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Glycemic Control and Cardiovascular Risk Assessment A Study on HbA1c and HsCRP Levels in Type 2 Diabetes Mellitus

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ORIGINAL ARTICLE

Glycemic Control and Cardiovascular Risk Assessment: A Study on HbA1c and Hs-CRP Levels in Type 2 Diabetes Mellitus

Kontrol Glikemik dan Penilaian Risiko Kardiovaskular: Studi Kadar HbA1c dan Hs-CRP pada Diabetes Melitus Tipe 2

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ABSTRACT

Background:
Type 2 diabetes mellitus (T2DM) represents a major risk factor for cardiovascular disease. Diabetic patients have a 2-4 fold higher risk of developing coronary heart disease compared to the non-diabetic population. Cardiovascular complications constitute the leading cause of morbidity and mortality in diabetic patients, with cardiovascular disease-related deaths accounting for 65-75% of total mortality in the diabetic population. Poor glycemic control serves as a key factor in the pathogenesis of cardiovascular complications in diabetes. Chronic hyperglycemia triggers various pathophysiological mechanisms, including increased oxidative stress, systemic inflammation, endothelial dysfunction, and accelerated atherosclerotic processes. Hemoglobin A1C (HbA1C) as a parameter of long-term glycemic control has been proven to strongly correlate with the risk of microvascular and macrovascular complications in diabetes. This study aims to analyze the correlation between glycemic control assessed through HbA1C and systemic inflammatory status measured through Hs-CRP as a predictor of cardiovascular risk in patients with type 2 diabetes mellitus.

Methods:
An analytical cross-sectional study on 53 T2DM patients at the Prolanis Clinic in East Jakarta (purposive sampling). HbA1c examination using the HPLC method and Hs-CRP using the Turbidimetric Immunoassay method were conducted at PRODIA laboratory. Correlation was analyzed using Spearman's correlation test.

Results:
The study revealed a mean HbA1C level of 7.2% and a mean Hs-CRP level of 2.9 mg/L. Statistical analysis demonstrated a significant correlation between HbA1C and Hs-CRP (p-value = 0.014) with a Spearman correlation coefficient of 0.336.

Conclusion: There is a significant positive correlation between HbA1c and Hs-CRP levels.

Keywords: Cardiovascular risk; type 2 diabetes mellitus; HbA1C; Hs-CRP; inflammation

ABSTRAK

Latar Belakang:

Diabetes melitus tipe 2 (T2DM) merupakan faktor risiko utama penyakit kardiovaskular. Pasien diabetes memiliki risiko 2-4 kali lebih tinggi mengalami penyakit jantung koroner dibandingkan populasi non-diabetes. Komplikasi kardiovaskular menjadi penyebab utama morbiditas dan mortalitas pada pasien diabetes, dengan angka kematian akibat penyakit kardiovaskular mencapai 65-75% dari total kematian populasi diabetes. Kontrol glikemik yang buruk menjadi faktor kunci patogenesis komplikasi kardiovaskular pada diabetes. Hiperglikemia kronis memicu berbagai mekanisme patofisiologis, termasuk peningkatan stres oksidatif, inflamasi sistemik, disfungsi endotel, dan percepatan proses aterosklerosis. Hemoglobin A1C (HbA1C) sebagai parameter kontrol glikemik jangka panjang telah terbukti berkorelasi kuat dengan risiko komplikasi mikrovaskular dan makrovaskular pada diabetes. Penelitian ini bertujuan menganalisis korelasi antara kontrol glikemik yang dinilai melalui HbA1C dengan status inflamasi sistemik yang diukur melalui Hs-CRP sebagai predictor resiko kardiovaskular pada pasien diabetes melitus tipe 2.

