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Assessment of Serum Levels of CA19-9 and Amylin in Relation to Glycemic Control in Type-2 Diabetic Patients

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Abstract

Both carbohydrate antigen 19-9 (CA19-9) and amylin are pancreatic biomarkers that are highly affected by the metabolic stress associated with diabetes.

Therefore, studying these two biomarkers reflects the metabolic status related to glycemic control.

A cross-sectional study was conducted on 108 patients with type 2 diabetes at the National Diabetes Center from October 2025 to April 2026. Patients were divided into two equal groups based on their glycemic control. ELISA was used to measure serum CA19-9 and amylin levels, and the diagnostic accuracy of these biomarkers was determined using the receiver operating characteristic (ROC) curve.

The results showed a significant increase in both CA19-9 and amylin in the group of patients with poor glycemic control ($p=0.001$), and a positive correlation was observed between CA19-9 and amylin in all patients ($r = 0.5219$, $p=0.0001$). Statistical analysis of the ROC curve demonstrated the high discriminatory power of CA19-9 and amylin in distinguishing between patients with good and poor glycemic control. This study concluded that poor glycemic control is strongly associated with elevated CA19-9 and amylin levels, as well as being interrelated, possibly due to the effect of glucose toxicity.

Therefore, the combined assessment of these biomarkers may provide additional clinical information for evaluating metabolic stress in patients with type 2 diabetes.

Keywords: Amylin, CA19-9, Glycemic Control, Type 2 Diabetes Mellitus.

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Introduction

Diabetes mellitus (DM) is a long-term disorder based on a disturbance in metabolic processes, in which the glucose metabolism is highly affected due to a defect in insulin function and/or secretion, making its serum level highly elevated, which is the basic feature in the diagnosis of all types of diabetes mellitus and the main cause of the subsequent complications associated with this disease (1-3). The cases of DM are increasing in numbers around the world, with type 2 being the most prevalent type, for which prevention and control are difficult (4).

Carbohydrate antigen 19-9 (CA19-9), also known as Sialyly-Lewis-a, was first noticed to be expressed on the cell surface of colon cancer cell lines, and after its discovery, it has been used as a tumor marker to diagnose and monitor gastrointestinal cancers, particularly pancreatic cancer. However, recent studies have indicated that serum CA 19-9 levels may also be elevated in non-malignant conditions, including diabetes mellitus, because it can also be produced normally by many epithelial cells in the pancreas, but the exact mechanism is not fully understood (5-9). However, it was suggested that during the pathogenesis of diabetes mellitus, the destruction in the pancreatic tissue due to a chronic inflammatory process in the pancreas, which results from the chronic elevation in serum glucose levels and poor glycemic control, was implicated in the elevation in serum levels of CA19-9, probably due to its release from destroyed pancreatic tissue (8,10,11). Besides that, it can reflect the presence of pancreatic dysfunction through reduction in insulin production and secretion, which in turn could affect the function of ductal cells of the pancreatic exocrine gland; hence, it could be used to give an idea about both endocrine and exocrine pancreatic dysfunction (10).

In this regard, clinical studies involving DM patients with type 2 showed that the serum levels of CA19-9 were strongly affected by the degree of glycemic control; however, it appeared to be dependent on the pathological process associated with the different types of DM, which were strongly involved in it (10-12).

Amylin, also known as "islet amyloid poly-peptide (IAPP)", is a peptide hormone with 37 amino acids that is co-secreted with insulin by pancreatic beta-cells in smaller quantities, therefore, it is considered as the main source for the amylin that appears in the circulation, Amylin plays a significant role in the regulation of serum glucose levels after meals through decreasing glucagon secretion from alpha cells, slowing the emptying of the stomach and thus promoting satiety (13-15). In healthy individuals, it is secreted as soluble monomers into the bloodstream and then removed by the kidneys; however, in diabetic patients, and due to different etiology, serum levels of Amylin will be so low in type 1 no matter it was a fasting or after meals due to the destruction of beta cell by the immune system that responsible for their secretions, while with type 2, it appeared to show what called compensatory elevation in its levels due to overproduction of amylin during the early stages and lost the ability of pancreatic cells to deal with normally, additionally it starts to aggregate by converting to insoluble oligomers which are called by “islet amyloid” that will deposit, and build up in the pancreas, causing a cytotoxic effect, leading to beta-cell destruction and finally lost which considered as one of the hallmark for type 2 (15-19). So, it could give an idea about the secretory function of the beta-cell based on the degree of destruction that is associated with DM (20-22). For that reason, the elevated serum levels of Amylin correlated with the

AIMCJ. (2026),3; (2): 142-156
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inadequate management of blood glucose, which increases its serum levels with insulin that occurs in order to compensate for this elevation (15).

The glycated haemoglobin (HbA1c) is commonly used for monitoring the adherence of patients to treatment, since it gives an idea about the average of serum glucose levels in the last 3 months; thus, it is considered a guide for long-term glucose toxicity (10,23). It has been used to determine if patients were well-controlled or not, in which patients with a value of HbA1c < 7% were considered well-controlled, while those with a value of ≥7% were poorly controlled in line with the American Diabetes Association guidelines (24).

