Original Article

Correlation of Blood Glucose Levels with Profiles Hematology on Patient Diabetes Mellitus with Ulcer Diabetes

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Abstract

Background: Diabetes Mellitus (DM) is a metabolic disorder that often leads to diabetic ulcers and persistent hyperglycemia. This condition can cause vascular and metabolic abnormalities, affecting bone marrow performance and altering the hematological profile of patients. This study investigates the correlation between blood glucose levels and hematological profiles in DM patients with diabetic ulcers. **Materials and Methods:** A quantitative, experimental laboratory study was conducted with 30 blood samples from DM patients at Ulin Hospital Banjarmasin, Indonesia, in February 2023, using purposive sampling. Hematological profiles were analyzed with an automatic hematology analyzer, while blood glucose levels were measured using Point-of-Care Testing (POCT). The Erythrocyte Sedimentation Rate (ESR) was assessed by the Westergren method. Pearson and Spearman coefficients were used to compare ESR results at different intervals, and a regression equation was derived to predict conventional ESR values from micro ESR results. Statistical analysis was performed using multiple correlation regression. **Results:** The correlation analysis revealed significant relationships between blood glucose and hematological parameters: hemoglobin (p = 0.013), hematocrit (p = 0.011), Mean Corpuscular Volume (MCV) (p = 0.044), and Mean Corpuscular Hemoglobin (MCH) (p = 0.152). No significant correlation was found between blood glucose and the number of erythrocytes (p = 0.997), Mean Corpuscular Hemoglobin Concentration (MCHC) (p = 0.152), total leukocytes (p = 0.082), or platelet count (p = 0.484). **Conclusions:** A moderate correlation (r = 0.422) was observed between blood glucose levels and the hematological profile in DM patients with diabetic ulcers.

Keywords: *Diabetes, glucose, hematology, ulcer*

Introduction

Diabetes Mellitus (DM) is a metabolic disorder characterized by hyperglycemia because of abnormality in insulin secretion, insulin performance, and both. Several pathogenic processes in the development of diabetes mellitus cause damage, resulting in pancreatic beta cells insulin deficiency up to abnormality and resistance to insulin performance. Complications of diabetes mellitus include retinopathy with potentially lost vision, nephropathy leading to kidney failure, neuropathy, and peripheral at-risk ulcer diabetes until amputation. As well as neuropathy autonomous causes gastrointestinal, genitourinary, cardiovascular, and dysfunction symptoms sexual.[1]

Based on data from the International Diabetes Federation, 351.7 million people aged productive (20–64 years) had diagnosed or undiagnosed diabetes in 2019. The estimated amount will increase to 417.3 million in 2030 and reach 486.1 million in 2045.[2] In Indonesia, East Java occupies 5th most people with diabetes mellitus in a way national. Prevalence DM sufferers aged ≥15 years in Indonesia experienced an increase from 6.9% in 2013 to 8.5% in 2018.[3] It is reported that around 40–70% of cases of amputation of the lower extremities are caused by nontrauma due to the feet.[4] Diabetes or Diabetic Foot Ulcer (DFU) is one of the complications caused by diabetes mellitus sufferers who block large blood vessels in the lower extremities that result from gangrene in the leg, so they must be amputated.[5] DM sufferers risk experiencing DFU approximately 25% during their life.[6]

Research proves that profile hematology experiences changes in DM patients. Persistent hyperglycemia causes erythrocytes

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to experience enhanced glucose concentration, resulting in the glycation of hemoglobin, prothrombin, fibrinogen, and other proteins involved in the blood clotting mechanism.[7] Several change profiles affecting hematology erythrocytes, leukocytes, and factors coagulation have proven to be directly related to diabetes mellitus. Abnormalities and other hematologies reported in DM patients include erythrocyte, leukocyte, dysfunctional platelets, increased MCHC, and decreased MCV.[8] In research in Banjarmasin, the results obtained a meaningful relationship between Mean Corpuscular Volume (MCV) and fasting blood glucose, 2 hours postprandial, HbA1c, Homeostasis Model Assessment of Insulin Resistance (HOMA-IR).[9] Other research shows significant differences in red blood distribution (RDW) between diabetes patients and controls. 17 (56.70), count lymphocytes absolute, and total neutrophils absolute. They are also increasing significantly in DM patients compared with controls. Mean Platelet Volume (MPV) and platelet distribution width also experience enhancement in a way that is significant in DM patients.[9]

