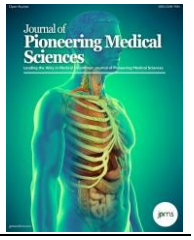
Journal of Pioneering Medical Sciences
Received: July 08, 2024 Accept: Sep 23, 2024 Publish: November 04, 2024.
Volume 13, Issue 6, Pages 4-12

DOI: https://doi.org/10.61091/jpms2024130602



Research Article

A Retrospective Study of The Prevalence of Diabetic Ketoacidosis in Saudi Adolescents and Adults with Type 1 Diabetes

Mohammed Zaid Aljulifi[1*], Moeber Mahzari[2,3,4], Hadania Adil Fatani[3,4,5], Husam I Ardah[3,6]

[1]Department of Family and Community Medicine, College of Medicine, Majmaah University, Majmaah 11952, Saudi Arabia
[2]Department of Medicine, Division of Endocrinology, King Abdulaziz Medical City, Ministry of National Guard Health Affairs, Riyadh, Saudi Arabia
[3]King Abdullah International Medical Research Center, Riyadh, Saudi Arabia
[4]College of Medicine, King Saud bin Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia
[5]Department of Family Medicine, King Abdulaziz Medical City, Ministry of National Guard Health Affairs, Riyadh, Saudi Arabia
[6]Department of Biostatistics and Bioinformatics, King Abdullah International Medical Research Center, Riyadh, Saudi Arabia
Corresponding author: Mohammed Zaid Aljulifi (e-mail: m.aljulifi@mu.edu.sa).

Abstract: **Objectives:** To assess the frequency and predictors of diabetic ketoacidosis (DKA) in adolescents and adults with type 1 diabetes (T1DM). **Methodology:** This retrospective analysis involved patients over the age of 12 who were monitored at the endocrine clinic of King Abdulaziz Medical City in Riyadh from July 2019 to July 2020. A comparison was made between patients with diabetic ketoacidosis (DKA) and those without, utilizing the chi-squared test or Fisher's exact test for categorical variables and the t-test or Kruskal-Wallis test for continuous variables. Independent risk factors were determined through multivariate logistic regression analysis. ***Results*:** Among the 262 patients diagnosed with Type 1 Diabetes Mellitus (T1DM), 56.1% were female, with an average age of 22.6 years (± 8.07). Approximately 58% of these patients reported a history of diabetic ketoacidosis (DKA), and 46.9% experienced DKA at the time of diagnosis. The average glycated hemoglobin level recorded was 9.0% (± 1.80). Missing appointments at the endocrine clinic was linked to increased hospital admissions due to DKA. Of those with a DKA history, 81.6% experienced it once annually, while 18.4% had multiple hospitalizations. The average age of patients during admission was 18.1 years (± 7.33), with an average hospital stay of 2.9 days (± 1.53). Although most DKA episodes were classified as mild to moderate, 19.7% were severe. The primary reason for DKA was identified as noncompliance with insulin therapy, accounting for 52% of cases. **Conclusions:** DKA is frequently observed in individuals with T1DM in Saudi Arabia, largely attributed to nonadherence to insulin therapy. Around one-third of these patients encounter recurrent or severe episodes of DKA. It is advisable to engage in regular conversations regarding insulin adherence and the management of illness-related complications.

Keywords: Diabetic ketoacidosis, Type 1 diabetes, Saudi Arabia, Prevalence, Risk factors.

INTRODUCTION

Type 1 diabetes mellitus (T1DM) is an autoimmune disease that affects beta cells in the pancreas [1]. T1DM incidence doubled between 1990 and 2008, from 2.8% to 4%, with more than 90,000 children diagnosed annually [1-2]. The estimated worldwide prevalence is 9.5% [3]. According to the 10th edition of the International Diabetes Federation Diabetes Atlas, there are 28,900 Saudi children and adolescents with T1DM, and Saudi Arabia ranks 10th in terms of T1DM prevalence [4]. Two Saudi-based studies found that the crude incidence rate was approximately 27.5 per 100,000 per year [5,6]. The expected annual increase in incidence in Saudi Arabia is approximately 16.8% [6]. Furthermore, many studies have found that the mean age at T1DM diagnosis in Saudi patients is between 6 and 10 years [5,7–10]. Approximately 68% of Saudi

children and adolescents have uncontrolled T1DM, with an overall glycated hemoglobin (HbA1c) level of 9.4 ± 2.4% [11,12].

