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Original Article

THE USE OF ANALOG INSULIN AND BLOOD KETONE LEVELS IN PATIENTS WITH TYPE 1 DIABETIC KETOACIDOSIS: A RETROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Objective: The objective of this study is to examine the sociodemographic factors associated with ketoacidosis events in these patients and describe the effect of analog insulin and blood ketone levels on the occurrence of ketoacidosis.

Methods: A retrospective observational study was conducted at Dr. M. Djamil Padang Hospital with a cross-sectional approach. Participants included in the study were all Diabetic Patients with Diabetic Ketoacidosis admitted from 2019 to 2023. The method employed was total sampling based on predefined inclusion and exclusion criteria. Data analysis was performed using univariate and bivariate methods and also, multivariate analysis is used to identify confounding factors. A descriptive analysis was presented for analog insulin and the blood ketone levels. Ethical approval for the study was obtained from Health Research Ethics Committee, Dr. M. Djamil Padang Hospital, West Sumatra, Indonesia (No: DP.04.03/D. XVI. XI/118/2024).

Results: 35 patients of type 1 diabetic ketoacidosis were included in this study. All patients were treated with analog insulin therapy, specifically a combination of Levemir and Novorapid. The predominant sociodemographic group comprised adolescents aged 10–18 y (62.8%), with a mean age of 12.4 y. The majority of patients were female (54.2%) and had a primary education level (80%). However, the findings revealed that 25 of the 35 patients (71.42%) achieved normal ketone levels after receiving analog insulin therapy, while 10 patients (28.57%) did not normalize their ketone levels. 85.7% patients had comorbidities which the majority are Urinary Tract Infections and Bronchopneumonia.

Conclusion: Analog insulin therapy was effective in normalizing blood ketone levels in 71.42% of patients, though 28.57% did not achieve normalization. Age have a partial impact on the normalization of blood ketone levels in diabetic ketoacidosis patients, while education level, gender and comorbidities show no significant influence.

Keywords: Type 1 diabetes mellitus, Ketoacidosis, Insulin, Ketone levels, Effect

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INTRODUCTION

According to estimates by the International Diabetes Federation (IDF), the number of people with diabetes worldwide reached 425 million in 2017, increasing to 463 million in 2019. This fig. is projected to continue rising to 578 million by 2030. Southeast Asia ranks third in terms of diabetes prevalence globally, with a rate of 11.3%. Indonesia is the only Southeast Asian country included among the top ten countries with the highest number of diabetes cases, with around 10.7 million people affected. As a result, Indonesia significantly contributes to the diabetes burden in Southeast Asia. The prevalence of diabetes in Indonesia also rose, from 6.9% in 2013 to 8.5% in 2018, according to Riskesdas 2018 data [1].

According to Waleed's 2022 research, 41.7% of individuals newly diagnosed with Type 1 Diabetes Mellitus (DM) experienced Diabetic Ketoacidosis (DKA), with 61.6% classified as severe DKA and 38.4% as moderate DKA. Waleed also identified a significant increase in biochemical indices, including elevated ketone levels, in patients with diabetic ketoacidosis. DM has the potential to trigger DKA, a life-threatening condition. People with Type 1 diabetes are at a higher risk of developing DKA compared to those with Type 2 diabetes, particularly due to non-compliance with therapy. Faisal's 2020 research found that the incidence of ketoacidosis was more common among women and adolescents, with the majority of these adolescents having primary levels of education [2].

To reduce the prevalence of DM, patient treatment is evaluated with the hope that while DM cannot be cured, it can be controlled, improving the quality of life for patients receiving insulin therapy. Therefore, the researchers are interested in pursuing this study.

MATERIALS AND METHODS

Research design

This study is a retrospective observational study utilizing a cross-sectional approach. The primary instruments employed were patient medical records, particularly focusing on laboratory test results and drug administration details.