In diabetes mellitus, the clinical explanation of elevated serum levels of CA19-9, a tumor marker which is commonly used for monitoring the ductal adenocarcinoma of the pancreas, could provide a challenge. Studying both CA19-9 and Amylin could provide further understanding of how the pancreatic dysfunction associated with type 2 diabetes mellitus affects their serum levels and the role of glycemic control in this, since both of these biomarkers are present in pancreatic tissues; thus, CA19-9 results could be clarified by measuring serum Amylin levels and vice versa.

Therefore, the study aims to evaluate and compare the serum levels of CA19-9 and Amylin in patients with type 2 diabetes mellitus in correlation to the extent of glycemic control.

Material and Methods:

Study design and Studied population

This study was designed to be a cross-sectional study and conducted between October 2025 and April 2026 at the National Diabetic Center (NDC)/ Mustansiriyah University, and the written approval to conduct this study was obtained from the research committee at Baghdad Health Directorate- Al-karkh Training and Human Development Center, no.206, dated August 12, 2025 which also included the ethical approval for all study procedures. one hundred and eight patients of both sexes with type-2 diabetes mellitus were involved after the explanation of the aim of this study, and verbal consent was obtained from the studied patients. The height and weight of those patients were measured to calculate the body mass index (BMI) using the equation (BMI = Weight (kg)/ Height(m2)). In addition to that, patients' medical history and socio-demographic information were obtained according to the study's questionnaire.

Inclusion criteria:

Fasting overnight, type 2 diabetic patients of both sexes above the age of 18 years.

Exclusion criteria:

Included type 2 diabetic patients who were non-fasting or on insulin therapy, other types of DM, patients with a history of recent infection or inflammation, thyroid dysfunction, pancreatitis, advanced liver disease, chronic renal disease, on chemotherapy or immunosuppression therapy, pregnant, and breastfeeding ladies.

Laboratory tests:

Fasting venous blood specimens of about 5 mL were obtained from the studied patients; about 2ml was used to determine glycated haemoglobin using the automated immunoturbidimetry method with a kit manufactured by Roche (Basel, Switzerland), and the remaining quantity (3ml) of whole blood was left for 15 minutes to clot, then it was subjected to centrifugation (3000 rpm for 10 minutes). The obtained serum was divided into two parts. To assessment of glycemic and lipid marker about 2 ml of sera was taken to performed the tests at the same day of blood collection the laboratory of NDC, using

AIMCJ. (2026),3; (2): 142-156
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the glucose oxidase method from a kits manufactured by Roche, (Basel, Switzerland) to assess fasting blood glucose (FBG) levels, triglyceride (enzymatic colorimetric method), cholesterol (enzymatic colorimetric method) and high-density lipoprotein- cholesterol (HDL-c) (direct homogenous method). The remaining amount of the sera (about 1ml) was frozen (-20 0C) to assess both CA19-9 (Human CA19-9 ELISA Kit, Cat: ELK1198) and Amylin (Human IAPP-AMYLIN ELISA Kit, Cat: ELK4831) using the ELISA technique by kits manufactured by ELK Biotechnology, Wuhan, China, later, when the collection of samples was completed.

Statistical Analysis:

The data of this study were analyzed using the statistical package of the social sciences SPSS 26, in which mean and standard deviation were obtained; GraphPad Prism and Excel were used to visualize the data; both an independent student's t-test and a Chi-square test were used for the categorical data evaluation. A one-way Analysis of Covariance (ANCOVA) was used to evaluate the differences between the main study biomarkers while controlling for the biochemical confounding factor, followed by pairwise comparison. Additionally, Receiver Operating Characteristic (ROC) analysis was used to evaluate the differentiation power of CA19-9 and Amylin. Binary logistic regression analyses were performed to evaluate the independent predictive value of serum CA19-9 and Amylin levels in determining the glycemic control status. A p-value of less than 0.05 was considered statistically significant.

Results:

A total of 108 patients with type 2 DM were included in this study, and they were divided into two equal groups (each of 54) based on their glycemic control, as shown in Figure 1.

The studied groups showed no statistically significant differences ($p>0.05$) regarding the socio-demographic characteristics of age, disease duration, sex, smoking status, and the clinical characteristics of Body Mass Index (BMI), as shown in Figures 2 and 3.

Figure 4 shows the clinical and biochemical characteristics of the studied patients, in which there was a highly significant elevation in the levels of the glycemic markers in patients whose glycemic control was poor as their fasting blood glucose (208.27±75.19) and HbA1c % (9.55 ±1.99) compared to those with good control in which the FBG was (132.51±33.94), and HbA1c (6.11±0.60) with a ($p= 0.001$). Moreover, regarding lipid profile, both triglycerides and cholesterol serum levels were significantly elevated in patients with poor glycemic control, with cholesterol (202±43.71), and triglyceride (163.31± 24.16), compared to those with good glycemic control (cholesterol levels (154.61±27.23), and triglyceride (111.07±24.47), ($p=0.001$). In contrast, the HDL-c levels were significantly elevated in patients with good glycemic control (51.07±19.10), compared to those with poor glycemic control (39.44±10.43) ($p=0.001$).

This study, as shown in Figure 5, shows a significant elevation in serum levels of CA19-9 (28.29±7.78) and Amylin (52.98±5.04) in the poor glycemic control group compared to the good glycemic control group, CA19-9 (15.10±3.52) and Amylin (31.90±7.20), with a $p= 0.001$.

