ORIGINAL ARTICLE

GA/HbA1c Ratio Predicts the Occurrence of Diabetic Ketoacidosis and Disease Severity in Children with Type 1 Diabetes Mellitus

Wei Wang [1, *], LiHua Qiu [2, *], TianTian Li [3], DongMei Sun [4], Qi Cao [5]

These authors contributed equally to this work
[1] Department of Pediatrics, Shijiazhuang Fifth Hospital, Shijiazhuang City, Hebei Province, China
[2] Department of Pediatrics, Huaian Hospital of Huaian City, Huaian City, Jiangsu Province, China
[3] Department of Pediatrics, Yanshan People's Hospital, Cangzhou City, Hebei Province, China
[4] Department of Cardiovascular Medicine, Yanshan People's Hospital, Cangzhou City, Hebei Province, China
[5] Department of Pediatrics, The First People's Hospital of Nanning, Nanning City, Guangxi Zhuang Autonomous Region, China

SUMMARY

Background: **Pediatric type 1 diabetes mellitus (T1DM) is a significant endocrine condition, with diabetic ketoacidosis (DKA) posing a life-threatening risk. The aim of this study was to investigate the potential of the glycated albumin (GA) to glycosylated hemoglobin (HbA1c) ratio in predicting the occurrence of DKA and disease severity in children with T1DM.**

Methods: **In this study, 224 children with T1DM were retrospectively analyzed and divided into non-DKA group (n = 142) and DKA group (n = 82). The patients' GA and HbA1c levels as well as other related biochemical indexes were detected, and the GA/A1c ratio was calculated and analyzed for its correlation with the occurrence of DKA and disease severity. Meanwhile, the value of GA/A1c ratio in predicting DKA was evaluated by using the receiver operating characteristic curve and the area under the curve.**

Results: **In the DKA group, both GA and GA/A1c ratio were elevated, and patients with severe DKA had especially high GA/A1c ratio. GA/A1c ratio was effective in clinically predicting the occurrence and severity of DKA. Increased GA and GA/A1c ratio correlated with the high risk of DKA in T1DM patients. For T1DM patients, a greater GA/A1c ratio indicated a higher risk of DKA compared to GA. There was a linear relationship between GA/A1c ratio and DKA, and when the GA/A1c ratio was greater than 2.465, an increase in the GA/A1c ratio was positively correlated with a significant increase in the risk of developing DKA in T1DM.**

Conclusions: **GA/A1c ratio can be used as an effective indicator to predict the occurrence of DKA and its severity in pediatric T1DM patients, and the higher the GA/A1c ratio, the higher the risk of DKA and the severity of the disease in patients.**

(Clin. Lab. 2025;71:xx-xx. DOI: 10.7754/Clin.Lab.2024.241225)

Correspondence:
Qi Cao
Department of Pediatrics
The First People's Hospital of Nanning
No. 89, Qixing Road, Qingxiu District
Nanning City
Guangxi Zhuang Autonomous Region, 53001
China
Email: qicaodr@163.com

KEYWORDS

INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disease characterized by hyperglycemia caused by either insufficient insulin secretion or resistance to insulin [1]. Type 1 DM (T1DM) constitutes about 90% of DM

cases in children worldwide. The incidence rate of classical T1DM for all ages in China is estimated at 1.01 per 10 million, with the most common onset age being 10 to 14 years [2]. The incidence of DM in children under five is rising annually by 5 - 34%, with a noticeable shift towards younger age groups [3].

Currently, only about 15% of DM children in China have achieved glycemic control, and poor glycemic control can lead to acute complications of DM, such as diabetic ketoacidosis (DKA) or hyperosmolar hyperglycemia state. DKA occurs due to insufficient insulin secretion, accompanied by abnormal elevation of circulating insulin-antagonist hormones such as growth hormone, catecholamines, glucagon, and cortisol, which disrupts the balance of glucose, fats, proteins, electrolytes, and acid-base balance and leads to metabolic disorders, such as hyperglycemia, ketonemia, ketonuria, and acidosis [4].

In DKA, the buildup of acidic substances like ketone bodies and lactate leads to high anion gap (AG) metabolic toxicity [5]. This acidosis affects the affinity of albumin and hemoglobin for oxygen, which in turn affects tissue oxygen supply and energy metabolism. In addition, the disease stress state triggered by DKA secretes a large number of stress hormones, such as cortisol and epinephrine, which promote an increase in blood glucose, leading to an increase in glycated albumin (GA). Both GA and HbA1c measure blood glucose over time, with GA representing the average over 2 - 3 weeks and HbA1c reflecting a longer-term average. GA is an early Amadori-glycated protein between glucose and serum albumin, with a shorter change duration than HbA1c. It is superior to HbA1c in reflecting blood glucose fluctuations [6].