Patient criteria

The population in this study comprised all patients with type 1 diabetes mellitus treated at M. Djamil Padang Hospital from 2019 to 2023. The study applied a total sampling technique, including participants who satisfied the established inclusion and exclusion criteria. The inclusion criteria encompassed patients with type I diabetes mellitus experiencing ketoacidosis who underwent analog insulin therapy and had complete ketone test results. Patients with incomplete ketone body test data were excluded from the study.

Study variables

This study includes independent variables such as sociodemographic factors (age, gender, education level, and presence of comorbid diseases). The dependent variable in this study is the ketone levels after analog insulin therapy. Ketone levels are categorized into two groups: normal, indicated by a negative blood ketone test result, and abnormal, indicated by a positive blood ketone test result.

Data analysis

Univariate analysis was applied to each variable in the study to determine the distribution and percentage of each. The independent variables were presented in a distribution table, displaying the frequency and percentage for each. While a descriptive analysis was conducted to present analog insulin therapy and blood ketone levels in patients with type 1 Diabetes Mellitus Ketoacidosis. Then, multivariate analysis is used to identify confounding factors.

Ethical approval

This research received ethical approval from Health Research Ethics Committee, Dr. M. Djamil Padang Hospital, West Sumatra, Indonesia (No: DP.04.03/D. XVI. XI/118/2024).

RESULTS

In this study, there were 50 type I diabetes mellitus patients who experienced ketoacidosis. However, 15 patients were excluded due to missing laboratory data, particularly blood ketone level analysis. Therefore, 35 patients met the inclusion and exclusion criteria and were included as subjects in this study. Table 1 describes the distribution of the sociodemographic factors of Diabetic Ketoacidosis (DKA) Patients.

Table 1: The sociodemographic factors of diabetic ketoacidosis patients

Sociodemographics factors	Category	Number of patients (n=35)	Percentage (%)
Age	Babies and toddlers (<5 y)	2	5.7
	Children (5-9 y)	6	17.14
	Teenager (10-18 y)	23	65.7
	Adult (19-59 y)	4	11.4
Overall (Mean±SD)	12.4±5.19		
Gender	Male	17	48.5
	Female	18	51.4
Educational Level	Primary	28	80
	Secondary	7	20
	University/Higher Education	0	0

Table 2 describes keton levels after analog insulin therapy in DKA Patients. The study results indicated that 25 out of 35 patients (71.42%) successfully achieved normal ketone levels following insulin therapy, while 10 patients (28.57%) did not reach normal ketone levels.

Table 2: Ketone levels after analog insulin therapy

Keton levels	Number of patients (n=35)	Percentage (%)
Normal	25	71.42
Abnormal	10	28.57

Table 3: Comorbidities factors of patients DKA

Comorbidities factors	Number of patients (n=35)	Percentage (%)
Exist	30	85.7
None	5	14.3

Table 4: Distribution of comorbid diseases in DKA patients

Comorbid diseases	Number of patients (n=30)	Percentage (%)
Acute Kidney Injury	6	20
Sepsis	3	10
Bronchopneumonia	8	26.7
Urinary Tract Infection (UTI)	8	26.7
Community-acquired pneumonia (CAP)	3	10
Obesitas	1	3.3
Candidiasis Vulvaganilis	1	3.3

In multivariate analysis, it is essential that the data be dichotomous and categorical, meaning it is categorized into two groups of comorbidities: infectious diseases and non-infectious diseases. Fig. 1 showed that comorbidities are predominantly infectious diseases, accounting for 77%, while non-infectious diseases make up 23%.

