

Variability of endothelial biochemical parameters and their association with cardiovascular diseases in patients with type 2 diabetes at Bafoussam Regional Hospital in Cameroon

Christelle Pougoua Djuimo¹, Guy Sedar Singor Njateng^{1,2*}

¹Department of Biochemistry, Faculty of Science, University of Dschang, P.O. Box 67 Dschang, Cameroon

²Department of Pharmaceutical sciences, Faculty of Medicine and Pharmaceutical Sciences, University of Dschang, P.O. Box 96 Dschang, Cameroon

Correspondance:

✉ **Assoc. Prof. Dr Guy S.S. Njateng**

Email: njatguysedars@yahoo.fr

Background: Type 2 diabetes (T2D) is a major public health problem, particularly in low- and middle-income countries. It is often associated with an increased risk of cardiovascular complications, promoted by vascular endothelial dysfunction. This work aims to analyze the variability of endothelial biochemical markers (endothelin-1 and eNOS) and their association with cardiovascular diseases in patients with T2D at the Bafoussam Regional Hospital.

Method: A descriptive, cross-sectional, and analytical study was conducted between April and June 2025 on 100 patients. The markers measured included fasting blood glucose, HbA1c, lipid profile, endothelin-1, endothelial nitric oxide synthase (eNOS) and troponin I. Statistical analysis was performed using SPSS v26.

Results: The results obtained showed a predominance of women (63%, n=63/100) over men (37%, n=37/100) and the age group of 35-64 years (62%, n=62/100) was the most represented. The levels of glycated hemoglobin (p-value=0.0232), LDL cholesterol (p-value=0.039), and high total cholesterol (p-value=0.025), were significantly associated with endothelial dysfunction by the elevation of endothelin-1 and the decrease of *endothelial nitric oxide synthase*. Similarly, high levels of endothelin 1 (p value=0.001) and low levels of *endothelial nitric oxide synthase* (p-value=0.002) were significantly associated with cardiovascular diseases through elevated blood troponin I levels.

Conclusion: This study revealed a significant association between glycemic and lipid imbalance and endothelial dysfunction and a correlation between endothelial dysfunction and the occurrence of cardiovascular diseases, particularly myocardial ischemia.

Keywords: Type 2 diabetes, endothelium, eNOS , endothelin-1, cardiovascular complications.

1. INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disease characterized by prolonged hyperglycemia, resulting from insulin resistance and/or impaired pancreatic secretion [1]. It is now a real public health problem, particularly in low- and middle-income countries. In 2021, an estimated 537 million adults were living with diabetes worldwide, and this figure could reach 783 million by 2045 [2].

In Cameroon, the prevalence of diabetes is estimated at between 6% and 8% in adults, with a higher concentration in urban areas [3]. This increase is linked to several factors: sedentary lifestyle, obesity, unbalanced diet, aging of the population, and inequalities in access to care [4].

Complications of T2D are numerous, including retinopathy, nephropathy, neuropathy and especially cardiovascular disease (CVD), which represents the main cause of mortality in diabetic patients [5]. One of the first steps of these complications is the dysfunction of the vascular endothelium, a cell layer essential for the regulation of vascular tone, hemostasis and vascular permeability [6].

This dysfunction is notably characterized by a decrease in endothelial nitric oxide synthase (eNOS) , responsible for the production of nitric oxide (NO), a key vasodilator, and an elevation of endothelin-1 (ET-1) , a potent vasoconstrictor [6,7]. Chronic hyperglycemia activates deleterious metabolic pathways such as the polyol pathway, the formation of advanced glycation end products (AGEs), and protein kinase C, which alters vascular balance [1].

Numerous publications have shown that elevated ET-1 levels and decreased eNOS concentrations are associated with rapid progression of atherosclerosis, vascular damage, and an increased risk of major cardiovascular events [5,7]. Troponin I, on the other hand, is a

specific cardiac biomarker that can indicate silent myocardial damage in diabetic patients, even before the onset of clinical symptoms [8].

Despite the importance of these markers, few Cameroonian studies have focused on the variability of eNOS and ET-1, and their association with lipid, glycemic and cardiac profile in T2D patients. This research aims to fill this gap.