Hyperglycemia influences the body's response to inflammation and immunity against the resulting chronic inflammation and decline of function cells in the immunity body so that infections can manifest more severely in DM patients.[10] Hyperglycemia also affects all tissues of the body, including marrow bones. This effect is related to the glycation of proteins, substances, and other chemicals and changes physiological from erythrocytes. Previous research shows that hyperglycemia causes enhancement of erythrocytes, MCV, MCH (mean corpuscular hemoglobin), and MCHC (mean corpuscular hemoglobin concentration). Micro and macroangiopathy concomitant hyperglycemia can shorten the lifespan of erythrocytes.[5] Research has generally been carried out in DM patients without notice of complications such as ulcer diabetes. Further research is needed to find a correlation between hyperglycemia and profile hematology in DM patients with ulcer diabetes. The aim of this research is multiple correlation tests, obtained are the available meaningful relationship between blood glucose with hemoglobin.

Materials and Methods

This study used a quantitative design with practices in an experimental laboratory. This study used 30 blood samples from diabetes mellitus patients at Ulin Hospital, Banjarmasin, in February 2023. These were taken through data collection techniques using purposive sampling with criteria. Namely, DM patients have ulcer diabetes and levels of blood glucose more than 200 mg/dL. Blood glucose levels are checked using the Point-of-Care Testing (POCT) method. Hematology profile examination uses an automatic mode with a Hematology Analyzer (Medonic M-series M32). Blood sedimentation rate examination uses the Westergreen method. The data obtained are then analyzed in statistics using the correlation test regression multiple with IBM SPSS Statistics Version 29.

Ethical considerations

The procedure was reviewed and granted ethical clearance (Number: 1903-KEPK) by the Institutional Review Board (IRB) at the Banua Institute, on January 23, 2023. The authors certify that they have obtained all appropriate patient consent for the use of any identifiable patient information included in this manuscript. All procedures followed were in accordance with the ethical standards of the institutional research committee and with the Helsinki Declaration of 1975, as revised in 2013.

Results

Table 1 show that women have diabetic ulcers of various types of diabetes more than man. There are 23 (76.70%) female patients and 7 (23.30%) male patients. Based on

Table 1: Characteristics patient diabetes mellitus with ulcer diabetes (*n*=30)k

Variable	Category	*n* (%)
Gender	Male	7 (23.30)
	Female	23 (76.70)
Age	40-49 years old	9 (30)
	50-59 years old	16 (53.30)
	60-69 years old	4 (13.30)
	70-79 years old	1 (3.30)
Amount erythrocytes***	Low	6 (20)
	Normal	24 (80)
	(M=3.6-5.0×10^6/µL)	
	(F=4.2-5.4×10^6/µL)	
Hemoglobin***	Low	13 (43.30)
	Normal	17 (56.70)
	(M=12-15 g/dL)	
	(F=14-17 g/dL)	
Hematocrit***	Low	21 (70)
	Normal	8 (30)
	(M=37-43%)	
	(F=40-50%)	
MCV*	Low	6 (20)
	Standard (80-97 µm^3	24 (80)
MCH**	Low	6 (20)
	Standard (27-31 pg)	24 (80)
MCHC**	Average (32-36%)	28 (93.30)
	Tall	2 (6.70)
Leukocytes****	Normal (4-10×10^3/µL)	17 (56.70)
	Tall	13 (43.30)
LEDs****	Normal	3 (10)
	(M=0-15 mm/hour)	
	(F=0-20 mm/hour)	
	Tall	27 (90)
Platelets***	Normal (150-400×10^3 µL)	22 (73.30)
	Tall	8 (26.70)

*Hematology Analyzer Test (HCT). **Point of Care Testing (POCT). ***Complete Blood Count (CBC). ****Erythrocyte Sedimentation Rate (ESR)

facet age, DM patients with ulcers diabetes are in the range aged 50–59 years 16 (53.30%) people, and the most significant second are 9 (30%) people aged between 40 and 49 years, with a range of minimum age 41 years and maximum 70 years.