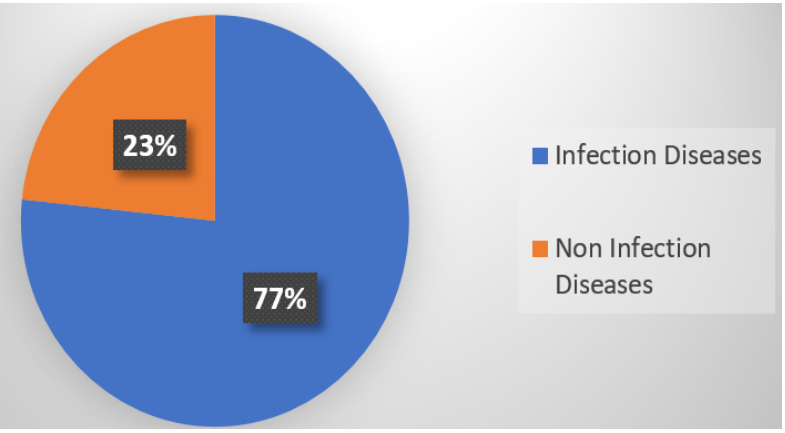

Fig. 1: Comorbid disease categories in DKA patients

Table 5: The multivariate analysis of keton level and sociodemographic and comorbidities factors in DKA patients

Variable		p-value	OR	95% C. I.	
				Lower	Upper
Step 1[a]	Gender	0.945	0.931	0.123	7.056
	Age (Year)	0.036	1.411	1.023	1.946
	Education level	0.076	0.042	0.001	1.397
	Comorbidities	0.875	0.840	0.096	7.382
Step 2[a]	Age (Year)	0.034	1.412	1.026	1.944
	Education level	0.075	0.043	0.001	1.373
	Comorbidities	0.887	0.861	0.110	6.738
Step 3[a]	Age (Year)	0.035	1.411	1.024	1.946
	Education level	0.076	0.044	0.001	1.394

DISCUSSION

In this study, data were collected from type 1 Diabetes Mellitus patients who experienced ketoacidosis and received analog insulin therapy. The data included gender, education level, age, comorbidities, the most recent ketone examination. There were 90 type 1 diabetes mellitus patients, and after reviewing the medical records, 50 patients had experienced ketoacidosis. However, 15 patients were excluded due to incomplete data, such as missing laboratory examination results. A total of 35 patients had complete medical records and became the subjects of this study.

The ketone data used in this study were from the most recent ketone examination during a single hospitalization when the patient experienced a recurrence of ketoacidosis. The patients included had received insulin therapy. When collecting this data, the researcher also confirmed the type of insulin administered to determine the most commonly used insulin for Type 1 diabetes mellitus patients experiencing ketoacidosis at Dr. M. Djamil Padang Hospital. Once the data were collected, they were analyzed using univariate, bivariate and multivariate analysis to identify confounding factors.

Sociodemographic factors of type 1 diabetic ketoacidosis patients

Sociodemographic factors, including age, gender, and education level, were obtained from type 1 diabetes mellitus patients who experienced ketoacidosis at Dr. M. Djamil Padang Hospital. This data was retrieved from the medical records of these patients.

The study found that 17.14% of pediatric patients with type 1 diabetes mellitus experienced ketoacidosis, 65.7% were adolescents and 11.4% were adults with a mean age of 12.4 y (table 1). The results indicate that the majority of patients were adolescents. This is likely because the first episode of diabetic ketoacidosis (DKA) often occurs during adolescence, and adherence to insulin therapy is typically lower at this age. Therefore, comprehensive education for both patients and parents, as well as appropriate therapy, is crucial. Preventing DKA requires proper and effective management of diabetes mellitus.

The results of this study are consistent with a study by Tamara (2020), which found that the adolescent age group had the highest incidence of ketoacidosis, at 48.72%. This indicates that the majority of patients with ketoacidosis are female and adolescents. The International Society for Pediatric and Adolescent Diabetes (ISPAD) states that being an adolescent is one of the risk factors for DKA [3].

The data in the table 1 shows that out of 35 type 1 diabetes mellitus patients who experienced ketoacidosis while using insulin therapy, 17 were male (48.5%) and 18 were female (51.4%). These results align with research by Dewata *et al.* (2020), which found that women experienced more DKA, with percentages ranging from 52.47% to 66.67% (4). However, other studies found that men experienced more DKA than women, with a percentage of 58.5% [4].