Diabetes ketoacidosis (DKA) is common in patients with T1DM [13]. DKA is characterized by a deficiency of endogenous insulin, which is associated with increased activity of counter-regulatory hormones, leading to hyperglycemia and ketoacidosis [14]. Notably, DKA could be a clinical presentation of a new T1DM diagnosis. It is estimated that 15%–70% of patients have DKA at diagnosis, especially if they were diagnosed with T1DM before the age of 2 years [15]. DKA at diagnosis is considered a predictor of poor blood sugar control later in life [16] and a determinant of poor quality of life in adolescents with T1DM [17]. In Saudi Arabia, 26%–77% of Saudi children and adolescents with T1DM present with DKA at diagnosis [6,7,9,18–23]. Furthermore, DKA commonly occurs as an acute decompensation in patients with known T1DM. Physiological stressors, such as infection and pregnancy, are usually associated with the development of DKA in patients with T1DM. However, DKA more commonly occurs due to noncompliance with insulin therapy.

DKA is categorized as mild, moderate, or severe, depending on the degree of acidosis. Patients with moderate-to-severe DKA require intensive care. DKA represents approximately 6.5% of all pediatric intensive care unit (ICU) admissions [24].

Studies of adult Saudi patients with T1DM are limited. Therefore, this study aimed to assess the frequency and predictors of DKA in adolescents and adults with T1DM at the King Abdulaziz Medical City, Riyadh.

MATERIAL AND METHODS

This study was a retrospective chart review of patients with T1DM aged >12 years who attended endocrinology clinics at King Abdulaziz Medical City (KAMC), Riyadh, between July 2019 and July 2020. In total, 262 patients were included in this study. The dependent variable was the history of admission for DKA. The independent variables included current age, sex, age at diagnosis of T1DM, HbA1c levels before or around DKA, insulin regimen, documented reason for DKA, adherence to endocrine clinic/diabetic educator appointments, and presence of other autoimmune diseases. DKA diagnosis was based on the following criteria: blood glucose ≥250 mg/dL, arterial pH <7.3, serum bicarbonate ≤15 mEq/L, high anion gap, moderate ketonuria, or ketonemia.

Data were collected using a structured data-collection sheet. The data were tracked for up to 15 years for every patient. Quality control was applied through double data entry. Patient privacy and confidentiality were assured, no identifiers were collected, and hard and soft copies of all data were kept in a secure place within the KAMC premises. This study was approved by the institutional review board of the King Abdullah International Medical Research Center (KAIMARC) with project no. RC19/287/R. The requirement for written consent was waived because of the retrospective study design. We conducted the study in accordance with the ethical guidelines of KAIMARC.

The mean and percentage of research participants were computed for characterization. To identify the risk variables for DKA, study participants were separated into two groups based on their history of DKA. The two groups (patients with and without DKA) were compared using the chi-squared or Fisher's exact test for categorical factors and the t-test or Kruskal-Wallis test for continuous variables, respectively. The chi-square test was used when the expected count was at least five in each cell in the contingency table, while Fisher's exact test was used when the expected count in any cell was less than five.

T-tests or the Kruskal–Wallis test were used for group comparisons for continuous variables. T-test is used for normally distributed variables, while the Kruskal–Wallis test is used for abnormally distributed variables. Independent risk factors were identified using multivariate logistic regression analysis. The likelihood of acquiring DKA was modelled as the dependent variable in the multivariate logistic regression model, and the independent variables included all variables that were discovered to be connected with the development of DKA as well as potential confounders (sex, age, and DM). For patients with T1DM, both with and without DKA, an additional logistic regression model that was covariate-adjusted (age, sex, and comorbidities) was utilized to calculate the adjusted odds ratio (aOR). Covariates were selected based on the results of univariate testing and the variables' clinical relevance. A significance level of $\alpha = 0.05$ was established. SAS 9.4 was used for statistical analysis (SAS Institute Inc., Cary, NC, USA).

RESULTS

The records of 262 patients were reviewed, of which 56.1% were female. The mean age of the sample was 22.6 ± 8.07 years, and the mean age at T1DM diagnosis was 11.6 ± 6.02 years. Approximately 58% of the sample had a history of DKA, and 46.9% had DKA at diagnosis. The mean HbA1c level was 9.0 ± 1.80% (Table 1).