This study shows no correlation between them in the patients of each of the studied groups (poor and good glycemic control), with $p= 0.9888$ and 0.7231, respectively.

AIMCJ. (2026),3; (2): 142-156
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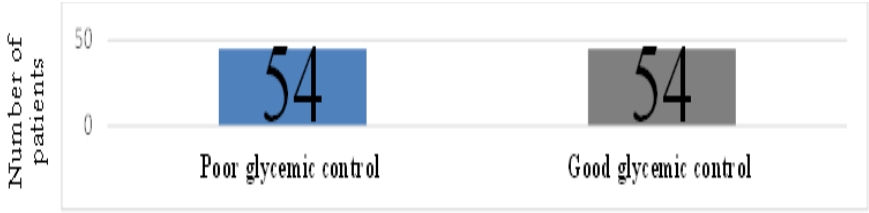

Figure 1: The distribution of the studied patients based on their glycemic control status (poor glycemic control group n=54, and good glycemic control group n=54).

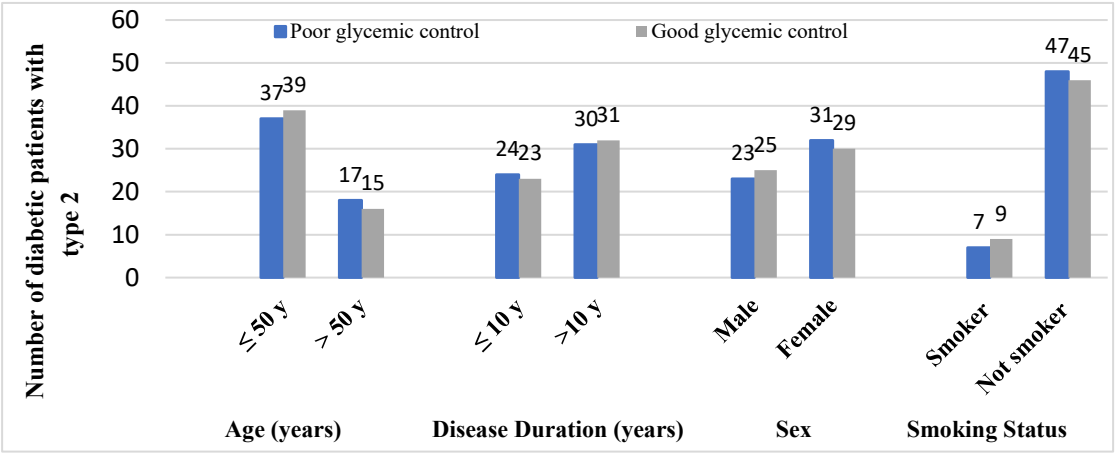

Figure 2: The demographic and clinical characteristics distribution among the studied patients.

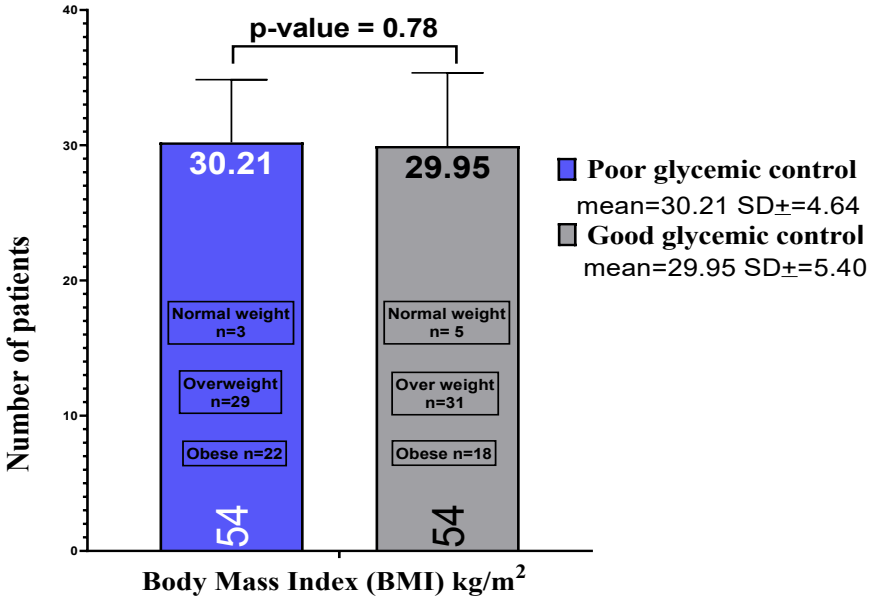

Figure 3: The distribution of BMI (kg/m2) among the patients of both groups.