Female are believed to be at higher risk for diabetic ketoacidosis (DKA) because their bodies tend to store more fat, which increases the risk of obesity and diabetes. Additionally, female are 30 times more likely than male to experience urinary tract infections, and according to the European Association of Urology (2018), nearly half of all female will experience an episode of cystitis at least once in their lifetime. This infection is one of the most common triggers of DKA, as noted in several studies. Beyond biological factors, mental health issues such as depression are also more common in female than in male [5].

Based on the table 1, it can be seen that the majority of patients have primary education levels (80%), which includes, consisting of no formal education, elementary school, and junior high school education, while 20% of patient have secondary education levels, it includes high school or vocational school. The level of education significantly influences changes in attitudes and healthy living behaviors. Patients with primary levels of education may find it difficult to receive and understand health information, which can affect their ability to address and manage their health problems effectively. Primary education levels may be linked to challenges in managing diabetes, potentially increasing the risk of DKA, which is education level is just one of several influencing factors [6].

Ketone levels

Table 2 showed that the results of this study indicate that 25 patients (71.42%) out of 35 managed to achieve normal ketone levels after receiving insulin analog therapy, while 10 patients (28.57%) did not achieve normal ketone levels. Among the 10 patients who did not reach normal ketone levels, several factors were identified. According to the medical records and hospital discharge summaries, these patients were sent home despite not achieving normal ketone levels because their clinical conditions were assessed as improved. Additionally, they were considered to have a good understanding of diabetes management and how to handle high ketone levels. In general, these patients have comorbid infections and Acute Kidney Injury (AKI). Infections are a major trigger for DKA as they increase stress hormones like cortisol, which antagonize insulin and worsen ketone production. Severe infections may delay metabolic recovery. Beside that, AKI reduces the renal clearance of ketones, prolonging their presence in the blood. Dehydration and electrolyte imbalances, common in AKI, further hinder DKA resolution [28].

A study conducted by Kanikarla shows that high ketone levels are associated with a reduction in the number of insulin receptors on the cell surface, which leads to increased insulin resistance [8]. According to research by Putu N *et al.* in 2023, insulin therapy affects ketone levels by inhibiting lipolysis and stimulating lipogenesis. Insulin inhibits ketogenesis by triggering the dephosphorylation of hormone-sensitive lipase and activating lipogenesis through the stimulation of acetyl CoA carboxylase. In adipocytes, the dephosphorylation of hormone-sensitive lipase inhibits the breakdown of triglycerides into fatty acids and glycerol. This results in a decrease in the substrate available for ketogenesis, leading to negative ketone results in the urine [7].

Analog insulin

In this study, it can be observed that RSUP Dr. M. Djamil Padang uses Levemir and Novorapid, where Levemir is a long-acting analog insulin and Novorapid is a rapid-acting analog insulin. The results of this study align with research conducted by Trivanka in 2021, which states that insulin use patterns include both rapid-acting and long-acting insulins. Short-acting and intermediate-acting insulins are not used because they have longer onset and duration of action

compared to rapid-acting insulin. Human insulin, which falls into the short-acting and intermediate-acting categories, tends to increase the risk of hypoglycemia due to its longer duration of action, potentially causing a significant decrease in glucose levels. This results in a higher risk of hypoglycaemia [8]. Insulin prevents the formation of ketones and helps convert ketones into bicarbonate. In recent years, randomized controlled trials in children with diabetic ketoacidosis (DKA) have shown that injections of analog insulins are an effective treatment for DKA [9].

This study did not evaluate patient adherence to insulin injections. Assessing patient compliance would require a prospective approach, whereas this study was conducted retrospectively. This study did not assess whether insulin doses were appropriate for DKA patients because it used a retrospective design. Retrospective studies rely on existing records, which makes it difficult to evaluate treatment details such as insulin dosing or adjustments made during the acute phase of DKA. Proper assessment of insulin dosing usually requires real-time data collection in a prospective study, where patient responses and clinical conditions can be closely monitored and tailored.