Table 1: Characteristics of patients with type 1 diabetes (n=262) T1DM, type 1 diabetes mellitus; DKA, diabetic ketoacidosis; HbA1c, glycated hemoglobin

Variable		Frequency n (%)
Sex	Male	115 (43.9%)
	Female	147 (56.1%)
Age (years)	12–<20	112 (42.7%)
	20–<40	141 (53.8%)
	≥ 40	9 (3.5%)
Marital status	Single	216 (82.4%)
	Married	42 (16.0%)
	Other	4 (1.5%)
Age at diagnosis	<2 years	4 (1.5%)
	2–<12 years	141 (53.8%)
	12–<20 years	90 (34.4%)
	≥20 years	27 (10.3%)
T1DM patients with a documented history of DKA		152 (58.0%)
T1DM patients without a documented history of DKA		110 (42.0%)
DKA at T1DM diagnosis		122 (46.9%)
Last measured HbA1c	≤7–8	81 (30.9%)
	>8–10	121 (46.2%)
	>10	60 (22.9%)
Type 1 diabetes autoantibodies	Positive	101 (38.5%)
	Negative	58 (22.1%)
	Not known	103 (39.3%)

The proportion of autoimmune diseases, psychiatric disorders, and diabetic complications was higher in patients with a history of DKA than in those without DKA; however, the difference was not statistically significant. There was an association between missing endocrine clinic appointments and a history of DKA (p = 0.0188) (Table 2).

Table 2: Frequency of associated diseases and complications in T1DM cases with or without a history of DKA

Variable		T1DM patients without a documented history of DKA	T1DM patients with a documented history of DKA	Total	p-value
Type 1 diabetes autoantibodies (positivity)	Positive *n* (%)	44 (40.0)	57 (37.5)	101 (38.5)	0.2602 **
	Negative *n* (%)	19 (17.3)	39 (25.7)	58 (22.1)	
	Not done *n* (%)	47 (42.7)	56 (36.8)	103 (39.3)	
Thyroid disorder *n* (%)		18 (16.4)	18 (11.8)	36 (13.7)	0.2941 **
Vitiligo *n* (%)		2 (1.9)	3 (1.9)	5 (1.9)	1.0000 ^^
Other autoimmune diseases *n* (%)		5 (4.6)	12 (7.7)	17 (6.5)	0.0920 ^^
Psychiatric disorders *n* (%)		6 (5.6)	9 (5.8)	15 (5.7)	0.8726 **
Microvascular complications	No complication *n* (%)	96 (87.3)	122 (80.3)	218 (83.2)	0.2161 ^^
	Nephropathy *n* (%)	6 (5.5)	12 (7.9)	18 (6.9)	
	Retinopathy *n* (%)	3 (2.7)	11 (7.2)	14 (5.3)	
	Neuropathy *n* (%)	1 (0.9)		1 (0.4)	
	Nephropathy + retinopathy *n* (%)	3 (2.7)	7 (4.6)	10 (3.8)	
	Retinopathy + Neuropathy *n* (%)	1 (0.9)		1 (0.4)	
Number of endocrine clinic visits	Mean (SD)	2.1 (1.28)	2.3 (1.29)	2.2	0.1108

in the previous year				(1.29)	^
Number of DM educator clinic visits in the previous year	Mean (SD)	1.2 (1.52)	1.4 (1.72)	1.3 (1.64)	0.3842 ^
Number of no-shows for the endocrine clinic in the previous year	Mean (SD)	0.5 (0.73)	0.7 (0.98)	0.6 (0.89)	0.0188 ^
Number of no-shows for DM educator clinic visits in the previous year	Mean (SD)	0.3 (0.73)	0.2 (0.57)	0.3 (0.64)	0.7606 ^

^ using Kruskal–Wallis test.
**** using the chi-squared test.**
^^ using Fisher exact test.

T1DM, type 1 diabetes mellitus; DKA, diabetic ketoacidosis; SD, standard deviation

As shown in Table 3, female patients had more recurrent DKA episodes than male patients (29 vs. 13); however, this difference was not significant (p = 0.3440). Although the average age at diagnosis of T1DM was lower for patients with recurrent DKA than for those with a history of DKA alone, this difference did not reach statistical significance (p = 0.0714). Moreover, approximately 18.4% of the sample had one or more episodes of DKA in the previous year (p = 0.0009).