Metode: *Studi potong lintang analitik pada 53 pasien T2DM di Klinik Prolanis Jakarta Timur (purposive sampling). Pemeriksaan HbA1c dengan metode HPLC dan Hs-CRP dengan metode Turbidimetric Immunoassay dilakukan di laboratorium PRODIA. Korelasi dianalisis menggunakan uji korelasi Spearman.*

Hasil: *pada studi ini didapatkan rerata kadar HbA1C adalah 7.2% dan rerata Hs-CRP adalah 2.9 mg/L. Analisis statistik menunjukkan korelasi signifikan antara HbA1C dan Hs-CRP (p-value = 0.014) dengan koefisien korelasi Spearman 0.336.*

Kesimpulan: *Terdapat korelasi positif yang signifikan antara kadar HbA1c dan Hs-CRP*

Kata kunci: *Diabetes melitus tipe 2; HbA1C; hsCR; inflamasi*

INTRODUCTION

The global prevalence of type 2 diabetes mellitus (T2DM) has demonstrated a significant escalation attributable to alterations in human lifestyle patterns and behavioral modifications.[1,2] Diabetes has emerged as a predominant cardiometabolic disorder, affecting 10.5% of the adult population (aged 20-79 years) in 2021, with projections indicating an increase to 12.2% by 2045.[2,3] The prevalence exhibits higher rates in urban areas (12.1%) compared to rural regions (8.3%), and in high-income countries (11.1%) versus low-income nations (5.5%). The most substantial relative increase is projected to occur more frequently in middle-income countries (21.1%) than in high-income (12.2%) and low-income countries (11.9%), including Indonesia, T2DM prevalence demonstrates an alarming trend, with continuously rising incidence rates paralleling societal changes in lifestyle and dietary patterns.[1]

Diabetes mellitus extends beyond an isolated health concern, constituting a principal risk factor for cardiovascular disease. Diabetic patients exhibit a 2-4 fold elevated risk of developing coronary heart disease compared to non-diabetic populations.[4] Cardiovascular complications represent the primary cause of morbidity and mortality in diabetic patients, with cardiovascular-related deaths accounting for 65-75% of total mortality in the diabetic population.[4,5] Poor glycemic control serves as a pivotal factor in the pathogenesis of cardiovascular complications in diabetes. Chronic hyperglycemia triggers various pathophysiological mechanisms, including enhanced oxidative stress, systemic inflammation, endothelial dysfunction, and accelerated atherosclerosis.[1]

This condition creates a vicious cycle that accelerates the progression of cardiovascular disease in diabetic patients.[1,2]

Hemoglobin A1C (HbA1C), as a long-term glycemic control parameter, has been demonstrated to correlate with microvascular and macrovascular complications in diabetes.[6] HbA1C reflects the average blood glucose levels over the preceding 8-12 weeks and serves as the gold standard for monitoring glycemic control in diabetic patients. The American Diabetes Association has recognized an HbA1c level of 6.5% or higher as a diagnostic threshold for diabetes and an HbA1c level of >7% as a poor glycemic control.[6] Conversely, high-sensitivity C-Reactive Protein (Hs-CRP) represents a sensitive systemic inflammatory biomarker that has been recognized as an independent predictor of cardiovascular risk. Low-grade chronic inflammation constitutes a crucial characteristic of type 2 diabetes mellitus and plays a significant role in the development of cardiovascular complications.[7] Elevated Hs-CRP levels in diabetic patients not only reflect systemic inflammatory status but also correlate with glycemic control levels and future cardiovascular event risk.[8,9] Given the concerning projected increase in diabetes prevalence, particularly in middle-income countries such as Indonesia, the identification of predictive biomarkers for cardiovascular risk becomes critically important for timely preventive interventions. Therefore, understanding the relationship between glycemic control and inflammatory status becomes essential in the comprehensive management of diabetic patients.

This study aims to analyze the correlation between glycemic control assessed through HbA1C and systemic inflammatory status measured through Hs-CRP in T2DM patients. Although the relationship between glycemic control and cardiovascular complications in type 2 diabetes mellitus has been extensively documented, research specifically analyzing the correlation between HbA1C and Hs-CRP as systemic inflammatory biomarkers in the Indonesian population remains limited. This study contributes novel insights into understanding the interaction between long-term glycemic control and chronic inflammatory status in T2DM patients in Indonesia, who possess distinct demographic and genetic characteristics compared to Western populations.