Elevated HbAc1 and blood pressure are associated with exacerbation of T1DM [7]. DKA at the time of diagnosis of DM in adolescents is associated with higher HbAc1 [8]. In the past few years, there has been an increasing interest in the potential role of GA, HbAc1, and particularly the GA/A1c ratio in managing DM. Studies have shown that the GA/A1c ratio may be associated with insulin sensitivity, insulin resistance, and the risk of microvascular complications. For example, GA and the GA/A1c ratio are markedly elevated in patients with insulin autoimmune syndrome who possess insulin antibody affinity (InsAb), as opposed to those who are InsAb-negative [9]. In addition, GA is associated with retinopathy in DM patients [10]. Nonetheless, a meta-analysis highlighted that the occurrence of DKA in children with T1DM and severe COVID-19 did not show a correlation with HbAc1 [11].

Children are more prone to treatment noncompliance due to their limited cognitive ability and self-management of the disease, thus increasing the risk of DKA. Therefore, improving DM care in children requires finding biomarkers that can predict DKA's onset and severity at an early stage.

Given the context, this study aimed to explore the potential of the GA/A1c ratio as a biomarker for predicting the onset and severity of DKA in children with T1DM.

MATERIALS AND METHODS

Study population

Information was gathered by accessing and reviewing the medical records in Shijiazhuang Fifth Hospital, with the search criteria of age ≤ 18 years and the date of hospitalization or arrival to monitor the disease progression from December 1, 2020, through June 1, 2024. Included patients met the World Health Organization diagnostic criteria for T1DM. Inclusion criteria: 1) T1DM diagnosis met the relevant criteria in the Expert Consensus on the Standardized Diagnosis and Management of Type 1 Diabetes Mellitus in Chinese Children (2020) [12]; 2) DKA developed following a diagnosis of T1DM, and the diagnostic standards matched those outlined in the Guideline for the Management of Diabetic Ketoacidosis in Children (2009), i.e. blood glucose > 11.1 mmol/L, venous blood pH < 7.3, or HCO_3- < 15 mmol/L, ketonemia and ketonuria; and 3) clinical data were complete. Exclusion criteria: 1) organ failure and 2) chronic complications other than DKA, such as T1DM peripheral neuropathy, T1DM peripheral vasculopathy, T1DM ophthalmopathy, and T1DM nephropathy.

A total of 224 children with T1DM, aged 2 - 18 years old, were included, out of which 82 (36.61%) children had DKA, and 142 (63.39%) were diagnosed with T1DM only. The study was approved by the Shijiazhuang Fifth Hospital research ethical review board, and informed consent was waived.

The following information were obtained from the database: general data (age, gender, family history of DM, duration of T1DM) and laboratory information (white blood count [WBC], hematocrit, platelet count, plasma pH at admission, plasma osmolality, bicarbonate [HCO_3-], sodium [Na], potassium, chloride [Cl], AG [Na-CI-HCO_3-], blood urea nitrogen [BUN], creatinine, C-reactive protein, random blood glucose values, GA, and HbAc1). GA/HbAc1 ratio was calculated.

DKA disease severity was further differentiated according to pH and HCO_3- [13]. Mild: pH < 7.3, or HCO_3- < 15 mmol/L; moderate: pH < 7.2, or HCO_3- < 10 mmol/L; severe: pH < 7.1, or HCO_3- < 5 mmol/L.

Statistical analysis

The sample size of the study was estimated using G*Power software version 3.1.9.2 with a significance level of $\alpha = 0.05$, power of $1-\beta = 0.8$, effect size of d = 0.5, and two-sided tests were performed. Statistical analyses were performed using SPSS 20.0 software (IBM, NY, USA). The Shapiro-Wilk test was used to determine the normality of the data. For the normal distribution, measurement data were shown as mean ± standard deviation and comparatively analyzed by Student's t-test; for the skewed distribution, data were shown as

Table 1. Clinical characteristics of DKA and non-DKA patients.