Table 3: Characteristics of patients with a documented history of DKA (n= 152)

Variable		**Number of DKA episodes**			**Total**	**p-value**
		1 DKA n = 110	**2 DKA n = 21**	**≥ 3 DKA n = 21**	**n = 152**	
Sex	Male	48 (43.6%)	7 (33.3%)	6 (28.6%)	61 (40.1%)	0.3440 **
	Female	62 (56.4%)	14 (66.7%)	15 (71.4%)	91 (59.9%)	
Age	Mean (SD)	21.8 ± 7.10	21.8 ± 6.94	20.9 ± 7.35	21.7 ± 7.07	0.8561 ^
Marital status	Single	92 (83.6%)	17 (81.0%)	19 (90.5%)	128 (84.2%)	0.4424 ^^
	Married	16 (14.5%)	3 (14.3%)	1 (4.8%)	20 (13.2%)	
	Other	2 (1.8%)	1 (4.8%)	1 (4.8%)	4 (2.6%)	
Age at diagnosis	Mean (SD)	12.0 ± 6.24	9.3 ± 3.73	10.3 ± 6.48	11.4 ± 6.05	0.0714 ^
No. of admissions due to DKA in the previous year	No DKA during the previous year	98 (89.1%)	12 (57.1%)	14 (66.7%)	124 (81.6%)	0.0009 ^^
	One DKA admission in the previous year	11 (10.0%)	7 (33.3%)	6 (28.6%)	24 (15.8%)	
	≥ 2 DKA admissions in the previous year	1 (0.9%)	2 (9.5%)	1 (4.8%)	4 (2.6%)	

^ using Wilcoxon rank sum test.
**using the chi-squared test.
^^using Fisher exact test.

DKA, diabetic ketoacidosis; SD, standard deviation.

The mean age of the patients admitted with DKA was 18.1 ± 7.33 years. The mean duration of hospital stay was 2.9 ± 1.53 days, the average HbA1c level was 11.1 ± 1.95%, and most patients had HbA1c levels >8%. Most DKA episodes during the admissions were mild-to-moderate; however, 19.7% were severe. Noncompliance with insulin, followed by infection, were the two primary causes of DKA (Table 4).

Table 4: Characteristics of patients admitted due to DKA

Variable		**Frequency**
Age at admission	Mean (SD)	18.1 ± 7.33
Length of stay	Mean (SD)	2.9 ± 1.53
Length of stay	1–2 days	35 (46.1%)
	3–4 days	30 (39.5%)
	≥ 5 days	11 (14.5%)
DKA type	Mild *n* (%)	30 (39.5%)
	Moderate *n* (%)	31 (40.8%)
	Severe *n* (%)	15 (19.7%)
HbA1c level during or within 6 months of DKA	Mean (SD)	11.1 ± 1.95
HbA1c level during or within 6 months of DKA	≤7–8	4 (5.3%)
	>8–10	22 (29.3%)
	>10	49 (65.3%)

Cause of DKA as documented in the file	Not compliant with insulin	78 (52%)
	Newly diagnosed	16 (10.7%)
	Not documented/Unknown	14 (9.3%)
	Upper respiratory tract infection	12 (8%)
	Other infections*	18 (12%)
	COVID-19	3 (2%)
	Pump malfunction	3 (2%)
	Other causes^	6 (4%)
Insulin regimen before admission due to DKA	MDI	124 (82.6%)
	Insulin pump	5 (3.3%)
	No treatment	16 (10.6%)
	Mixed insulin	4 (2.7%)
	Metformin	1 (0.7%)

* Other infections include gastritis/gastroenteritis, community-acquired pneumonia, cellulitis, tooth abscess, colitis, pancreatitis, and pneumonia.
^ Other causes include lipohypertrophy, stress, empagliflozin-related DKA, deep vein thrombosis attack, menstrual distress, and pregnancy.
COVID-19, coronavirus disease 2019; DKA, diabetic ketoacidosis; HbA1c, glycated hemoglobin; SD, standard deviation; MDI, multiple dose insulin

Logistic regression estimated that a 1% increase in HbA1c level was associated with a 26% elevation in the odds of having DKA (p = 0.0028) (Table 5).