AIMCJ. (2026),3; (2): 142-156
doi.org/10.58564/AIMCJ3.2.2026.322

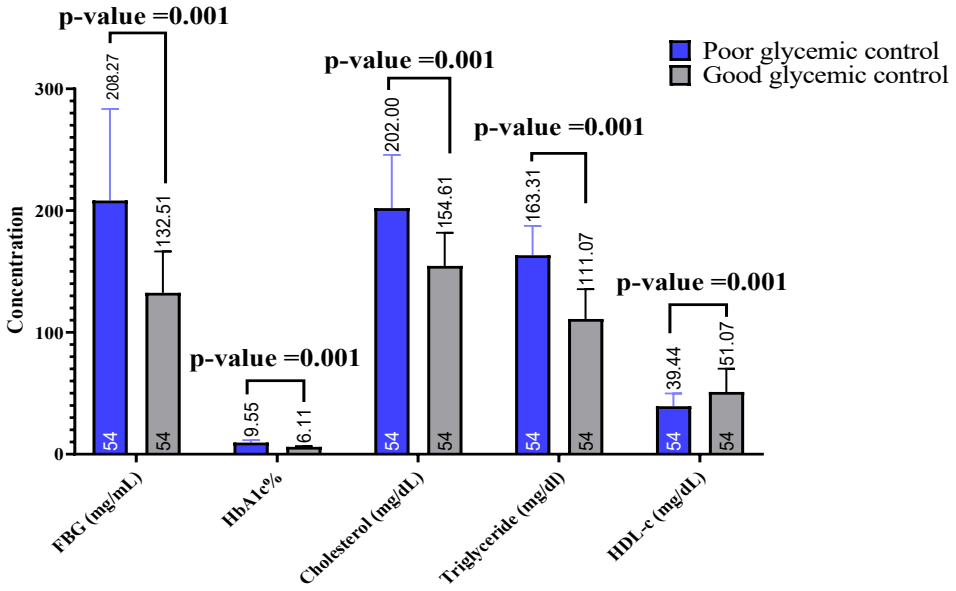

Figure 4: The distribution of glycemic markers and lipid profiles among the patients of the two groups.

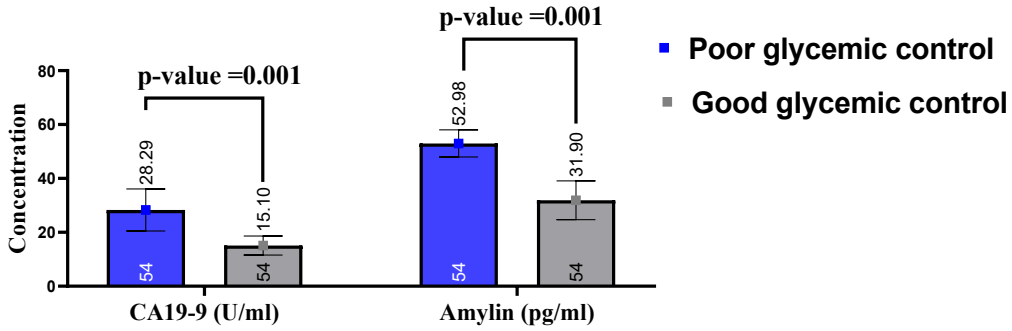

Figure 5: The distribution of CA19-9 (U/ml) and Amylin (pg/ml) serum levels among the patients of the two studied groups.

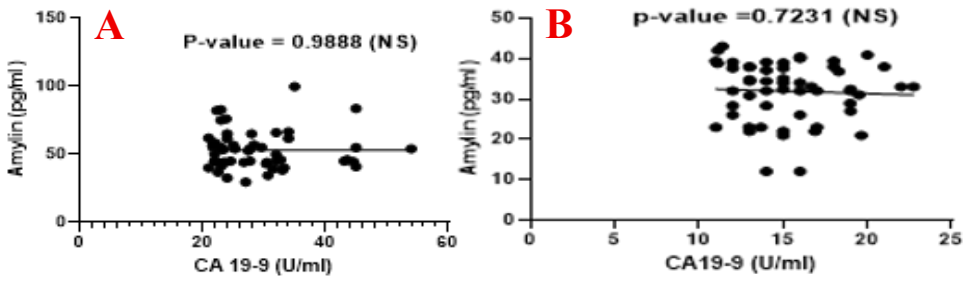

Figure 6: Scatter plot showing the correlation between CA19-9 (U/ml) and Amylin (pg/ml): A/ in poor glycemic control, B/ in good glycemic control.

AIMCJ. (2026),3; (2): 142-156
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Moreover, this study showed that CA19-9 and Amylin had no correlations with glycated haemoglobin (HbA1c%) and the parameters of lipid metabolism (triglyceride, cholesterol and HDL-c) in each group of poor and good glycemic control p>0.05, as shown in Figures 7 and 8.