Indices	Non-DKA (n = 142)	DKA (n = 82)	p
Age, years	11.2 ± 4.2	9.4 ± 3.8	< 0.001
Gender, male/female	74/68	39/43	0.512
Family history of DM	21 (14.79)	12 (14.63)	0.975
DM duration, months	3 [0.5, 24.6]	2 [0.2, 13.8]	< 0.001
WBC (10^3/mm^3)	9.4 [4.0, 12.4]	10.2 [4.0, 19.6]	< 0.001
Hematocrit level (%)	41.6 [36.2, 46.2]	40.2 [35.6, 47.5]	0.925
Platelet, mm^3	227 [156, 299]	289 [176, 462]	< 0.001
Plasma pH (at admission)	7.39 ± 0.11	7.16 ± 0.12	< 0.001
Mean osmolality mOsm/Kg (at admission)	298 ± 11.5	301.5 ± 10.3	0.726
HCO_3- mEq/L (at admission)	22.1 [22.5, 24.2]	10.0 [3.6, 17.6]	< 0.001
Na mEq/L	138.0 [134.0, 143.0]	128.0 [126.0, 140.0]	0.005
K mEq/L	4.2 [3.5, 5.6]	4.3 [3.2, 5.6]	0.51
Cl mEq/L	99.0 [98.0, 104.0]	98.0 [96.0, 104.0]	0.791
Anion gap mEq/L	13.2 [10.9, 14.2]	21.2 [12.3, 31.0]	< 0.001
BUN mg/dL	12 [10, 21]	16 [11, 22]	0.058
Creatinine mg/dL	0.7 [0.6, 0.9]	0.7 [0.4, 0.9]	0.764
DKA severity			
Mild	/	28 (34.15)	/
Moderate	/	22 (26.83)	/
Severe		32 (39.02)	/
CRP mg/dL	0.52 [0.42, 3.12]	0.61 [0.4, 3.22]	0.128
Random blood glucose (at admission) mmol/L	16.0 ± 7.2	20.6 ± 8.9	< 0.001
GA %	15.33 ± 1.89	15.69 ± 1.46	< 0.001
HbAc1 %	6.23 [5.61, 7.07]	6.33 [5.87, 6.62]	0.7011

Continuous data are displayed as X ± S or median (M1, M3). Categorical values are shown as n (%). Student's *t*-test or Mann-Whitney U test was used to assess the differences between the continuous values of the two groups. Chi-squared test was used to assess the differences in categorical variables.
DM - diabetes mellitus, WBC - white blood cell count, HCO$_3$- - bicarbonate, BUN - blood urea nitrogen, DKA - diabetic ketoacidosis, GA - glycated albumin, HbAc1 - glycosylated hemoglobin. p < 0.05 was statistically significant.

median (M1, M3) and analyzed by Mann-Whitney U-test. Count data were expressed as frequency (n) and rate (%) and were tested using chi-squared test. The value of GA and GA/A1c ratio in differentiating patients with DKA from those with non-DKA or in differentiating patients with mild-moderate and severe DKA was evaluated by using the receiver operating characteristic curve (ROC) and area under the curve (AUC). The cutoff values obtained from the curves were also used to

calculate the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Using multivariate logistic regression with the non-DKA group as the reference, the correlation between the GA/A1c ratio and the risk of developing DKA was assessed adjusting or not adjusting for confounders, and the odd ratio (OR) and 95% confidence interval (CI) were calculated. Restricted cubic spline curves (RCS) were plotted using the software package 4.0.5 for the R

3

Table 2. Cutoff value, sensitivity, and specificity of GA and GA/A1c ratio in differentiating DKA and DKA severity.

Distinguished categories	Index	AUC (95% CI)	p	Cutoff	Sensitivity %	Specificity %	PPV %	NPV %
DKA and non-DK	GA	0.743 (0.678 - 0.809)	< 0.001	16.85	60.98	78.17	39.22	63.79
	GA/A1c ratio	0.613 (0.537 - 0.689)	0.005	2.46	62.2	58.45	47.32	74.11
Mild-moderate and severe DKA	GA	0.733 (0.525 - 0.841)	0.001	15.25	87.5	58.82	56	87.5
	GA/A1c ratio	0.783 (0.679 - 0.887)	< 0.001	2.585	68.75	81	68.75	80

AUC - area under the curve, 95% CI - 95% confidence interval, PPV - positive predictive value, PPV - negative predictive value. p < 0.05 was statistically significant.

Table 3. Unadjusted and adjusted multivariate logistic regression analysis of the correlation between GA/A1c ratio and DKA.

	GA		GA/A1c ratio	
	OR (95% CI)	p	OR (95% CI)	p
Model 1	1.65 (1.33 - 2.05)	< 0.001	4.51 (1.09 - 18.73)	0.038
Model 2	1.58 (1.23 - 2.24)	< 0.001	3.45 (2.21 - 15.57)	0.066
Model 3	1.75 (1.34 - 2.62)	< 0.001	3.67 (2.57 - 15.95)	0.046

Model 1 - without any adjustment, Model 2 - after adjusting for age and gender, Model 3 - further adjusted for DM family history and DM duration. p < 0.05 was statistically significant.

Arbeit-PClanguage. Data were plotted using GraphPad Prism 8 (GraphPad, CA, USA). p < 0.05 was considered statistically significant.