Table 5: Logistic regression analyses with 95% confidence intervals for significant confounders of DKA

Effect	Beta	Standard Error	Odds Ratio	[95% Confidence interval]	p-value
Sex (male vs. female)	-0.3513	0.2594	0.704	(0.42, 1.17)	0.1758
Age at T1DM* Diagnosis	-0.0110	0.0215	0.989	(0.95, 1.03)	0.6071
Number of endocrine visits in the previous year	0.1150	0.1064	1.122	(0.91, 1.38)	0.2798
Number of diabetic educator visits in the previous year	0.0451	0.0831	1.046	(0.89, 1.23)	0.5870
Last measured HbA1c	0.2345	0.0784	1.264	(1.08, 1.47)	0.0028

T1DM, type 1 diabetes mellitus; DKA, diabetic ketoacidosis; HbA1c, glycated hemoglobin

Table 6: DKA severity prevalence in previous Saudi-based studies

Author	Study period	Age group (years)	DKA severity prevalence		
			Mild	Moderate	Severe
Kulaylat and Narchi, 2001 [7]	1986–997	below 15	-	-	37% *
Habib, 2005 [20]	1992–2004	below 15	-	-	15.1%*
Satti et al., 2013 [24]	2000–2004	below 15	18.4%	38.2%	43.4%
Naeem et al., 2015 [36]	1995–2013	below 14	-	-	53%*
Al Shaikh et al., 2019 [19]	2005–2015	below 18	35.1%	32.5%	32.5%*
Al-Ghamdi and Fureeh, 2018 [9]	2007–2016	below 20	27.1%	53.1%	19.8%*
Batwa et al., 2022 [21]	2015–2019	below 17	24.5%	9.4%	24.5%*
Alrubean et al., 2011 [41]	1985–2005	13–40	-	-	5.8%**
Almalki et al., 2016 [39]	2014–2015	Above 12	-	-	19.3%^
Babaker et al., 2022 [23]	2015–2017	Below 15	28.8%	67.1%	4.1%*
Alahmadi et al., 2018 [27]	2010–2016	14–40	43.3%	29.1%	27.6% ^^
Alotaibi et al., 2022 [43] ^	2018–2020	Above 15	-	-	15.7% ^^

* Severe DKA if pH less than 7.1
** Percentage of patients who required ICU admission
^ Including type 1 and type 2 diabetes
^^ Severe DKA if pH less than 7

DKA, diabetic keto-acidosis

DISCUSSION

DKA is a common complication in patients with T1DM, occurring in up to two-thirds of cases [25]. Similarly, in this study, approximately 58% of the patients had DKA. The proportion in this study was higher than that in previous studies from the region. For example, Alhayek et al. reported that 31% of patients with T1DM had a history of DKA [26]. Another study from the western region of Saudi Arabia reported a 20.6% annual incidence rate of DKA during the study period [27]. These differences could be related to the longer duration of our study, as it spanned a 15-year period and included different study populations.

In this study, 46% of the patients had DKA at T1DM diagnosis. According to the American Diabetes Association, approximately 30% of patients with T1DM present with DKA upon diagnosis [28]. Notably, Saudi Arabia is considered to have one of the highest occurrences of DKA at T1DM diagnosis. The proportion of patients with newly diagnosed T1DM presenting with DKA in Saudi Arabia varies, with a reported rate of up to 59% [29]. Another study reported that 25% of patients admitted to the ICU with DKA were newly diagnosed with T1DM [30]. Similarly, studies from the Gulf region have reported varying proportions of DKA on initial presentation at the time of T1DM diagnosis. Specifically, the proportions were 37%, 31%, and 80% in Kuwait, Oman, and the United Arab Emirates, respectively [31–33]. In the United Kingdom, approximately 25% of patients newly diagnosed with T1DM present with DKA [34]. The overall adjusted DKA prevalence on initial presentation with T1DM was estimated at 29.9% in 13 countries across three continents [35].

In this study, the mean age at T1DM diagnosis was 11.6 ± 6.02 years. This finding is consistent with other studies that reported that the median age at T1DM diagnosis was 0–14 years [23,26,36]. In contrast, some studies from Saudi Arabia on younger populations reported that the age at T1DM diagnosis ranged from 5.5–10 years [5,7–10,18,21,22,24]. Internationally, the age at T1DM diagnosis is reported to be 9.2 ± 4.1 years in the UAE [33], 6.7 ± 3.7 years in Oman [31], and 10.3 (range 0.8–16.6 years) in the UK [34]. The discrepancy between the studies might be due to differences in the study populations.