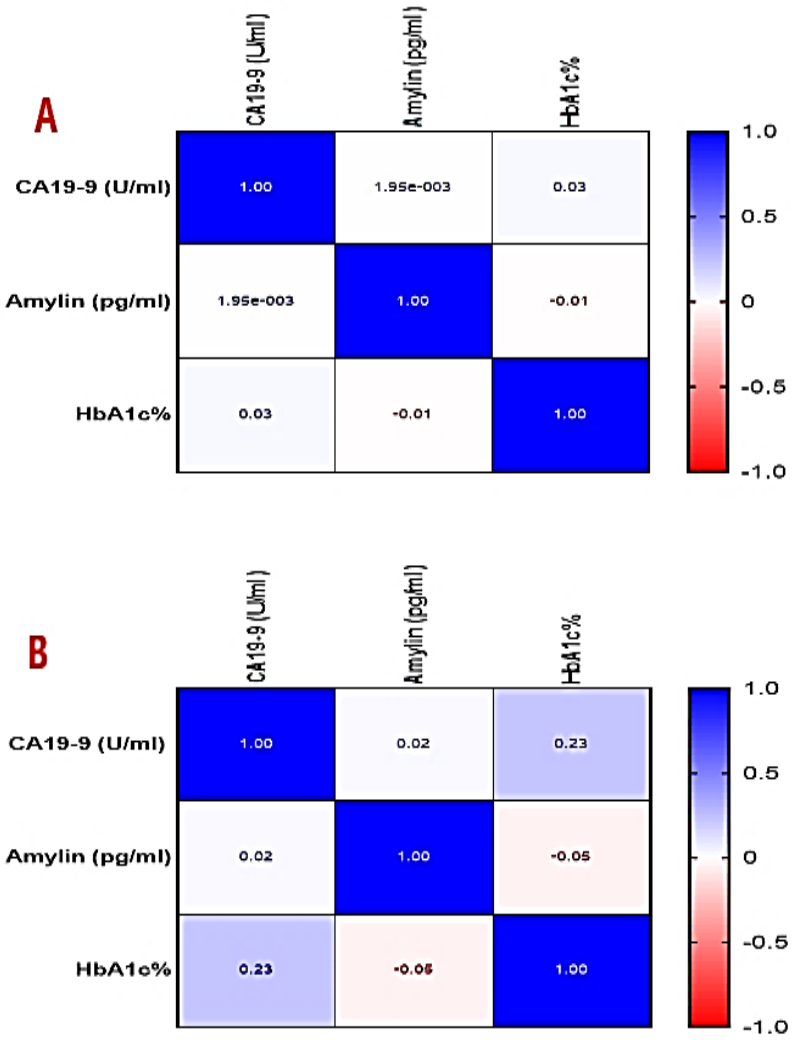

Figure 7: Heat map showing the correlation between CA19-9 (u/ml), Amylin(pg/ml) and HbA1c % in A/Poor glycemic control group, B/ good glycemic control group.

To evaluate the primary differences in the serum levels of CA19-9 (U/ml) and Amylin (pg/ml) between the two studied groups while controlling for potential clinical and metabolic confounding factors (FBG, HbA1c, cholesterol, triglyceride, and HDL-c), one-way analysis of covariance (ANCOVA) was conducted as shown in Tables 1,2.3 and 4.

Regarding CA19-9, after controlling for the covariate factors, serum total cholesterol was the only covariate showing a significant confounding effect (F=4.991, p=0.0028), as shown in Table 1. Moreover, the pairwise comparison showed that patients with poor glycemic control had a significantly higher adjusted mean CA19-9 compared to the group with good glycemic

AIMCJ. (2026),3; (2): 142-156
doi.org/10.58564/AIMCJ3.2.2026.322

control, with mean difference =14.51 (95% CI:10.45-18.57, p-value <0.001), and the model explained 57.3% of the variance with the adjusted R2=0.573, as shown in Table 2.