RESULTS

Clinical characteristics of patients and GA/A1c ratio
Out of the 224 patients with T1DM, 113 (50.45%) were male and 111 (49.55%) were female. Table 1 shows the general demographics and routine laboratory indices of DKA and non-DKA patients. Patients in the non-DKA cohort were known to be older and had a longer duration of T1DM (p < 0.001). The DKA cohort had higher WBC and platelet counts at diagnosis (p < 0.001). The DKA cohort had lower plasma pH (p < 0.001), Na (p = 0.005), HCO_3- (p < 0.001), and higher AG (p < 0.001). In addition, patients with DKA had higher randomized glucose values and GA levels (both p < 0.001). We did not observe any significant difference between the two cohorts of children with hematocrit and plasma osmolality, which was due to the fact that the presence of acute renal impairment and clinical signs of cerebral edema was not detected in these patients at DKA diagnosis.
The GA/A1c ratio was lower in the non-DKA cohort than in the DKA cohort (Figure 1A, p < 0.001); of inter-est, the GA/A1c ratio was higher in patients with severe DKA than in those with mild and moderate DKA (Figure 1B, p < 0.001, p = 0.04). The GA/A1c ratio was marginally greater in patients with moderate DKA compared to those with mild DKA, but the difference was not statistically significant, and the small sample size might have impacted the robustness of this analysis.

Correlation analysis of GA, GA/A1c ratio, and DKA
Next, the value of GA and GA/A1c ratio in differentiating non-DKA from DKA and DKA severity was analyzed using ROC and AUC (Figure 2; Table 2). GA had a better discriminatory value than the GA/A1c ratio in non-DKA versus DKA (AUC, 0.743 vs. 0.613). However, PPV and NPV at a threshold value of 16.85% for GA were significantly lower than the threshold value of 2.46 for the GA/A1c ratio. In assessing the discriminatory value of mild-moderate and severe DKA, relative to GA, a GA/A1c ratio of 2.585% had higher AUC (0.783 vs. 0.733), specificity (81.00% vs. 58.82%), and PPV (68.7 % vs. 56.00%).
Table 3 shows the correlation between GA, GA/A1c ratio, and DKA after adjusting for confounders. The analysis, which adjusted for multiple variables including age, gender, family history of DM, and DM duration using a multifactorial logistic regression model, revealed that an increase in GA and GA/A1c ratio was associ-
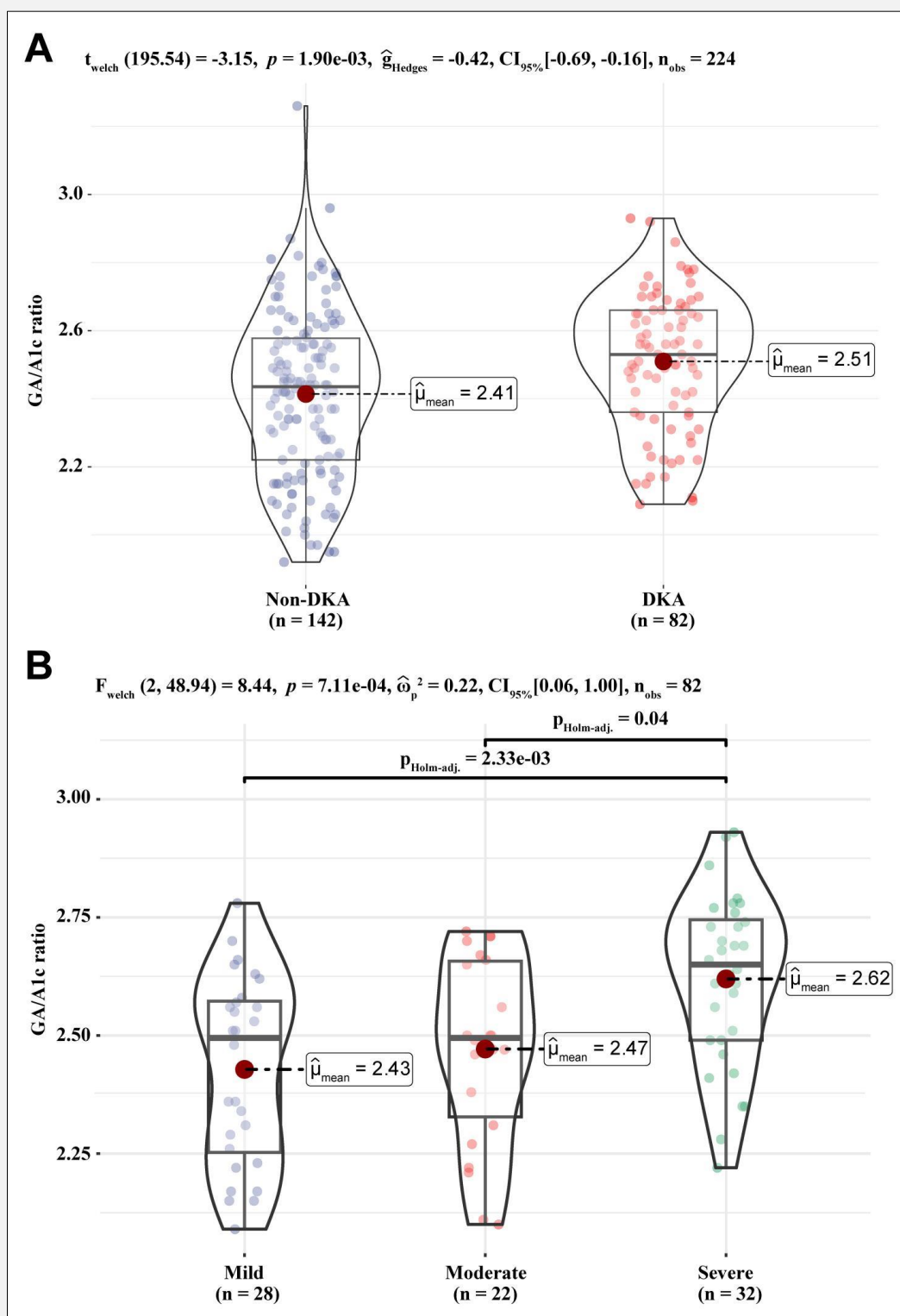
Figure 1. Comparison of GA/A1c ratios between groups of patients.