METHODS

This analytical cross-sectional study was conducted among participants of the Prolanis Diabetes Clinic in East Jakarta. The total clinic population consisted of 64 individuals with T2DM, of whom 53 subjects were included using purposive sampling. Five people were excluded due to absence during blood collection, and 6 people were excluded for showing Hs-CRP results > 10 mg/L (indicating the presence of acute systemic inflammation that could be caused by various diseases).[10] Eligible participants were men and women aged 40–60 years with a diagnosis of T2DM. Exclusion criteria included any known cardiovascular, neurological, malignancy, or pulmonary diseases, as well as any current illness or history of inflammatory conditions that could affect Hs-CRP levels, such as rheumatoid arthritis, gout, or infections.

To justify the sample size, a power estimation was conducted based on the correlation coefficient (r = 0.81) reported in a previous study by Reddy et al. (2024)[6], which found a strong positive relationship between HbA1c and Hs-CRP levels in patients with T2DM and myocardial infarction. Assuming a significance level of 0.05 and statistical power of 80% (β = 0.20), the minimum

number of subjects required to detect a statistically significant correlation of similar strength would be considerably less than the 53 subjects included in this study. Therefore, the chosen sample size was considered statistically adequate and appropriate for the study objective.

Venous blood samples were collected and processed by the certified PRODIA Laboratory for HbA1c and Hs-CRP. HbA1c were measured using HPLC standardized under the National Glycohemoglobin Standardization Program (NGSP) with Tina-quant HbA1c kit on Cobas Integra analyzer, serving as a marker of long-term glycemic control. Hs-CRP levels were determined using a validated turbidimetric immunoassay method with i-CHROMA™ hsCRP-ALL in one kit (Boditech Med Inc) to assess systemic inflammation and cardiovascular risk.

The study protocol was reviewed and approved by the Ethics Committee of the Faculty of Medicine, Trisakti University (No.055/KER/FK/II/2023). Descriptive statistics were used for demographic and clinical characteristics, with means and standard deviations for continuous variables and percentages for categorical data. The correlation between HbA1c and Hs-CRP was analyzed using Spearman's rank correlation test. Data analysis was performed using SPSS software.

RESULTS

The distribution of subject characteristics based on gender, age, blood pressure, HbA1C levels, and Hs-CRP is presented in Table 1. This study involved 53 subjects with T2DM, comprising 36 females (67.9%) and 17 males (32.1%). The age distribution revealed that the majority of subjects were within the 40-60 years age range, accounting for 40 individuals (75.5%), while 13 subjects (24.5%) were aged >60 years.

The mean systolic and diastolic blood pressure values in this study demonstrated a mean systolic blood pressure of 138.2 mmHg and a diastolic blood pressure of 87.7 mmHg. The mean HbA1C level among subjects was 7.2%, indicating poor glycemic control. The study results showed a mean Hs-CRP level of 2.9 mg/dL, indicating an intermediate risk. Cardiovascular risk assessment using Hs-CRP levels according to American Heart Association criteria revealed that 8 participants (15.1%) had low risk (Hs-CRP <1 mg/L), 28 participants (52.8%) had intermediate risk (Hs-CRP 1.0-3.0 mg/L), and 17 participants (32.1%) had high risk (Hs-CRP >3 mg/L).[11]

A non-parametric Spearman correlation analysis was conducted to examine the correlation between glycemic control parameters, hemodynamic variables, and Hs-CRP as a cardiovascular risk predictor among 53 patients with T2DM. The results of the correlation analysis are presented in Table 2. The analysis revealed a statistically significant positive correlation between HbA1c levels and Hs-CRP concentrations ($r = 0.336$, $p = 0.014$). This correlation indicates that elevated HbA1c levels are associated with increased Hs-CRP levels, suggesting a correlation between poor glycemic control and cardiovascular risk in diabetic patients.

Regarding hemodynamic parameters, systolic blood pressure demonstrated a significant positive correlation with Hs-CRP levels ($r = 0.277$, $p = 0.044$). This finding suggests that elevated systolic blood pressure is associated with increased inflammatory markers, potentially indicating the role of hypertension in cardiovascular risk enhancement through inflammatory pathways. Conversely, diastolic blood pressure showed no significant correlation with Hs-CRP levels ($r = 0.059$, $p = 0.673$).