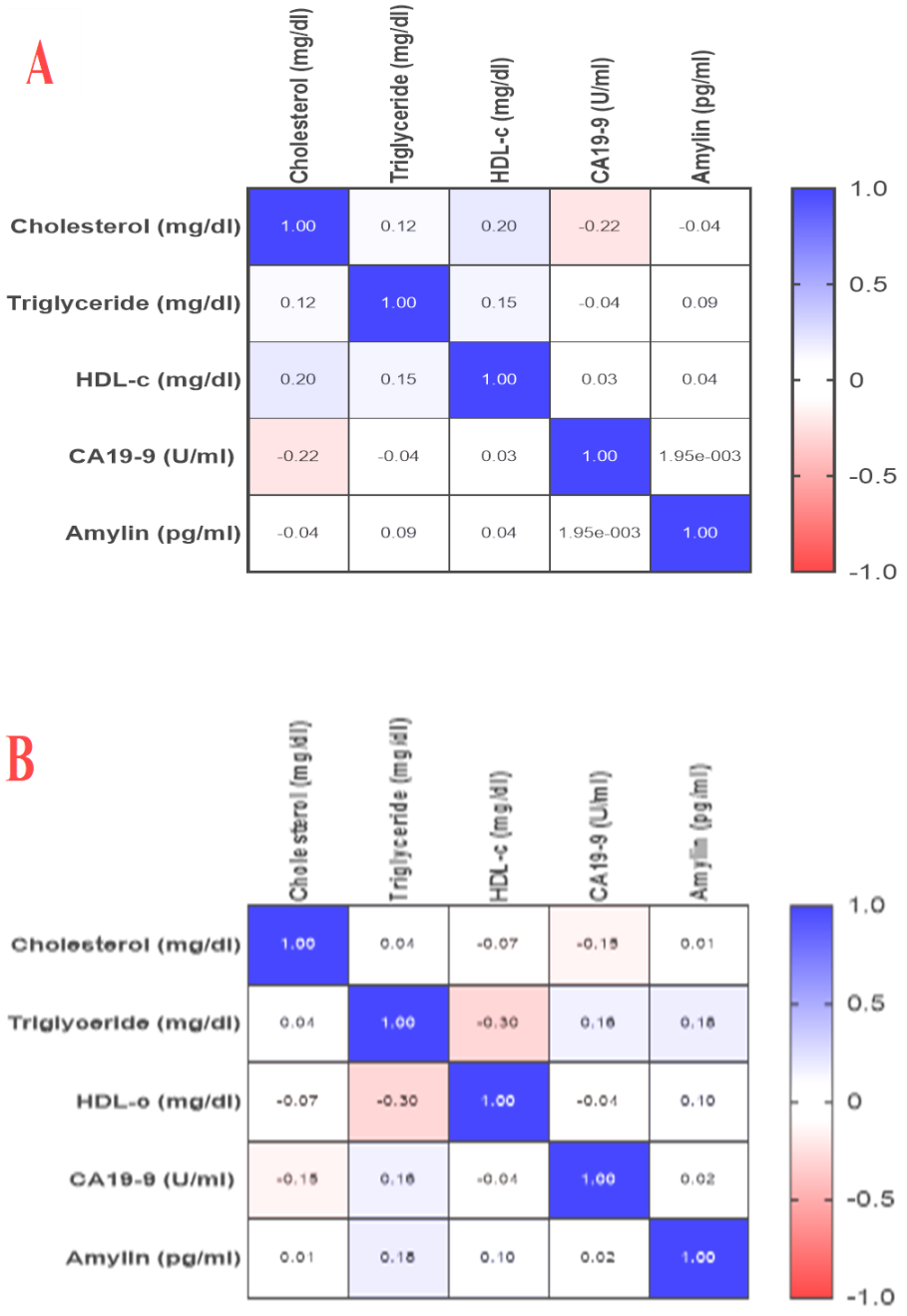

Figure 8: Heat map showing the correlation between CA 19-9, Amylin, cholesterol, triglycerides, and HDL-c: A/ in poor glycemic control, B/ in good glycemic control.

AIMCJ. (2026),3; (2): 142-156
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Table 1: one-way ANCOVA summary for serum CA19-9 (U/ml) level controlling for clinical and metabolic covariates.

Dependent Variable: CA 19-9 (U/ml)					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5473.515[a]	9	608.168	16.936	.000
Intercept	411.559	1	411.559	11.461	.001
FBS (mg/dl)	123.788	1	123.788	3.447	.066
HbA1C%	95.872	1	95.872	2.670	.105
Cholesterol (mg/dl)	179.213	1	179.213	4.991	.028
Triglyceride (mg/dl)	.003	1	.003	.000	.993
HDL (mg/dl)	.032	1	.032	.001	.976
BMI (kg/m^2)	.680	1	.680	.019	.891
Study groups	1804.821	1	1804.821	50.259	.000
Error	3519.230	98	35.911		
Total	61438.645	108			
Corrected Total	8992.745	107			
a. R Squared = 0.609 (Adjusted R Squared = 0.573)					

Table 2: Pairwise comparison of adjusted mean of CA19-9 (U/ml) serum levels between the studied groups (poor glycemic control VS good glycemic control).

Pairwise Comparisons						
Dependent Variable: CA 19-9 (U/ml)						
(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference [b]	
					Lower Bound	Upper Bound
Poor control	Good control	14.508*	2.046	.000	10.447	18.569
Good control	Poor control	-14.508*	2.046	.000	-18.569	-10.447

**The mean difference is significant at the .05 level.*

Regarding Amylin, similarly, a significant difference between the two studied groups persisted after covariate adjustment, while other covariate factors showed no significant confounding effect, as shown in Table 3. The pairwise comparison between the study groups confirmed the presence of significant elevated adjusted mean of Amylin serum levels in patients with poor glycemic control compared to those with good glycemic control, with a mean difference=21.66 (95% CI:13.95-29.37, p<0.001), and the model explained 45.4% of the variance with the adjusted R2 =0.454, as shown in Table 4.

AIMCJ. (2026),3; (2): 142-156
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Table 3: one-way ANCOVA summary for serum Amylin (pg/ml) level controlling for clinical and metabolic covariates

Dependent Variable: Amylin (pg/ml)					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	12670.601[a]	9	1407.845	10.881	.000
Intercept	889.375	1	889.375	6.874	.010
FBS (mg/dl)	.020	1	.020	.000	.990
HbA1C%	14.602	1	14.602	.113	.738
Cholesterol(mg/dl)	230.964	1	230.964	1.785	.185
Triglyceride(mg/dl)	42.410	1	42.410	.328	.568
HDL (mg/dl)	16.252	1	16.252	.126	.724
BMI (kg/m^2)	47.879	1	47.879	.370	.544
Study groups	12679.390	98	129.382		
Total	219946.479	108			
Corrected Total	25349.991	107			
a. R Squared = 0.500 (Adjusted R Squared = 0.454)					

Table 4: Pairwise comparison of adjusted mean of Amylin (pg/ml) serum levels between the studied groups (poor glycemic control VS good glycemic control).