Comorbidities factors

The results of the study showed that 85.7% of patients with type 1 diabetic ketoacidosis at Dr. M. Djamil Padang General Hospital had comorbidities, while 14.3% did not (table 3). Almost all DKA patients had comorbidities, including infections. These results are consistent with previous studies, which also identified infections as one of the most common triggering factors. The types of infections frequently observed include sepsis, urinary tract infections, and respiratory tract infections[10]. Based on the data in table 4, which describes the distribution of comorbidities diseases in DKA Patients, the majority are Urinary Tract Infections and Bronchopneumonia, which are included in infectious diseases. Around 77 % of DKA patients have comorbidities in infectious diseases (fig. 1).

In addition, the presence of infection can delay the detection of diabetic ketoacidosis (DKA) symptoms, leading to late recognition by patients and their families, which increases the risk of DKA. Patients with diabetes mellitus (DM) are particularly susceptible to infections because the condition puts them in an immunocompromised state [11]. Based on research and medical records, most patients with diabetic ketoacidosis (DKA) are found to be in a state of malnutrition. This is because many patients experiencing DKA are either having their first attack or have recently been diagnosed with type 1 diabetes mellitus. These new patients often have symptoms for less than two months before the DKA attack, such as polyphagia, polydipsia, and weight loss. This weight loss frequently leads to malnutrition [11].

Sociodemographic factors on ketone levels

Table 5 presents the results of the multivariate analysis examining the relationship between the dependent variable (blood ketone levels) and independent variables, including sociodemographic factors (gender, age, and education level) and comorbidities, categorized as infectious and non-infectious diseases. The analysis was conducted in three steps:

a. First Model: The initial model revealed that gender had the highest p-value and odds ratio (OR), leading to its exclusion from the subsequent steps. Age demonstrated a significant influence, with a p-value of 0.036, while the other variables were not significant.

b. Second Model: After excluding gender, comorbidities were found to have the highest p-value and OR, warranting their removal in the next step.

c. Third Model: In the final step, age maintained a significant relationship with blood ketone levels, with a p-value of 0.035 and an OR of 1.411. However, education level did not show a significant association with blood ketone levels.

These findings highlight age as the primary factor influencing blood ketone normalization in this analysis. These findings are relevant with research by Veauthier *et al.*, which age is an important factor in how blood ketone levels are affected in diabetic ketoacidosis (DKA). Younger children, particularly those under 2 y old, are more likely to develop DKA. Research shows that age significantly impacts how ketones are produced and how they return to normal levels [26]. This result is also in line with the study by Paul *et al., in* which the connection between age and the severity of diabetic ketoacidosis (DKA) highlights how important age is when evaluating both the risk and treatment for this condition. Younger individuals, particularly those under 2 y old, are at a higher risk for severe outcomes. Therefore, age must be carefully considered in DKA assessments and management strategies [27].

Based on the research results, a p-value of 0.945 was obtained for the gender variable in relation to ketone levels. This indicates that there is no influence of gender on ketone levels in type 1 diabetes mellitus patients experiencing ketoacidosis at Dr. M. Djamil Padang General Hospital. These findings are consistent with research conducted by Wang *et al.* in 2022, which reported a p-value of 0.3337. This suggests that gender does not affect ketone levels [13]. In this study, it can be seen that there is no influence on ketone levels from sociodemographic factors because ketone levels depend on comprehensive and coordinated care during patient hospitalization [14].

According to the study findings, a p-value of 0.076 was obtained for the education level variable in relation to ketone levels. This indicates that there is no influence of education level on ketone levels in hospitalized patients with type 1 diabetes mellitus experiencing ketoacidosis at Dr. M. Djamil Padang Hospital. These results differ from the study conducted by Han J *et al.* in 2020, which reported a p-value of 0.008. This suggests that education level does have an effect on ketone levels [12]. Education level has no effect on ketone levels because ketone levels depend on comprehensive and coordinated care during patient management [14].

In addition, the reason for the lack of influence between education level and ketone levels in this study may be that even patients with primary education can achieve normal ketone levels if they are compliant with their treatment [23]. Other studies suggest that education can influence behavior and motivation towards adopting healthier lifestyles. Primary education levels are often associated with less motivation to utilize health services, whereas higher education levels typically facilitate better access to and use of health information and services. Education is considered a predisposing factor that affects individuals' knowledge, attitudes towards health, and overall health behaviors [12].