Table 1 shows that 9 (20%) people in total erythrocytes of DM patients with ulcer diabetes experience a decrease, while 80% is still within normal limits. Hemoglobin levels in DM patients also experienced a reduction in 13 (43.30%) people, and as many as 56.70% were still within the normal range. Twenty-one people (70%) experienced decreased hematocrit levels in DM patients; the remaining (30%) were within the normal range. On index erythrocytes, the results include 6 DM patients (20%) experiencing a decline in MCV and MCH values, and the other 80% still within normal limits.

On leukocytes, there were 17 (56.70%) people DM patients with ulcers suffering from diabetes; meanwhile, DM patients who experienced enhancement amount platelets as many as 8 (26.70%) people and 73.30% were within normal limits. For the value rate, 27 (90%) people Experienced Blood Sedimentation (LED) from DM patients, and only 10% of the LED value was still within normal limits.

Based on Table 2, it is obtained. The average blood glucose was 311 mg/dL (above the standard value). The average number of erythrocytes is 4.24 × 106/µL (within the normal range). The average hemoglobin was 12.3 g/dL (within the normal range). The average hematocrit (HCT) was 34.9% (below average). The mean corpuscular volume (MCV) was 82.6 fL (within the normal range). mean corpuscular hemoglobin (MCH) was 29.30 pg (within the normal range). The mean corpuscular hemoglobin concentration (MCHC) was 35.5% (within the normal range). The average number of leukocytes is 10.5 × 103/µL (above the standard value). The average number of platelets is 347 × 103/µL (within the normal range). The average speed of ESR was 64 mm/hour (above average value).

Based on Table 3, the mark coefficient regression between blood glucose and erythrocytes is 1.869 with $p = 0.997$, which is statistically insignificant ($p > 0.05$). An enhancement rate glucose of 1 mg/dL can increase erythrocytes by 1.869 × 106/µL. Coefficient value regression between blood glucose and hemoglobin, i.e., negative 824.416 with $p = 0.013$, means significant ($p < 0.05$). An enhancement rate glucose of 1 mg/dL is possibly reduced 824,416 g/dL hemoglobin levels. The coefficient regression between glucose and hematocrit is 296.832 with $p = 0.011$, which is significant ($p > 0.05$). Increasing 1 mg/dL of glucose can increase hematocrit to 296.832.

The coefficient regression between glucose and MCV is negative 306.657 with $p = 0.044$, which is significant ($p < 0.05$). Increasing 1 mg/dL of glucose can reduce MCV by 306,657 fL. The coefficient regression between glucan and MCHC is 863.337 with $p = 0$, which is significant ($p < 0.05$). 1 mg/dL enhancement rate of glucose possibly increased MCHC by 863,337 pg. Coefficient regression between glucose and MCHC, i.e., negative 395.851 with $p = 0.152$, means insignificant ($p > 0.05$). In addition, 1 mg/dL enhancement rate of glucose possibly reduced MCHC by 395.85%. The coefficient value regression between glucose and quantity leukocytes is negative 7.375 with $p = 0.082$, which means it is insignificant ($p > 0.05$). An enhancement rate glucose of 1 mg/dL is possibly lower leukocytes of 7.375 × 103/µL. Coefficient regression between glucose by quantity platelets that is negative 0.140 with $p = 0.484$ means it is insignificant ($p > 0.05$). An enhancement rate glucose of 1 mg/dL is a possible lower platelet amount of 0.140 × 103/µL. Coefficient regression between glucose at an erythrocyte sedimentation rate is negative 1.574 with $p = 0.010$, which means significant ($p < 0.05$). 1 mg/dL of an enhanced glucose rate can increase blood sedimentation by 1.574 mm/hour.

Based on Table 3, the R-Square value is 0.422 (this shows a moderate correlation) or 42.20%. This means that the rate of glucose influenced by the profile of the variables hematology amounted to 42.20%, while the remainder (57.80%) was influenced by other variables not studied.

