric patients with DKA developed AKI, with 38.5% classified as mild and 18.0% as severe (15). Alyahyawi et al observed that among 373 pediatric patients with DKA, 299 (80.2%) developed AKI, comprising 98 (26.3%) at stage 1, 118 (31.6%) at stage 2, and 83 (22.3%) at stage 3 (18).

Electrolyte disturbances are also frequently reported. In a previous study by Onyiriuka and Oyenusi, hyponatremia was present in 25.5% and hyperkalemia in 10.6% of pediatric DKA cases at admission (19). Notably, studies from diverse geographic regions, including North America, Asia, and Africa, have consistently identified hyponatremia as the most common sodium abnormality and hyperkalemia as the most frequent potassium disturbance at presentation (20). The association between AKI with hyperchloremia and hyperkalemia has been highlighted in recent research (20-22), which demonstrates that AKI is independently associated with hyperkalemia during DKA, likely due to impaired renal potassium excretion in the context of acidosis and insulin deficiency (20). Furthermore, hyperchloremia has been implicated as both a marker and a potential contributor to AKI in DKA, with studies showing higher serum chloride levels in patients with AKI and a significant correlation between chloride and creatinine concentrations (21,22). However, the causal relationship between hyperchloremia and AKI remains debated, as some evidence suggests that hyperchloremia may be more a consequence of AKI or iatrogenic fluid therapy than a direct cause (22). Recent randomized controlled trials and meta-analyses comparing balanced crystalloids to normal saline in DKA management have not demonstrated significant differences in major adverse kidney events or hypokalemia incidence, though balanced fluids may reduce the risk of hyperchloremia (23). Variability in AKI incidence across studies is partly attributable to differences in diagnostic criteria (KDIGO vs. pediatric-Risk, Injury, Failure, Loss [p-RIFLE]), patient age, DKA severity, and the proportion of recurrent versus new-onset diabetes cases (24). In summary, the high rates of AKI and electrolyte disturbances observed in the current cohort are in line with, or slightly above, the upper range of previous reports, reinforcing the recognition of these complications as frequent and clinically significant in pediatric DKA.

The frequent occurrence of AKI and electrolyte disturbances in pediatric DKA has important clinical implications, as these complications are associated with increased morbidity, prolonged hospital stays, and potential long-term sequelae (14). Notably, AKI during DKA has been linked to a substantially increased risk of developing microalbuminuria and, by extension, diabetic kidney disease) in children with type 1 diabetes, with

each episode of AKI conferring a 56% higher hazard for microalbuminuria and multiple episodes increasing the risk up to fivefold (25). Furthermore, the presence of AKI may hinder the resolution of metabolic acidosis and delay recovery, particularly in cases of severe or persistent kidney injury, although most AKI episodes are reversible with appropriate fluid and insulin therapy (15). Over-resuscitation with intravenous fluids and the development of hyperchloremia have been associated with delayed kidney recovery and may exacerbate renal injury, highlighting the need for careful fluid management tailored to the degree of dehydration (26). Clinical guidelines now emphasize the importance of early recognition, cautious rehydration, and vigilant monitoring of electrolytes and renal function throughout DKA management to minimize the risk of complications such as cerebral edema, arrhythmias, and persistent kidney dysfunction (10). Providers should maintain a high index of suspicion for hyperkalemia in patients with AKI, severe acidosis, or known diabetes, as these children are at increased risk for life-threatening cardiac arrhythmias (20). The identification of risk factors such as older age, higher heart rate, lower serum bicarbonate, higher corrected sodium, and elevated blood urea nitrogen at presentation can aid in early risk stratification and targeted interventions (17). Importantly, younger children (≤5 years), those with severe DKA, and those with recurrent episodes are at particularly high risk for AKI and may benefit from intensified monitoring and follow-up (24). Beyond renal outcomes, AKI during DKA has been associated with subtle neurocognitive deficits, including lower intelligence quotient (IQ) and impaired memory, which may persist after recovery and potentially worsen with repeated episodes (27). Given the potential for long-term renal and neurocognitive consequences, early identification, prevention, and management of AKI and electrolyte disturbances in pediatric DKA should be prioritized in both acute and follow-up care.