Pairwise Comparisons						
Dependent Variable: Amylin (pg/ml)						
(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Good control	Poor control	21.659*	3.884	.000	13.950	29.368
Poor control	Good control	-21.659*	3.884	.000	-29.368	-13.950

** The mean difference is significant at the 0.05 level.*

The performance of the main study biomarkers (CA19-9 and Amylin) as a tool to discrimination and identify the poor glycemic control that could related to pancreatic dysfunction in this study was evaluated using ROC analysis, as shown in Table 5 and Figure 9, respectively indicate that CA19-9 as a biomarker exhibited an excellent accuracy for this purpose with an area under the curve (AUC) of 0.99 (95% CI:0.985-1.00, p-value <0.001) at a cut-off value equal to 44.79 U/ml with a sensitivity of 99%, and a specificity of 100%. Similarly, Amylin also showed high potential as a biomarker that could also be used for this purpose, with an AUC of 0.96 (95% CI:0.914-0.992, p-value < 0.001) at a cut-off of 83.24, and sensitivity and specificity of 96% and 100%, respectively.

AIMCJ. (2026),3; (2): 142-156
doi.org/10.58564/AIMCJ3.2.2026.322

Table 5: Receiver Operating Characteristic (ROC) analysis of study biomarkers between poor and good glycemic control type 2 diabetic patients

The main biomarkers of the study	AUC	Cut-off value	Sensitivity	Specificity
CA19-9 (U/ml)	0.99	44.79	99%	100%
Amylin (pg/ml)	0.96	83.24	96%	100%

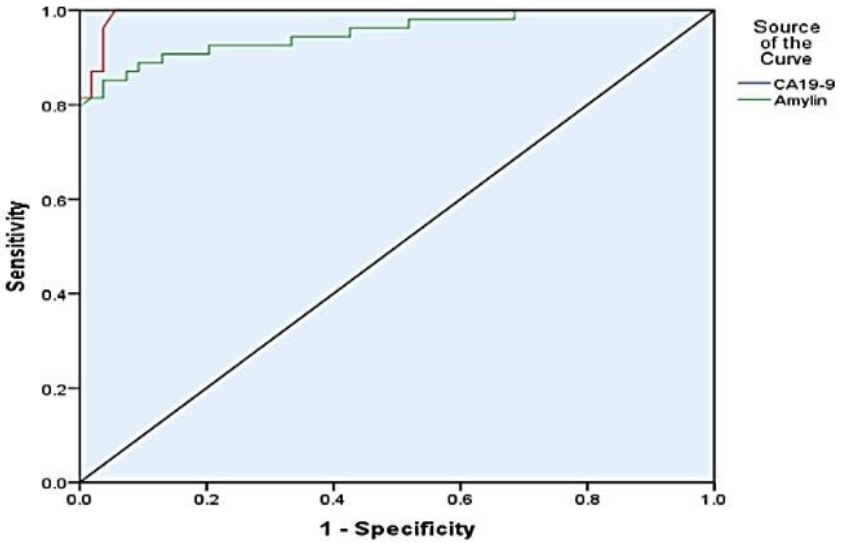

Figure 9: The Receiver Operating Characteristic curve of CA19-9 (U/ml) and Amylin (pg/ml).

Table 6 shows that the regression coefficient for CA19-9 was statistically significant, with an independent predictive value having an odds ratio of 5.67 (95%CI:1.867-17.213, p-value=0.002) and overall classification accuracy of 96.3%. In addition to that, Amylin had a significant independent predictive value with an odds ratio = 1.44 (95%CI:1.230-1691, p-value<0.001), producing a Wald statistic of 20.35 and a total predictive accuracy of 89.8%.

Table 6. Binary Logistic Regression Models for Predicting Glycemic Control Status.

Bi-omarker	Regres-sion coef-ficient	Std error	Wald Chi-Square	df	Sig.	Odds Ratio	95% C.I. for Odds Ratio (Lower–Upper)	Overall Accu-racy
CA19-9 (U/ml)	1.735	0.567	9.38	1	0.002	5.67	1.867 – 17.213	96.3%
Amylin (pg/ml)	0.366	0.081	20.35	1	<0.001	1.44	1.230 – 1.691	89.8%

AIMCJ. (2026),3; (2): 142-156
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Discussion

This current study assessed the serum levels of both CA19-9 and Amylin at the same time in diabetic patients with type 2. To the best of our knowledge, the previous studies investigated each one of these biomarkers alone. This current study involved 108 diabetic patients with type 2, and they were divided into two equal groups based on their glycemic control. The socio-demographic characteristics (age, sex, disease duration, and smoking habit) of the studied patients in both groups were balanced. This balance in addition to the equality in their number allowed for minimizing their effect on the studied parameters, especially the effect of duration of disease, which is known to affect the levels of CA19-9 and Amylin due to the deterioration that occurs in the pancreas (8, 15-19), as shown in Figures 1, 2, and 3. Furthermore, according to Figure 4, in this study, the existence of significant differences found in lipid and glucose parameters between the two studied groups based on blood glucose control was consistent with the pathophysiological nature of diabetes (25).

Regarding the main study biomarkers and as shown in Figure 5, the significant elevation of serum level of CA19-9 in patients who were unable to achieve good glycemic control is supported by the findings of a previous study done by Zhao et al that were performed on diabetic patients with type 2 and found that the patients who had the higher serum levels of CA19-9 had the highest HbA1c%, suggesting long-term metabolic stress and glucotoxicity leading to progressive damage to pancreatic cells and low-grade inflammation, leading eventually to the release of CA19-9 from the damaged pancreatic duct cells (8,26).