A - GA/A1c ratio in patients with DKA versus non-DKA. B - GA/A1c ratio in patients with mild, moderate, and severe DKA. μ_{mean} denotes the mean - F_{Welch} or t_{Welch} denotes the unequal variance F-test or t-test, g_{Hedges}, $CI_{95\%}$ denotes the effect size when the sample size of the study cohort is inconsistent, and when positive, there is a positive effect, and when negative, there is a negative effect. CI values that do not contain zero values indicate that the effect is statistically significant, i.e. the observed effect is unlikely to be due to chance. n_{obs} denotes the sample size.
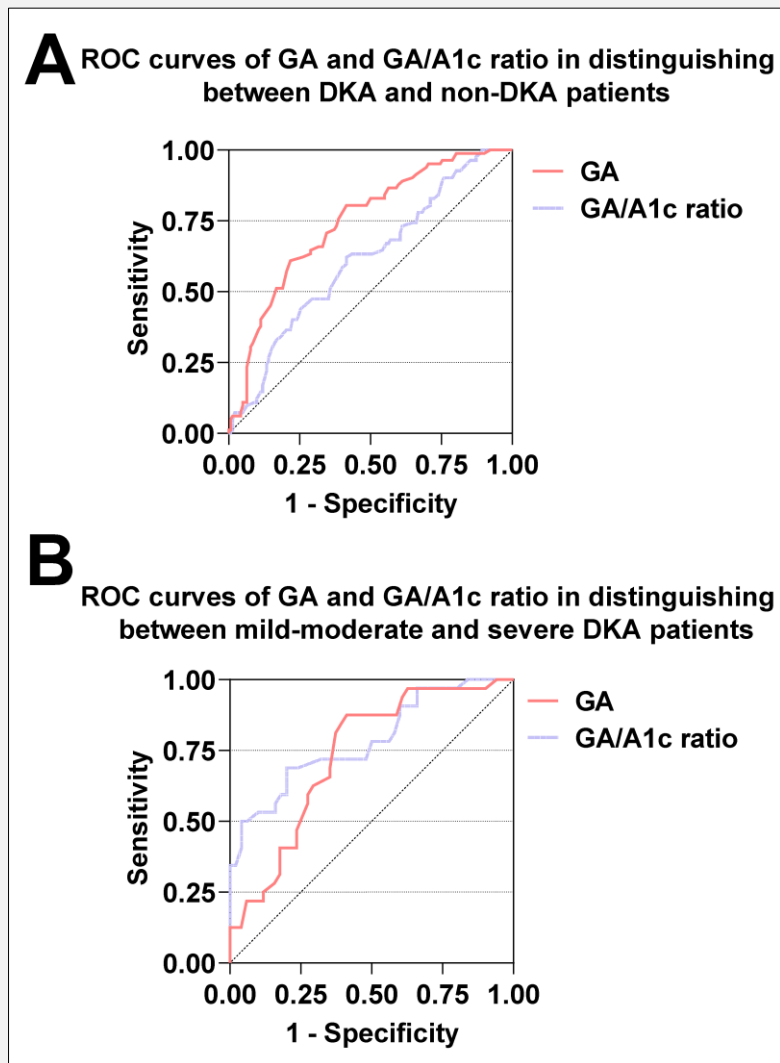
Figure 2. ROC curves of GA and GA/A1c ratio.

A - ROC curves of GA and GA/A1c ratio in distinguishing between DKA and non-DKA patients. B - ROC curves of GA and GA/A1c ratio in distinguishing between mild-moderate and severe DKA patients.

ated with a high risk of developing DKA in T1DM patients. GA was associated with the risk of developing DKA. Of interest, after adjustment for confounders, an elevated GA/A1c ratio indicated a higher risk of developing DKA in patients with T1DM compared with GA (OR, 95 CI% 3.67 [2.57 - 15.95] vs. 1.75 [1.34 - 2.62]). After adjusting for confounders, the RCS results showed that there was a linear relationship between the GA/A1c ratio and DKA (Figure 3), and an increase in the GA/A1c ratio was positively associated with a significant increase in the risk of developing DKA in T1DM when the GA/A1c ratio was greater than 2.465.