Individual education has the potential to influence efforts to improve adherence to treatment. Since diabetes mellitus is a chronic disease associated with lifestyle, sufficient knowledge is crucial for changing attitudes and behaviors related to treatment. In pediatric care, the knowledge and understanding of parents or families are essential for ensuring adherence to the treatment plan. Since parents typically oversee administering insulin and making key decisions about the child's care, their grasp of diabetes management—including insulin administration, dietary guidelines, and recognizing signs of hypoglycemia or DKA—is critical. Offering clear, easy-to-understand education and continuous support, customized for both the child and their family, can greatly enhance treatment outcomes and minimize the risk of complications [21].

Unfortunately, this study, conducted retrospectively while the patients were undergoing treatment, had limitations that prevented the collection of information about the parents' or families' understanding and the level of support they provided in administering insulin to their children at home.

Description of insulin therapy and ketone levels

The diagnosis of ketoacidosis can be confirmed by checking ketone levels. When a patient experiences ketoacidosis, the ketone test results are usually positive, indicating the presence of ketones in the blood or urine, which is an abnormal condition [15]. In this study, positive ketone test results were observed on the first day of treatment. The researcher aimed to evaluate the ketone test results on the last day of treatment after insulin therapy to determine whether the ketone levels had normalized.

Based on the study's results, analog insulin therapy has been shown to lower blood ketone levels, as evidenced by negative results in

blood ketone tests, indicating the absence of ketone compounds in the blood. This is shown by the results of blood ketone tests after administering analog insulin therapy to type 1 diabetic ketoacidosis patients. A total of 25 patients (71.42%) achieved normal ketone levels with negative test results, while 10 patients (28.57%) had abnormal levels with positive test results. These findings are consistent with the study by Vidyasagar *et al.* (2020), which stated that analog insulins are effective in the appropriate treatment of ketoacidosis [15].

Insulin works by inhibiting lipolysis (fat breakdown) and stimulating lipogenesis (fat formation). It also inhibits ketogenesis by activating the dephosphorylation of hormone-sensitive lipase and promotes lipogenesis through the stimulation of acetyl CoA carboxylase. In adipose cells, the dephosphorylation of hormone-sensitive lipase reduces the breakdown of triglycerides into fatty acids and glycerol, thereby decreasing the substrate available for ketogenesis. As a result, urine ketone tests are negative [15]. Improving medication adherence through patient education and preventing infections is essential to reduce DKA cases. Prompt administration of the correct insulin dose at the time of diagnosis can help shorten hospital stays. Blood sugar levels should be monitored hourly, and dextrose should be given to prevent hypoglycemia [22, 24].

Effect of comorbidities factors on ketone levels

According to the study findings in table 5, a p-value of 1.000 was obtained for the influence of comorbidities on ketone levels. This indicates that there is no significant effect of comorbidities on ketone levels in patients with type 1 diabetes mellitus experiencing ketoacidosis at Dr. M. Djamil Padang Hospital. These findings are consistent with a study conducted by Goetera *et al.* in 2020, which stated that successful management of ketoacidosis can be achieved in patients with comorbidities through proper management and routine monitoring [14].

In this study, there was no effect of insulin on achieving normal ketone levels because 21 patients with comorbidities were able to reach normal ketone levels. Despite having comorbidities, these patients achieved normal ketone levels due to the comprehensive and coordinated care provided by Dr. M. Djamil Padang Hospital. This thorough management likely accelerated their recovery process.

Apart from comorbidities, there are also triggering factors for ketoacidosis in type 1 diabetes mellitus. Several risk factors for diabetic ketoacidosis (DKA) in newly diagnosed cases include being very young (<2 y), delayed diagnosis, and low socioeconomic status, which leads to limited access to healthcare services. For patients already diagnosed with diabetes, risk factors for DKA include negligence in insulin use, poor metabolic control, a history of previous DKA episodes, acute gastroenteritis with persistent vomiting and difficulty maintaining hydration, mental disorders (including eating disorders), social challenges and difficult family conditions, females around puberty and adolescence, as well as those with limited access to medical services and failures in insulin pump therapy [18, 25].