2. Methods

2.1. Design and study population. This descriptive, cross-sectional and analytical study was conducted using two approaches (qualitative and quantitative) over a period of 3 months. The sample size was calculated using the following Lorenz formula $n = \frac{z^2 \times P(1-P)}{m^2}$

(where n = sample size; z = confidence level according to the standard normal distribution; z = 1.96; p = estimated proportion of the population with the characteristic, for a 95% confidence level; m = margin of error tolerated at 5%; P = 6.9, which is the prevalence of type 2 diabetes in Cameroon in 2022 according to the IDF [1]; m = 5%, which is the tolerated margin of error). This calculation yielded a sample size of 86 patients, which we extended to 100 patients in order to maximize the sample size. This study aimed to evaluate the effect of chronic hyperglycemia on the variability of endothelial biochemical parameters (endothelin-1, endothelial nitric oxide synthase), lipid profile and analyze their relationship with the occurrence of cardiovascular diseases in type 2 diabetic patients. The study was conducted at the Bafoussam Regional Hospital (HRB), in the internal medicine department and the clinical biochemistry laboratory. Participants in this study were patients aged 35 years and older whose diagnosis of type 2 diabetes was confirmed according to the American Diabetes Association recommendations which include fasting blood glucose on 2 occasions ≥ 1.26 g/L (7 mmol/L) and HbA1c level > 6.5 to 7% [9]. Written and signed informed consent was obtained from all participants involved in the study. Type 2 diabetic patients not fasting at the time of sampling and type 2 diabetic patients with recent cardiovascular disease were excluded from the study. The regional ethics committee for human health research in the western region gave its approval through an ethical clearance N^o/296/26/02/2025/CE/CRERSH-OU/VP.

2.2. Data collection. Before sample collection, an interview was conducted with the participants to present the objectives and possible constraints as well as the guarantees related to data confidentiality. This step allowed obtaining free and informed consent. It was followed

by a survey based on a structured questionnaire, designed to collect sociodemographic data and medical history. Among the included participants, blood pressure, weight and height were measured respectively by the sphygmomanometer, scale and height rod and subsequently blood sampling was carried out: blood samples of approximately 5 mL were collected in EDTA and heparin tubes and dry tube

2.3. Laboratory tests. Blood collected in the heparinized tube and dry tube was centrifuged at 3000 rpm for five minutes, allowing the isolation of plasma and serum. These were used for the determination of endothelin 1, eNOS for plasma and lipid profile, as well as troponin I for serum. As for whole blood collected in EDTA tube, it was used to measure the HbA1c concentration. In addition, the Finecare™ rapid quantitative immunoassay was used for the determination of troponin I and HbA1c levels [10].

2.4. Statistical methods. Data recorded on the survey forms were entered and analyzed using Microsoft Office Excel 2016 software. For the analysis of changes in the levels of glycemic, lipid, endothelial and cardiac biochemical markers. Pearson correlation and the use of univariate and multivariate binary logistic regression tests were performed using IBM SPSS Statistics version 26 software for the association between endothelial markers and cardiovascular complications. Significance threshold: $p < 0.05$; the confidence interval set at 95%.

3. Results

3.1. Demographic, clinical and anthropometric information.

Regarding the social, demographic, clinical and anthropometric results of the 100 type 2 diabetic patients included in our study (Table 1 and Figure 1): the population was predominantly female (63%) versus 37% male, with an average age of 57.87 (35-90) years; This population was divided into 2 age groups (35-64 years; 65 years and older), the age group of 35 to 64 years was the most represented and constituted 62% of the population. Depending on the duration of the disease, 3% of patients had a duration of diabetes between 21 years and more; 24% had a duration of diabetes between 11 and 20 years; 36% had a duration of diabetes between 6 and 10 years and 37% had a duration of diabetes between 1 and 5 years. 6 % of the population was underweight while 52% of this population had a normal BMI, 27% were overweight and 15% obese. This is shown in Table 1 and Figure 1

Table 1: Sociodemographic characteristics

Features	Staff	Percentages(%)
Sex		
Male	37	37
Female	63	63
Total	100	100.0
Age		
35-64 years old	62	62
65yearsAndmore	38	38
Total	100	100.0
Duration of diabetes		
1-5 years	37	37
6-10 years old	36	36
11-20 years old	24	24
21 years and older	3	3
Total	100	100.0
Body mass index (BMI)		
Underweight	6	6
Normal	52	52
Overweight	27	27
Obesity	15	15
Total	100	100