Based on Table 3, the values obtained the R-Square is 0.422 (this shows moderate correlation) or 42.2%. It means that glucose levels are influenced by variable hematological profile of 42.2%, while the rest (57.8%) were affected by other variables not studied. From statistical results obtained probability p Value (0.175 > 0.05), then it means that profile simultaneous hematology does not affect blood glucose levels.

Discussion

DM is an abnormality of metabolism that can cause various complications. There is vulnerability. Excessive exposure to infection causes DM patients to suffer easily from tract infections, urinary tract, tuberculosis, lung, and leg infections that can worsen critical ulcer diabetes. The number of reasons for gangrene or ulcer diabetes includes

Table 2: Mean (SD) blood glucose levels and profile hematology

Glucose (mg/dL)**	Erythrocytes (10^6/µL)*	Hb (g/dL)*	HCT (%)*	MCV (fL)*	MCH (pg)**	MCHC (%)**	Leukocyte (10^3/µL)*	Thrombosite (10^3/µL)*	LED (mm/hr)***
311 (77.76)	4.24 (0.70)	12.30 (1.91)	34,9 (5.82)	82,6±5,61	29.30 (2)	35.50 (1)	10.5 (4.86)	347 (102.26)	64 (38.26)

*Hematology Analyzer Test (HCT). **Point of Care Testing (POCT). ***Erythrocyte Sedimentation Rate (ESR)

Table 3: Analysis regression linear multiple correlation glucose with profile hematology

Variable Independent	b	*p*
Amount erythrocytes (10^6/μL)**	1.86	0.99
Hemoglobin (g/dL)*	-824.41	0.01*
Hematocrit (%)*	296.83	0.01*
MCV (fL)*	-306.65	0.04*
MCH (pg)**	863.33	0.04*
MCHC (%)**	-395.85	0.15
Amount Leukocytes (10^3/μL)*	-7.37	0.08
Amount Platelets (10^3/μL)*	-0.14	0.48
Rate End Blood (mm/hour)***	1.57	0.01*
R	0.65	
R^2	0.422	
Adj. R^2	0.16	
P	0.175	

*Hematology Analyzer Test (HCT). **Point of Care Testing (POCT). ***Erythrocyte Sedimentation Rate (ESR)

neuropathy, arterial disease, pressure, and foot deformity. Neuropathy causes an increased rate of persistent blood glucose, resulting in abnormal vascular and metabolic.

The research results show that DM sufferers in women are higher than men. This follows research found where 53.40% of DM sufferers are women and 46.6% are men.[11] In another study, the results showed that 71.10% of DM sufferers were of this type sex, female, and men as much as 28.90%. In this research, it is also known that there is a connection between type genitalia and the incidence of peripheral neuropathy diabetes,[12] which also becomes the reason for ulcer diabetes. This is because women, in a way physique, have a greater chance of experiencing enhancement index mass body.[13] The presence of a syndrome cycle of menstruation and menopause in women causes body fat to pile up, hindering the transportation of glucose into cells.[12,14]

Research data show DM patients with ulcers diabetes aged 50–59 years (53.30%) and 40–49 years (30%). This follows other research that shows most DM sufferers aged 45–64 years (67.20%).[11,15] Further study also states that most patients who suffer from DM are over 45 years.[16] This is because someone over 40 years old is vulnerable to experiencing complications of diabetes. The risk of diabetes is more tremendous because of glucose intolerance and ageing. Hence, insulin produced by pancreatic beta cells experiences a decrease.[16] This follows research by.[17] that age increases the risk of neuropathy peripheral diabetes. This is because if the body is over 30 years old, somebody will experience a change in physiologically capable lower function of his body.[18,19]

The statistical test results show a correlation between blood glucose and hemoglobin, hematocrit, MCV, and MCH. There is also no relationship between the quantity of erythrocytes and MCHC. However, these research data show the occurrence of anemia characterized by a decrease in erythrocytes, hemoglobin, and hematocrit in some DM patients. This follows other research that 26% of DM patients experience anemia with hemoglobin levels <11.5 g/dL.[17] Further research shows a significant reduction in mean hemoglobin, erythrocytes, hematocrit, and MCV in diabetes patients compared to nondiabetic controls.[20,21]