DISCUSSION

The aim of this study was to highlight the clinical characteristics of children with TIDM and DKA and to assess the association of the occurrence of DKA and disease severity with the GA/A1c ratio in these children. This study reported on children with T1DM who developed DKA, with DKA occurring in about one-third of the patients, and 39% of these cases were classified as severe. These DKA patients were characterized by younger age, shorter duration of DM, abnormalities in blood routine, and severe electrolyte disturbance, simi-
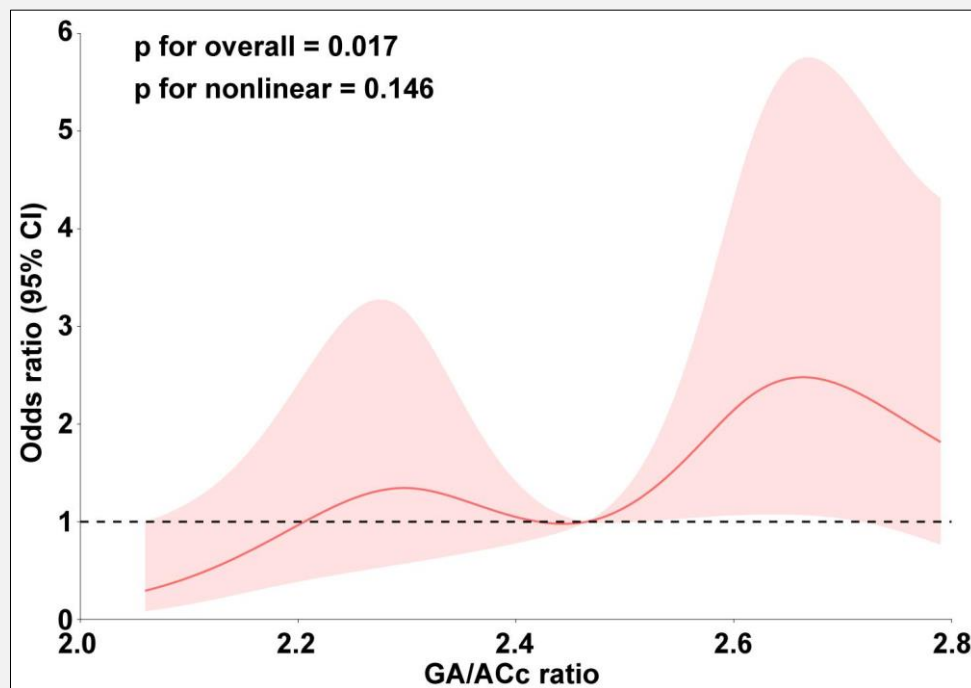
Figure 3. Analysis of the linear relationship between GA/A1c and the risk of DKA.

$P_{for\ overall}$ **is the p-value for the overall effect;** $P_{for\ nonlinear}$ **is the p-value for the nonlinear effect.**

lar to the clinical characteristics of children with DKA previously reported [14]. In addition, we observed leukocytosis in children with DKA on admission, which is common in DKA and does not indicate infection. The probable cause is attributed to disease stress with elevated levels of stress hormones [15]. DKA occurs when blood glucose control is poor, and high blood glucose leads to osmotic polydipsia, which in turn leads to hypovolemia. Unlike blood glucose, which reflects the immediate glycemic characteristics of the body and is easily influenced by multiple factors, HbAc1 and GA are less subject to fluctuations in external factors and better reflect the short-term average glycemic status of the body. In the present study, we did not observe a difference in HbAc1 between children with non-DKA and DKA. However, we observed that children with DKA had higher GA and GA/HbAc1 ratio and that children with severe DKA had higher GA/A1c ratio relative to children with mild-moderate disease. This suggests an association between an elevated GA/HbAc1 ratio and the risk of developing DKA in most children with T1DM.

The GA/HbAc1 ratio varies significantly among patients with different types of DM, especially in patients with acute-onset T1DM [16]. There is a strong correla-

tion between GA and HbAc1, which may be closely related to glycemic control in patients. In the context of DKA, monitoring the GA/HbAc1 ratio may help to better understand the metabolic status of patients. GA levels in DM patients may be significantly elevated at the onset of ketosis, whereas changes in HbA1c may be less sensitive than GA [17]. In addition, HbAc1 may be affected by other factors in some cases, such as erythrocyte longevity and HbAc1 variability. GA may have an advantage over HbAc1 in assessing glycemic control in DM patients, especially in the presence of other influencing factors [18]. This partly explains the phenomenon that there was no statistically significant difference in HbAc1 in DKA patients, but GA was significantly higher in DKA patients than in non-DKA patients. Therefore, assessing the GA/HbAc1 ratio may provide clinicians with more accurate information on DM management.