Female sex is a possible risk factor for DKA. In this study, female patients experienced more DKA episodes than male patients; however, the difference was not significant. Similar observations have been reported in previous studies [6,9,18,19,22,37]. Moreover, female patients may develop DKA in general and severe DKA more frequently than male patients [27,38–41].

It has been noted that most DKA episodes occur in the age range of 18–40 years [25]. Up to 28% of the patients had more than one episode of DKA, and approximately 18% had one or more DKA episodes in a year. The mean age of the patients admitted with DKA was 18.1 ± 7.33 years. Alrubean et al. reported that the mean age of patients admitted with DKA was 21.77 ± 7.2 years, and most cases (59%) were in the intermediate and secondary school age groups [41]. Furthermore, Almalki et al. found that the mean age at DKA admission was 21.4 ± 10.1 years, and 65% of patients had a previous DKA episode [39].

In this study, 69% of the patients had HbA1c levels >8%, with a mean of 9.0 ± 1.80%. The high percentage of poor and suboptimal diabetes control in this cohort is consistent with the results of previous studies [11,42].

The average HbA1c level around admission was 11.1 ± 1.95%, and elevated HbA1c levels were a predictor of DKA in this study. This finding is consistent with those of Almalki et al., Alotaibi et al., and Alahmadi et al., who reported HbA1c levels at admission as 11.9 ± 2.6%, 11.8 ± 2.6%, and 11.7 ± 2.9%, respectively [27,39,43]. Maahs et al. reported that HbA1c >7.5% is a predictor of DKA in patients with T1DM [44]. An HbA1c level ≥ 10% is an independent risk factor for DKA and increases the risk by four times compared to those below 8% [26]. However, HbA1c levels may not be a predictor of DKA severity [7,20].

Regarding DKA severity, 19.7% of the patients in this study had severe DKA. The mean length of hospital stay for all patients was 2.9 ± 1.53 days. Previous studies on pediatric and adolescent patients in Saudi Arabia found that 15%–43% of DKA cases were severe [7,19,20,24]. Conversely, in adult studies, severe cases accounted for 5.8%–27.6% of cases [27,39,41]. The mean length of hospital stay in the study by Almalki et al. was 4.6 ± 3.3 days, whereas that in the survey by Alrubean et al. was 6.56 ± 3.4 days [39,41]. Table 6 summarizes the important aspects of DKA reported in previous Saudi studies. The variation between studies could be related to differences in study population, time, and duration.

Similarly, Alotaibi et al. found that most admissions due to DKA were for patients between 18 and 40 years old, and approximately 35.6% had a history of readmission with DKA [43]. In contrast, Alahmadi et al. reported a much lower rate of DKA recurrence (approximately 8%) [27]. Similar findings have been reported in other regions worldwide. For example, in Iraq, the mean age at admission with DKA was reported to be 20.9 ± 6.3, and 49% of the patients had one or more episodes of DKA per year [45]. In Bahrain, 29 out of 89 patients with T1DM had recurrent DKA [46]. In the UK, 39% of patients were readmitted with DKA [40]. As individuals with T1DM transition into early adulthood, they begin to take on responsibilities for aspects such as diet,

carbohydrate counting, and insulin injections. This shift may lead to a decline in glycemic control and an increased incidence of DKA episodes in this age group compared to adolescents and children still under parental supervision.

In this study, noncompliance with insulin was the main reason for DKA, followed by infection. This finding is similar to many studies conducted locally, regionally, and internationally [23,27,30,36,39–41,43,46]. However, some studies, such as that by Satti et al., identified infections as the main reason for omitting insulin doses [24]. Therefore, it is important to regularly address insulin compliance and sick day management during patient follow-ups.

This study did not show any association between DKA and autoimmune diseases, such as hypothyroidism or vitiligo. This finding is similar to that of a previous study [19].

There was an association between DKA and the number of missed appointments in endocrinology/diabetology clinics ($p = 0.0188$). This finding has been reported in prior studies, where missing one follow-up visit per year was estimated to increase the risk of developing DKA by six times [26,40].