Anemia in diabetes is generally visible when accompany by complications of infection, heart disease, renal failure, and enteropathy. There is a connection between the amount of red blood cells and difficulties in microvasculature in type 2 DM. It was reported that the proportion of patients with microvasculature complications increases when the number of erythrocytes decreases.[18] Hyperglycemia is related to changes functional in the hemoglobin molecule, disorders osmotic, and viscosity cytoplasm in each cell. All these changes impact cell erythrocytes, including the number of erythrocytes, hemoglobin, hematocrit, MCV, MCH, and MCHC.[16] Hyperglycemia also affects the production of erythrocyte function as a physical characteristic, so it neither influences function nor directly affects the structure of the vasculature. Also, chronic DM complications will affect the life span, viscosity of cytoplasm, and deformability of red blood cells.[19]

The research results showed no correlation between leukocyte amounts and blood glucose levels. However, research data shows that 56.70% of DM patients with ulcer diabetes experience an enhanced amount of leukocytes. An increase in leukocytes can be caused by the presence of infection in wounds or diabetic foot ulcers experienced by DM patients. Diabetes patients experience increased amounts of leukocytes, lymphocytes, and neutrophils significantly compared to nondiabetics. The ascension of leukocytes happens along with the increase in oxidative stress triggered by the increased rate of blood glucose. Polymorphonuclear and mononuclear leukocytes can be activated by glycation end-product continuation and cytokines in hyperglycemia.[22] Research in China also shows enhanced leukocytes related to disorders rate fasting blood glucose (Impaired Fasting Glucose, IFG). Amount leukocytes as marker risk happen insulin resistance, diabetes, syndrome metabolism, and disease arteries coroner. There is a close relationship between the number of leukocytes and the prevalence of type 2 DM.[23] Other research also states acute and chronic hyperglycemia is related to insulin resistance in type 2 DM and hyperlipidemia.[24,25] An elevated level of leukocytes, even within the normal range, is associated with complications of chronic type 2 diabetes mellitus and can be used in predicting the development of complications of micro and macrovascular in DM patients.[26]

Research data show no significant relationship between platelets and blood glucose levels in DM patients.

However, as many as 8 (26.7%) DM patients experienced an enhancement amount of platelets. Enhancement index platelets indicated function platelets are more reactive and aggregate.[26] Other research also shows enhanced fibrinogen levels, albumin, and total platelets in DM patients with ulcer diabetes compared to DM patients without.[27] This is caused because, in diabetic foot ulcers, it increases fibrinogen levels due to existing thrombosis, platelets increase because of activation of inflammatory mediators, and serum albumin levels decrease because cytokines withdraw albumin from the intravascular space.[28]

The research results show a significant relationship between the erythrocyte sedimentation (ESR) rate and glucose. This indicates a strong correlation between inflammation and control glycemia in patients with type 2 diabetes mellitus, showing that inflammation plays a vital role in the pathogenesis of diabetes.[29] This follows other research that LEDs are independently related to the level and severity of complications in type 2 DM patients.[30] Further research also states that patients with high HbA1C and ESR levels also have a higher risk of experiencing amputation in the lower extremities.[31]

This research has several limitations, including a limited number of participants and a lack of consideration for the duration of diabetes-related ulcers or the severity of the injuries. Future studies should include more comprehensive parameters to determine which factors influence the hematological profile of diabetes patients with ulcers.

Conclusion

The study investigates how blood glucose levels affect hematological parameters in diabetic ulcer patients, mainly women aged 50 to 59. Many have low hemoglobin and hematocrit, elevated ESR, and high blood glucose, indicating poor glycemic control. Regression analysis shows that higher glucose correlates with lower hemoglobin, hematocrit, and MCV, while positively correlating with MCHC and ESR. The findings suggest that other factors also significantly influence glycemic control, indicating a need for further research.

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Conflicts of interest

Nothing to declare.

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