The multivariate analysis of independent variables (table 5), including sociodemographic characteristics (gender, age, and education) and comorbidities, which may influence the dependent variable (blood ketone levels) in DKA patients, identified age as the most significant factor affecting ketone levels, with a p-value of 0.035 (<0.05). The highest odds ratio (OR) was 1.411, indicating that each additional year of age increases the likelihood of ketone level normalization by 41.1%. Education level does not have a significant impact on blood ketone levels in DKA patients. However, gender and comorbidities may serve as confounding variables, potentially influencing the relationship between age and blood ketone levels in these patients.

Genetic factors contributing to type 1 diabetes include an overexpression of human leukocyte antigens (HLA) in certain individuals. Environmental triggers can then activate an autoimmune response targeting pancreatic beta cell components identified as autoantigens, resulting in an autoimmune attack [20].

Identifying the causes that trigger ketoacidosis should be done as quickly as possible, and treatment must be initiated promptly to manage the condition effectively. Infections, particularly urinary tract infections and pneumonia are often primary triggers of ketoacidosis. When an infection occurs, cortisol and glucagon secretion increases, leading to elevated blood glucose levels. If an infection is suspected, appropriate laboratory tests should be performed immediately, and treatment should begin without delay. It is also crucial for doctors to identify other potential triggering factors [19].

In addition, type 1 diabetes mellitus can also be caused by a combination of genetic and environmental factors, leading to the progressive destruction of pancreatic cells and resulting in absolute insulin deficiency. Although the exact cause of type 1 diabetes is still not fully understood, it is widely accepted that immune factors, particularly the autoimmune destruction of pancreatic cells by T cells, play a major role in its pathogenesis [16]. In terms of genetic factors, HLA genes, which are the most variable genes in the human genome, play a key role in the development of type 1 diabetes mellitus (T1DM), particularly HLA class II genes expressed on antigen-presenting cells (APCs). When APCs present antigens from beta cells to the immune system, a chronic immunological response occurs due to the inefficient regulation of immune reactions, leading to the destruction of beta cells [17].

Future research should focus on evaluating parental knowledge, education, and support, as these factors may significantly influence adherence to insulin therapy and the effective management of DKA, particularly in younger patients. Understanding the role of parents in ensuring treatment compliance and providing appropriate care could help improve outcomes in this vulnerable group. Parents identified four key periods during the first year following a type 1 diabetic (T1D) diagnosis when education and psychosocial support would be beneficial. Psychosocial interventions are particularly impactful between 3–6 mo post-diagnosis, once parents have gained foundational T1D management skills. These findings highlight the importance of regular psychosocial assessments and accessible, scalable interventions to support parents during the critical first year after diagnosis [29].

LIMITATION OF THIS STUDY

This study has several limitations. The sample size is relatively small due to the inclusion criteria, which significantly reduced the number of eligible participants, even though data was collected over a four-year period (2019–2023). Additionally, the retrospective approach used in the study limits its ability to evaluate real-time factors such as patient compliance or assess the appropriateness of insulin dosages administered. Future studies employing prospective designs with larger sample sizes could address these limitations to provide more comprehensive insights.

CONCLUSION

Analog insulin therapy successfully normalized blood ketone levels in 71.42% of patients, while 28.57% did not reach normal levels. Age have a partial impact on the normalization of blood ketone levels in diabetic ketoacidosis patients, while education level, gender and comorbidities show no significant influence.

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AUTHORS CONTRIBUTIONS

RY: Principal Investigator, Conceptualization, Supervision, Writing-Original Draft, Revision Manuscript, YS: Supervision, Review and Editing; and AS: Data Collection, Writing-Original Draft. All authors approved the final version of the manuscript.

CONFLICT OF INTERESTS

There is no conflict of interest from all the authors.

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