The strengths of this study were the study duration spanning 15 years and the inclusion of adolescents and adult patients. However, this study had some limitations. It was retrospective and conducted at a single center with a relatively small sample size. Therefore, there may have been risks, such as the absence of important data, and it may only represent part of the spectrum of the T1DM population in Saudi Arabia. Moreover, some important variables were not assessed in this study. Therefore, the generalizability of the study's findings should be interpreted cautiously, and more studies are required to consider those variables.

Further studies are required to assess the different aspects of DKA, especially in adult patients. These studies will contribute to understanding the risk factors for DKA, which will aid in planning effective interventions to minimize the prevalence of DKA. Reducing admissions due to DKA will positively impact patients' health and minimize the cost burden on the healthcare system.

CONCLUSIONS

DKA is common in patients with T1DM worldwide, including in Saudi Arabia, and is more frequent in young and female patients. The risk of developing DKA is increased by poor glycemic control and missed clinic visits. The most common causes of DKA are poor compliance with insulin therapy and infections.

Addressing insulin compliance and sick day management should be discussed with the patients regularly.

Data availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Institutional Review Board statement

This study was approved by the institutional review board of the King Abdullah International Medical Research Center (KAIMARC) with project no. RC19/287/R. All methods were carried out in accordance with KAIMARC guidelines and the Declaration of Helsinki guidelines.

Informed consent statement

The requirement for written consent was waived because of the retrospective study design.

Authors' contributions

All authors contributed to the study's conceptualization. Aljulifi and Fatani collected all the data. Ardah analyzed and interpreted the patient data. All authors discussed the results and read and approved the final manuscript.

Funding

The author extends the appreciation to the Deanship of Postgraduate Studies and Scientific Research at Majmaah University for funding this research work through the project number (R-2024-1349)

Acknowledgments

We thank King Abdullah International Medical Research (KAIMARC) for their support.