DISCUSSIONS

Based on the research data presented in Table 2, there is a distinct pattern of relationship between Hs-CRP and the components of systolic and diastolic blood pressure. The Spearman correlation analysis revealed a significant relationship between Hs-CRP and systolic blood pressure ($r = 0.277$, $p = 0.044$); however, no significant relationship was found with diastolic blood pressure ($r = 0.059$, $p = 0.673$). This finding provides an interesting insight into how systemic inflammatory markers interact with cardiovascular hemodynamic parameters in patients with type 2 diabetes mellitus.[8,9] Previous studies have established the relationship between diabetes and the occurrence of hypertension.[12] Diabetes and hypertension can increase the risk of each other, and when they occur together, they significantly elevate the risk of cardiovascular disease.[12-14]

Hs-CRP is an inflammatory marker produced by the liver and elevated during inflammation, including in the process of atherosclerosis, and has been proven as a marker that can predict cardiovascular disease risk.[6] This study demonstrated a significant relationship between systolic blood pressure and Hs-CRP but not with diastolic blood pressure. This phenomenon can occur because systolic blood pressure is more sensitive to vascular inflammatory changes compared to diastolic pressure, as systolic pressure reflects the strength of cardiac contraction and the elasticity of larger arterial blood vessels.[15] When chronic inflammation occurs, as indicated by increased Hs-CRP, arterial walls become stiffer and less elastic, which directly affects systolic pressure.[15] Conversely, diastolic pressure more reflects the resistance of smaller peripheral blood vessels and is not significantly influenced by inflammatory processes occurring in larger blood vessels.[14] Poor glycemic conditions trigger systemic inflammation that increases Hs-CRP.[1,2,6] This inflammation contributes to arterial stiffening, which has a greater impact on the systolic component of blood pressure.[15] Therefore, Hs-CRP as a predictor of cardiovascular inflammation demonstrates a stronger correlation with systolic pressure because both reflect vascular damage occurring in major arterial blood vessels, while diastolic pressure remains more stable and is not significantly affected by systemic inflammatory changes measured through Hs-CRP.[15-16]

High blood pressure (hypertension) and diabetes frequently occur simultaneously and increase the risk of cardiovascular disease. High blood glucose and elevated blood pressure can lead to vascular endothelial damage, subsequently leading to the formation of atherosclerosis.[4-5] The fundamental concept of atherosclerosis is arterial hardening due to the gradual accumulation of fatty plaques within the vessel walls. This plaque accumulation restricts blood flow.[4]

Atherosclerosis begins with endothelial activation, followed by a cascade of events (lipid accumulation, fibrous proliferation).[5] Non-enzymatic glycation reactions Interactions between glucose and proteins or lipoproteins within arterial walls are key mechanisms driving accelerated atherosclerosis under hyperglycemic conditions in type 2 diabetes mellitus. Prolonged hyperglycemia plays a central role in atherosclerosis pathogenesis by inducing multiple cellular alterations in vascular tissue that promote atherogenesis. [17-18]

Another important biochemical process accompanying type 2 diabetes mellitus is the formation of Advanced Glycation End Products (AGEs). These AGEs likely also underlie the general inflammatory process.[19] The formation and accumulation of AGEs are associated with aging processes and are accelerated in diabetes.[20] AGEs are produced under hyperglycemic conditions, but their production also occurs in situations characterized by oxidative stress and inflammation.[18]

Activation of AGE receptors can induce cascading inflammatory responses that cause increased inflammation, oxidative stress, enhanced calcium deposition, and increased vascular smooth muscle apoptosis. This contributes to the development of atherosclerosis. [21]

The synergistic reaction between hypertension and hyperglycemia causes atherosclerosis formation through at least two mechanisms: elevated hemodynamic pressure in hypertensive conditions damages the endothelium and upregulates the renin-angiotensin-aldosterone system, oxidative stress, and inflammation, which contribute to the close relationship between diabetes and hypertension.[22]