As the severity of DKA increases, the metabolic status of the patient deteriorates significantly, which may lead to an elevated GA/A1c ratio. It has been shown that GA/A1c ratio may be negatively correlated with factors such as body mass index and urinary albumin to creatinine ratio in patients with T1DM [19]. This suggests that GA/A1c ratio may have potential clinical value in

assessing cardiovascular risk and metabolic complications in DM patients. However, this study did not observe a statistical difference in BUN and creatinine in DKA patients versus non-DKA, although BUN levels were slightly higher in children with DKA. In hyperglycemia, osmotic polyuria occurs without early renal injury, and kidney function is restored to normal due to the kidneys' compensatory actions when the effect is reversed in a timely manner during hypoperfusion [20]. We did not observe these features with renal injury; however, this does not fully indicate the absence of renal injury. The GA/A1c ratio is also associated with the severity of nonalcoholic fatty liver disease in T2DM [21] and varies significantly with different urinary albumin excretion levels [22]. This suggests that changes in GA/A1c ratio may be associated with an early decline in renal function. The ROC results we obtained further highlighted the significance of the GA/A1c ratio for predicting DKA risk in children with T1DM. Compared to GA, GA/A1c ratio had a higher AUC in differentiating between mild to moderate and severe DKA. We believe that it is chronic hyperglycemia in patients with severe DKA that is associated with damage to various organ systems, including the kidneys. Earlier, we discussed that renal injury correlates with a higher GA/A1c ratio, and that ongoing hyperglycemia results in endothelial dysfunction and increased tissue susceptibility, which are indicative of microangiopathy [23]. However, the PPV of the GA/A1c ratio was higher in both differentiating DKA and severe DKA than in GA. Finally, multivariate logistic regression showed that elevated GA and GA/A1c ratio were risk factors for the development of DKA in patients with T1DM. The RCS results also confirmed a positive correlation between an increase in GA/A1c ratio and a significant increase in the risk for the development of DKA in T1DM when GA/A1c ratio was greater than 2.465.

There are several limitations to this study. First, given that this is a retrospective study with a relatively small sample size, the outcomes may be vulnerable to confounding errors and bias. Second, even though blood BUN and creatinine levels were not significantly increased in DKA patients, this does not rule out the presence of renal injury, and additional relevant indicators and clinical signs are necessary for comprehensive assessment. Third, GA and HbAc1 values for DKA patients are taken at the time they are diagnosed with DKA, not when T1DM is diagnosed. Finally, insulin pump therapy has an effect on HbAc1 levels in children with T1DM [24]; even though this study found no significant difference in HbAc1 between DKA and non-DKA, the possibility that it influences GA levels cannot be dismissed.

CONCLUSION

This study reveals that the risk of DKA in children with T1DM is associated with elevated GA and GA/A1c ratio.

Data Availability Statement:
Data is available from the corresponding author on request.

Ethical Approval Statement:
All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. All subjects were approved by Shijiazhuang Fifth Hospital (No. 201901HB-31).

Declaration of Interest:
The authors have no conflicts of interest to declare.

References:

1. Cho NH, Shaw JE, Karuranga S, et al. IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. Diabetes Res Clin Pract 2018;138:271-81. (PMID: 29496507)

2. Weng J, Zhou Z, Guo L, et al.; T1D China Study Group. Incidence of type 1 diabetes in China, 2010-13: population based study. BMJ 2018;360:j5295. (PMID: 29298776)

3. Iovane B, Cangelosi AM, Bonaccini I, et al. Diabetic ketoacidosis at the onset of Type 1 diabetes in young children Is it time to launch a tailored campaign for DKA prevention in children <5 years? Acta Biomed 2018;89(1):67-71. (PMID: 29633745)

4. Seo Y-J, Kum CD, Rho JG, Shim YS, Lee HS, Hwang JS. Comparison of the clinical characteristics and outcomes of pediatric patients with and without diabetic ketoacidosis at the time of type 1 diabetes diagnosis. Ann Pediatr Endocrinol Metab 2022;27(2): 126-33. (PMID: 35073669)

5. Sampani E, Sarafidis P, Dimitriadis C, et al. Severe euglycemic diabetic ketoacidosis of multifactorial etiology in a type 2 diabetic patient treated with empagliflozin: case report and literature review. BMC Nephrol 2020;21(1):276. (PMID: 32669085)

6. Shen Y, Lu L, Ding FH, et al. Association of increased serum glycated albumin levels with low coronary collateralization in type 2 diabetic patients with stable angina and chronic total occlusion. Cardiovasc Diabetol 2013;12:165. (PMID: 24209601)

7. Gregory JM, Slaughter JC, Duffus SH, et al. COVID-19 Severity Is Tripled in the Diabetes Community: A Prospective Analysis of the Pandemic's Impact in Type 1 and Type 2 Diabetes. Diabetes Care 2021;44(2):526-32. (PMID: 33268335)