Conversely, the findings of the current study disagreed with a study done by Avci. A. O. et al that concluded that poor glycemic control could not be the only factor implicated in the elevation in CA19-9 levels (27), the possible cause of this disagreement could be attributed to the difference in study design, sample size, and the characteristics of the included patients, which were not normally distributed in his study. An additional possible cause of the disagreement could be due to the effect of anti-diabetic medication that is taken by patients, which has a significant impact on the serum levels of CA19-9 (8).

When it comes to the serum Amylin levels, this current study was that its serum levels of Amylin were significantly elevated, with a p-value = 0.001 in patients with poor glycemic control when compared to those with good glycemic control, is probably because Amylin serum levels is influenced by serum glucose levels, in which the elevation in its levels associated with the elevation in Amylin serum levels by the induction of the secretion of more and more insulin and Amylin since it co-secreted with insulin from the pancreatic beta cell to compensate for this elevation before its failure which vary with the progression of the disease (28-32). This could probably be the reason behind this elevation; however, to our knowledge, no previous studies have assessed serum Amylin levels in patients with T2DM, and more studies are required to support this finding.

No association was found between CA19-9 and Amylin and between them and the other studied glycemic and lipid metabolic biomarkers in each studied group; this could probably be due to the small sample size; however, studies are required to confirm these findings. It is worth mentioning that regarding the associations between the studied biomarkers (CA19-9 and Amylin) and HbA1c, the studies were conflicting; some

AIMCJ. (2026),3; (2): 142-156
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found a positive correlation with HbA1c%, while others found no correlation between them, in which the presence or absence of these correlations mainly depends on the duration of the disease and the pathophysiology (8,26-28).

Based on the findings of this study, both serum levels of CA19-9 and Amylin showed strong potential as independent biomarkers associated with the extent of glycemic control in patients with T2DM. The one-way ANCOVA showed that both biomarkers were significantly elevated in diabetic patients with poor glycemic control ($p<0.001$), and this elevation remained statistically significant even after statistically controlling for clinical and metabolic confounding factors. Although total cholesterol showed a significant covariate effect ($p =0.028$) on CA19-9, the adjusted mean differences between the two studied groups remain significant (14.508U/ml with $p<0.001$), explaining 57.3% of the variance with Adjusted $R2=0.573$, which suggests that the elevation in CA19-9 is caused by chronic hyperglycemia secondary to metabolic stress rather than alteration in lipid profile.

Regarding ROC curve analysis in this study show that both CA19-9 and Amylin could distinguish between T2DM patients with poor glycemic control and good glycemic control, with an AUC of 0.99 (95% CI:0.985-1.00, $p<0.001$) and a cutoff value of 44.79 (U/ml), with a sensitivity of 99% and a specificity of 100% for CA19-9, Similarly, Amylin had an AUC of 0.96 (95% CI:0.914-0.992, $p< 0.001$) at a cut-off value of 83.24 (pg/ml) with a sensitivity of 96% and a specificity of about 100%. Binary logistic regression, which is used to identify the independent predictive capacity of CA19-9 and Amylin in this study, found that both CA19-9 and Amylin can act as potent independent predictive biomarkers to identify poor glycemic control in T2DM patients, with odds ratios of 5.67 and 1.44, and total accuracy of 96.3% and 89.8%, respectively.

Altogether, these findings suggest the possible use of both biomarkers as tools to detect the severity of glycemic dysregulation due to metabolic stress in T2DM. However, it is worth mentioning that these findings should be interpreted with caution due to the relatively small sample size (54 patients in each group), and further studies with a larger sample size are required.

Limitations of the study:

This study provides a deeper understanding of the clinical association of serum CA19-9 and Amylin in relation to glycemic control in T2DM; however, certain limitations have been found. First, the nature of the cross-sectional investigation held at one specialized center restricted the ability of the study to establish a direct causal link and the inability to generalize the findings of this study to a larger, more varied population, alongside the absence of a healthy control group. Second, this study focuses exclusively on patients with T2DM who were classified based on their glycemic control, so the findings of this study mainly reflect the pathophysiological stress of the pancreatic tissue specific to T2DM and may not be applied to patients with T1DM. Finally, all the studied patients were on anti-diabetic medication; therefore, the potential long-term effect of the anti-diabetic medication on these studied biomarkers, even though the confounding factors such as age, BMI, and disease duration were comparable between the studied groups, therefore, it requires further investigation on a larger sample size from many specialized diabetic centers with a longitudinal study design.

AIMCJ. (2026),3; (2): 142-156
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Conclusion

This study concluded that serum levels of CA19-9 and Amylin are significantly elevated in T2DM patients with inadequate glycemic control, independent of the potential effect of metabolic confounding factors. The combined assessment of CA19-9 and Amylin provides a better clinical assessment of the glycemic dysregulation during disease progression compared to when these biomarkers are evaluated individually.

Recommendation:

This study recommends a longitudinal study to determine the feasibility of using these biomarkers as a screening tool alongside blood glucose monitoring, using pancreatic imaging techniques or large-scale testing at different centers, with the aim of generalizing the study's findings to a broader population. Such studies will help establish cause-and-effect relationships between these biomarkers and assess the impact of disease duration on them. The study also recommends comparative studies between patients with type 1 and type 2 diabetes, between diabetic patients and those without diabetes, and between diabetic patients and patients with pancreatic cancer, to better understand the differences in the studied parameters among these diverse groups.

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