High-sensitivity C-reactive protein (Hs-CRP) is a systemic inflammatory marker that emerges as an independent risk factor for cardiovascular disease.[23-24] Elevated Hs-CRP levels are associated with increased risk of thrombotic events, including myocardial infarction. Increased Hs-CRP levels are also associated with increased risk of developing diabetes later in life. Furthermore, it has been found that Hs-CRP levels are higher in diabetic patients compared to those without diabetes.[25-27] This study demonstrated that Hs-CRP and HbA1c showed a significant relationship between them. This is consistent with studies conducted by Seo HY, Khairinisa G, and Reddy KSS, which stated that HbA1c levels increased significantly with increasing Hs-CRP.[6,7] In contrast to the study conducted by Sari EP (2023), which stated that her study results showed no significant correlation between HbA1c levels and CRP (p-value=0.171 and r=0.218).[8] The key differences between this study and Sari EP (2023) involve measurement sensitivity and sample size. Sari used a semi-quantitative latex agglutination method for CRP with a detection threshold of 0.6 mg/dL (6 mg/L), which is less sensitive for detecting low-grade inflammation compared to our validated turbidimetric immunoassay capable of measuring Hs-CRP below 0.1 mg/L. Hs-CRP's superior sensitivity allows identification of subtle inflammatory changes specifically relevant to cardiovascular risk assessment. The sample size difference is also crucial; Sari's 24 subjects versus our 53 participants significantly affects statistical power to detect associations.[8]

Hs-CRP directly participates in the pathogenesis of atherosclerosis through the inflammation of endothelial cells and coronary arterial smooth muscle cells. Hs-CRP levels in various morbidity and mortality assessments are considered as one of the factors taken into account and as one of the predictor factors added to the Framingham score that enhances cardiovascular risk prediction. While this study identified a statistically significant correlation between HbA1c and Hs-CRP, potential confounding factors must be acknowledged. Variables such as BMI, lipid profile, and medications—particularly statins, anti-inflammatory agents, and metformin—are known to influence systemic inflammation. Previous studies demonstrate that metformin reduces Hs-CRP levels by suppressing proinflammatory cytokine secretion in hepatocytes and macrophages, indicating anti-inflammatory properties beyond glucose control.[28] However, due to data limitations, these variables were not adjusted for in the current analysis. Future studies incorporating multivariable regression models are warranted to control for confounding variables and clarify the independent relationship between glycemic control and systemic inflammation.

CONCLUSIONS

This study demonstrates a significant positive correlation between HbA1c and Hs-CRP levels in T2DM, indicating that poor glycemic control is associated with increased systemic inflammation.

Additionally, Hs-CRP showed a significant correlation with systolic blood pressure but not with diastolic blood pressure, suggesting that inflammatory markers preferentially affect arterial stiffness and larger vessel dynamics. These findings support the use of Hs-CRP as a valuable biomarker for cardiovascular risk assessment in diabetic patients, particularly when combined with glycemic control parameters.

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AUTHORS CONTRIBUTION

The concept, analysis, and interpretation of data, drafting manuscript: Putri MA. Collecting data, assisted in developing research methodology: MAP, PA, DA, YI. Critical review of the manuscript: PA, DA, YI.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose

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Table 1. Distribution of Subject Characteristics

Variable	Frequency	min	max	mean±SD
Gender				
Men	17 (32.1%)			
Women	36 (67.9%)			
Age (year)				
40 – 60	40 (75.5%)			
>60	13 (24.5%)			
Inflammation risk categories				
Low risk (< 1.0 mg/L)	8 (15.1%)			
Intermediate risk (1.0 – 3.0 mg/L)	28 (52.8%)			
High risk (>3.0 mg/L)	17 (32.1 %)			
Tekanan Darah				
Sistolik (mmHg)		100	202	138.2 ± 19.6
Diastolik (mmHg)		70	115	87.7 ± 9.2
Serum Level				
HbA1c (%)		4.8	11.3	7.2 ± 1.8
Hs-CRP (mg/L)		0.3	9.7	2.9 ± 2.4

Table 2. Correlation Analysis Between HbA1C, Blood Pressure and Hs-CRP

		Hs-CRP
HbA1C	spearman Correlation	.336**
	Sig.(2-tailed)	.014*
Systolic blood pressure	spearman Correlation	.277**
	Sig.(2-tailed)	.044*
Diastolic blood pressure	spearman Correlation	.059
	Sig.(2-tailed)	.673

Spearman
**Correlation is significant at the 0.05 level (2-tailed)*
***Correlation is significant at the 0.01 level (2-tailed)*