8. Zaharieva DP, Ding VY, Addala A, et al. Diabetic Ketoacidosis at Diagnosis in Youth with Type 1 Diabetes Is Associated with a Higher Hemoglobin A1c Even with Intensive Insulin Management. Diabetes Technol Ther 2024;26(3):176-83. (PMID: 37955644)

9. Takeuchi T, Hirota Y, Nakagawa Y, et al. Glycated albumin (GA) and the GA/HbA1c ratio are higher in diabetic patients positive for insulin antibodies with high binding capacity and low affinity. Diabetol Int 2022;13(1):226-31. (PMID: 35059259)

10. Lee M-Y, Hsu W-H, Lai C-W, Chen S-C, Liang C-C. The association between glycated albumin, glycohemoglobin, and glycated albumin to glycohemoglobin ratio in diabetic retinopathy of prediabetes. Kaohsiung J Med Sci 2019;35(11):695-701. (PMID: 31483568)

11. Büttner BR, Tittel SR, Kamrath C, et al. Type 1 diabetes mellitus and SARS-CoV-2 in pediatric and adult patients - Data from the DPV network. J Diabetes 2022;14(11):758-66. (PMID: 36443963)

12. Subspecialty Group of Endocrinologic, Hereditary and Metabolic Diseases, the Society of Pediatrics, Chinese Medical Association; Editorial Board, Chinese Journal of Pediatrics. [Expert consensus on the standardized diagnosis and management of type 1 diabetes mellitus in Chinese children (2020)]. Zhonghua Er Ke Za Zhi 2020;58(6):447-54. (PMID: 32521955)

13. Maletkovic J, Drexler A. Diabetic ketoacidosis and hyperglycemic hyperosmolar state. Endocrinol Metab Clin North Am 2013; 42(4):677-95. (PMID: 24286946)

14. Del Pozo P, Aránguiz D, Córdova G, et al. Clinical profile of children with diabetic ketoacidosis in fifteen years of management in a Critical Care Unit. Rev Chil Pediatr 2018;89(4):491-8. (PMID: 30571823)

15. Stentz FB, Umpierrez GE, Cuervo R, Kitabchi AE. Proinflammatory cytokines, markers of cardiovascular risks, oxidative stress, and lipid peroxidation in patients with hyperglycemic crises. Diabetes 2004;53(8):2079-86. (PMID: 15277389)

16. Koga M, Murai J, Saito H, et al. Glycated albumin levels are higher relative to HbA1c levels in people with autoimmune acute-onset type 1 diabetes mellitus than in people with type 2 diabetes mellitus at the time of diagnosis. Diabetes Res Clin Pract 2011; 94(1):e12-4. (PMID: 21777990)

17. Suzuki S, Koga M, Amamiya S, et al. Glycated albumin but not HbA1c reflects glycaemic control in patients with neonatal diabetes mellitus. Diabetologia 2011;54(9):2247-53. (PMID: 21644010)

18. Jeon WS, Park SE, Rhee E-J, et al. The association of serum glycated albumin with the prevalence of diabetic retinopathy in Korean patients with type 2 diabetes mellitus. Diabetes Res Clin Pract 2016;116:46-53. (PMID: 27321316)

19. Kim W, Kim KJ, Lee B-W, Kang ES, Cha BS, Lee HC. The glycated albumin to glycated hemoglobin ratio might not be associated with carotid atherosclerosis in patients with type 1 diabetes. Diabetes Metab J 2014;38(6):456-63. (PMID: 25541609)

20. Ding F, Zhang S, Liu S, et al. Molecular Visualization of Early-Stage Acute Kidney Injury with a DNA Framework Nanodevice. Adv Sci (Weinh) 2022;9(20):e2105947. (PMID: 35508712)

21. Jung C-H, Lee B, Choi D-H, et al. Association of grade of non-alcoholic fatty liver disease and glycated albumin to glycated hemoglobin ratio in patients with type 2 diabetes mellitus. Diabetes Res Clin Pract 2017;125:53-61. (PMID: 28167326)

22. Katahira M, Hanakita M, Ito T, Suzuki M. The ratio of glycosylated albumin to glycosylated hemoglobin differs between type 2 diabetic patients with low normoalbuminuria and those with high normoalbuminuria or microalbuminuria. Diabetes Care 2013; 36(12):e207-8. (PMID: 24265377)

23. Marzuillo P, Iafusco D, Zanfardino A, et al. Acute Kidney Injury and Renal Tubular Damage in Children With Type 1 Diabetes Mellitus Onset. J Clin Endocrinol Metab 2021;106(7):e2720-37. (PMID: 33595665)

24. Piechowiak K, Szypowska A. Physiological factors influencing diabetes control in type 1 diabetes children with insulin pumps from diagnosis. Diabetes Metab Res Rev 2019;35(1):e3086. (PMID: 30325106)