Overall, electrolyte disturbances and AKI are highly prevalent in pediatric DKA, with hyponatremia and hyperkalemia being the most common abnormalities, and these complications significantly increase risks of delayed recovery, prolonged hospitalization, chronic kidney disease, and neurocognitive impairment. Evidence supports routine monitoring of kidney function and electrolytes as part of standard DKA care, especially in high-risk groups such as young children, those with recurrent or severe DKA, and patients with poor glycemic control. While balanced crystalloids may reduce hyperchloremia compared to normal saline, individualized fluid management remains essential, and future research should refine risk stratification tools, clarify mechanisms linking DKA, AKI, and neurocognitive outcomes, and optimize management strategies. A multidisciplinary approach involving acute care, endocrinology, nephrology, and neuropsychology is ultimately required to ensure comprehensive treatment and long-term follow-up.

Conclusion

This study demonstrates that electrolyte disturbances and AKI are highly prevalent among pediatric patients with DKA, with grade 1 AKI representing the most frequent stage. Hyponatremia and hyperkalemia emerged as the most common electrolyte abnormalities. These findings underscore the importance of early recognition and vigilant monitoring of renal function and electrolyte balance in children with DKA to optimize clinical outcomes and prevent complications.

Limitations of the study

This study has several limitations that should be considered when interpreting its results. First, its retrospective cross-sectional design relied on hospital records, which may have introduced information bias due to incomplete or inconsistent documentation. Second, as this is a single-center study conducted at Besat hospital in Hamadan, the findings may not be generalizable to other populations or healthcare settings. Third, the long study period (2011–2021) raises the possibility of changes in diagnostic criteria, laboratory techniques, or management protocols over time, which could affect outcome consistency. Fourth, the exclusion of patients with chronic comorbidities or incomplete records may have led to selection bias, potentially underestimating the true burden of electrolyte disorders and AKI. Finally, the absence of longitudinal follow-up limited the ability to assess long-term renal outcomes or recurrence of DKA, restricting interpretation to short-term hospital-based findings.

Acknowledgments

We thank the staff and administration of Besat hospital, Hamadan, for their support and access to medical records, and our colleagues who assisted with data collection and organization.

Authors' contribution

Conceptualization: Hossein Emad Momtaz and Marzieh Zahabi.
Data curation: Hossein Emad Momtaz and Marzieh Zahabi.
Formal analysis: Abbas Moradi.
Investigation: Abbas Moradi and Zahra Razavi.
Methodology: Abbas Moradi and Zahra Razavi.
Project management: Zahra Razavi.
Resources: All authors.
Supervision: All authors.
Validation: Zahra Razavi.
Writing–original draft: All authors.
Writing–review and editing: All authors.

Ethical issues

The research was conducted in accordance with the principles of the Declaration of Helsinki. This study was conducted at Besat Hospital and was derived from the

thesis of Marzieh Zahabi (Thesis #36593), approved by the ethics committee of the School of Medicine, Hamadan University of Medical Sciences, Hamadan, Iran, under the ethical code (IR.UMSHA.REC.1400.361; https://ethics.research.ac.ir/form/ox3fcfqx5bbuwgar.pdf) and approval date on July 31, 2021. Informed written consent was obtained from the guardians of all participants. Besides, the authors have observed ethical issues (including plagiarism, data fabrication, and double publication).

Conflicts of interest

The authors declare no conflict of interest.

Funding/Support

This study was supported by the Hamadan University of Medical Sciences, Hamadan, Iran (Grant #36593).

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of generative artificial intelligence (AI) and AI-assisted technologies in the writing process

While preparing this work, the authors utilized AI tools (Grammarly and Copilot) to refine grammar points and language style. Subsequently, they thoroughly reviewed and edited the content as necessary, assuming full responsibility for the publication's content.

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