REFERENCES

1. Katsarou, Anastasia, et al. "Type 1 diabetes mellitus." *Nature reviews Disease primers* 3.1 (2017): 1-17. https://doi.org/10.1038/nrdp.2017.16
2. Dabelea, Dana, et al. "Prevalence of type 1 and type 2 diabetes among children and adolescents from 2001 to 2009." *Jama* 311.17 (2014): 1778-1786. doi:10.1001/jama.2014.3201
3. Mobasseri, M., et al. "Prevalence and incidence of type 1 diabetes in the world: a systematic review and meta-analysis." Health Promotion Perspectives 10.2 (2020) doi: 10.34172/hpp.2020.18
4. Issaka, Ayuba, et al. "Association between urban–rural location and prevalence of type 2 diabetes and impaired fasting glucose in West Africa: a cross–sectional population–based epidemiological study." *BMJ open* 13.9 (2023) https://doi.org/10.1136/bmjopen-2022-063318
5. Habeb, Abdelhadi M., et al. "High incidence of childhood type 1 diabetes in al-madinah, north west saudi arabia (2004–2009)." *Pediatric diabetes* 12.8 (2011): 676-681. **https://doi.org/10.1111/j.1399-5448.2011.00765.x**
6. Abduljabbar, Mohammad A., et al. "Incidence trends of childhood type 1 diabetes in eastern Saudi Arabia." *Saudi medical journal* 31.4 (2010): 413-418.
7. Kulaylat, Naji A., and Hassib Narchi. "Clinical picture of childhood type 1 diabetes mellitus in the Eastern Province of Saudi Arabia." *Pediatric Diabetes* 2.1 (2001): 43-47. **https://doi.org/10.1111/j.1442-200X.2006.02242.x-i1**
8. Kulaylat, Naji A., and Hassib Narchi. "Clinical picture of childhood type 1 diabetes mellitus in the Eastern Province of Saudi Arabia." *Pediatric Diabetes* 2.1 (2001): 43-47. **https://doi.org/10.1111/j.1442-200X.2006.02242.x-i1**
9. Al-Ghamdi, A. H., and A. A. Fureeh. "Prevalence and clinical presentation at the onset of type 1 diabetes mellitus among children and adolescents in Al-Baha region, Saudi Arabia." Journal of Pediatric Endocrinology and Metabolism 31.3, (2018) https://doi.org/10.1515/jpem-2017-0059.
10. Said Al Magamsi, M., and H. Habib. "Clinical presentation of childhood type 1 diabetes mellitus in the Al-Madina region of Saudi Arabia."Pediatric Diabetes 5.2(2004) pp. 95-98. https://doi.org/10.1111/j.1399-543X.2004.00046.x.
11. Sayed, M. H., et al. "Risk factors and predictors of uncontrolled hyperglycemia and diabetic ketoacidosis in children and adolescents with type 1 diabetes mellitus in Jeddah, western Saudi Arabia." Journal of Diabetes 9.2 (2017)
12. https://doi.org/10.1111/1753-0407.12404.
13. Al-Agha, A., et al. "Metabolic control in children and adolescents with insulin-dependent diabetes mellitus at King Abdul-Aziz University Hospital." Journal of Clinical Research in Pediatric Endocrinology 3.4 (2011) 202-207. doi:10.4274/jcrpe.415.
14. Umpierrez, G. E. "Hyperglycemic crises: diabetic ketoacidosis and hyperglycemic hyperosmolar state." Diabetes Complications, Comorbidities and Related Disorders, 2020, pp. 595-614. https://link.springer.com/referenceworkentry/10.1007/978-3-030-36694-0_21
15. Dhatariya, Ketan K., et al. "Diabetic ketoacidosis." *Nature Reviews Disease Primers* 6.1 (2020): 40. https://doi.org/10.1038/s41572-020-0165-1.
16. Maletkovic, Jelena, and Andrew Drexler. "Diabetic ketoacidosis and hyperglycemic hyperosmolar state." *Endocrinology and Metabolism Clinics* 42.4 (2013): 677-695. DOI: 10.1016/j.ecl.2013.07.001
17. Duca, L. M., et al. "Diabetic ketoacidosis at diagnosis of type 1 diabetes predicts poor long-term glycemic control." Diabetes Care, 40.9,(2017)1249-1255. https://doi.org/10.2337/dc17-0558.
18. Al-Hayek, Ayman A., et al. "Assessment of health-related quality of life among adolescents with type 1 diabetes mellitus in Saudi Arabia." *Saudi Med J* 35.7 (2014): 712-7.
19. Ahmed, Ahmed M., et al. "Reduced frequency and severity of ketoacidosis at diagnosis of childhood type 1 diabetes in Northwest Saudi Arabia." *Journal of Pediatric Endocrinology and Metabolism* 29.3 (2016): 259-264. https://doi.org/10.1515/jpem-2015-0077
20. Al Shaikh, A., et al. "Incidence of diabetic ketoacidosis in newly diagnosed type 1 diabetes children in western Saudi Arabia: 11-year experience." Journal of Pediatric Endocrinology and Metabolism 32.8, (2019) 857-862. https://doi.org/10.1515/jpem-2018-0548.
21. Habib, Hamid Saeed. "Frequency and clinical characteristics of ketoacidosis at onset of childhood type 1 diabetes mellitus in Northwest Saudi Arabia." *Saudi medical journal* 26.1 (2005).
22. Batwa, Mawaddah, et al. "Diabetic ketoacidosis at the onset of type 1 diabetes mellitus among children and adolescents in Jeddah, Saudi Arabia: A study from the emergency department." *Cureus* 14.4 (2022). doi: 10.7759/cureus.24456
23. Albishi, L. A., et al. "Clinical demographic patterns of type 1 diabetes in Saudi children in Tabuk City, 2000-2010." *Journal of Diabetes Mellitus 7.2(2017) 41-54.

https://doi.org/10.4236/jdm.2017.72004.

24. Babiker, Amir, et al. "Frequency and risk factors of diabetic ketoacidosis in a specialized children's hospital, Riyadh: a cross-sectional study." *Oman Medical Journal* 37.1 (2022): e341. doi: 10.5001/omj.2021.124
25. Satti, S. A., et al. "Diabetic ketoacidosis in children admitted to pediatric intensive care unit of King Fahad hospital, Al-Baha, Saudi Arabia: precipitating factors, epidemiological parameters and clinical presentation." Sudanese Journal of Paediatrics 13.2(2013) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4949937/.
26. Kitabchi, Abbas E., et al. "Hyperglycemic crises in adult patients with diabetes." *Diabetes care* 32.7 (2009): 1335. doi: 10.2337/dc09-9032
27. Al Hayek, Ayman A., et al. "Factors associated with the presence of diabetic ketoacidosis: A retrospective analysis of patients with type 1 diabetes in Saudi Arabia." *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* 14.6 (2020): 2117-2122. https://doi.org/10.1016/j.dsx.2020.11.002