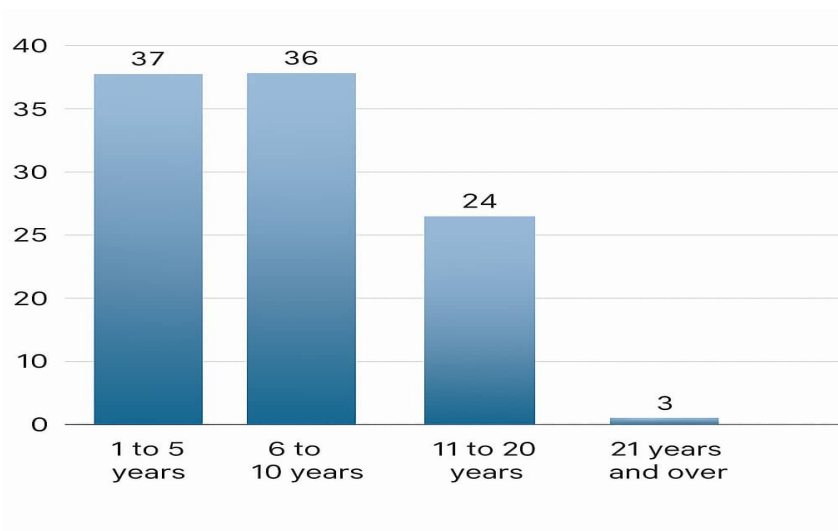


Figure 1: Distribution of participants according to duration of diabetes

The results of the clinical data in Figure 2 below represent the distribution of our participants according to the complications related to diabetes. It shows us that 92% (n=100) of participants presented at least one macro or micro vascular complication. Microvascular complications were less present with 6% (n=100) of participants having been at least once victim; 5% (n=100) presenting a renal failure and 1% participant presenting an autonomic neuropathy. Macrovascular complications were the most present with 86% (n=100); 28% presenting the diabetic foot; 5% of heart failure; 7% of stroke; 22% of peripheral arterial disease and 24% of coronary artery disease.

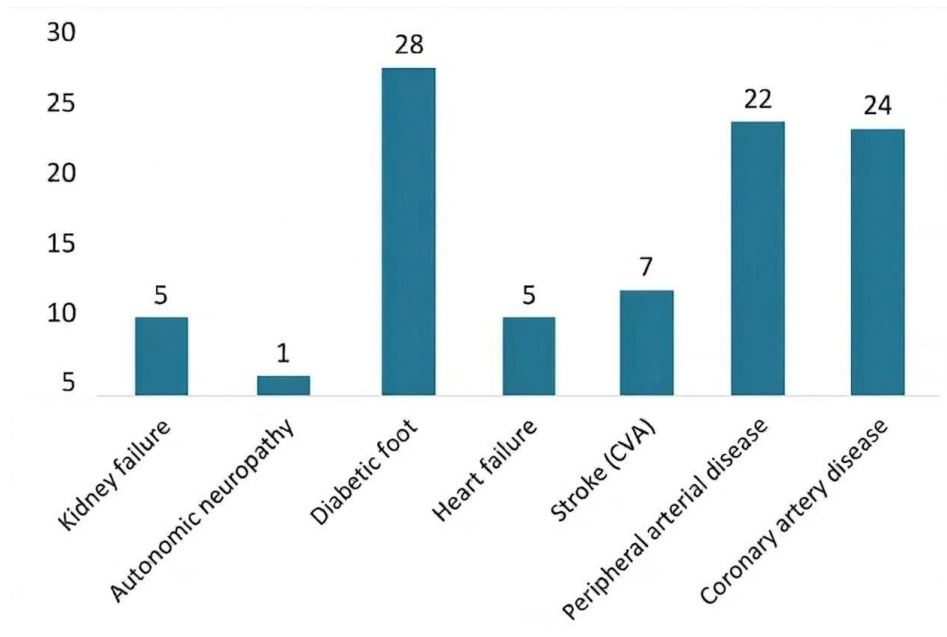


Figure 2: Prevalence of macro and micro vascular complications

3.2 Distribution of macrovascular complications

Table 2 below shows that the majority of participants with macrovascular complications (N=86) were female with a percentage of 65.1% (N=56), and the age group 35 to 64 years was the most affected by these diseases. Men were the least affected with a percentage of 34.88% (N= 30). Patients with a duration of 6 to 10 years of diabetes were more affected by these diseases. The normal BMI group (51%)was more affected followed by the Overweight BMI group then the other BMI groups.

➤ Diabetic feet

Table 2 below shows that the majority of participants with diabetic feet (N=28) were female with a percentage of 60.71% (N=11), and the age group most affected by this disease was the 35 to 64 years group with a percentage of 60.71% (N=11) of cases. Participants with a duration of diabetes more than 6 to 20 years were the most affected while the Normal BMI group was the most affected.

➤ Heart failure

Table 2 below shows that the majority of participants who had suffered from heart failure at least once (N=5) were male with a percentage of 80% (N=4), and the age group most affected by this disease was 35-64 years. In this study, patients with a normal BMI and a duration of diabetes ranging from 1 to 10 years were the most affected.

➤ Peripheral arterial disease

Table 2 below shows that the majority of participants with peripheral arterial disease (N=21) were female with a percentage of 72.7% (N=16), and the age group most affected by this disease was the 35-64 years group with percentage of 72.71% (N=12) of cases. Participants with a duration of diabetes more than 1 to 10 years were the most affected with a percentage of 72.7% (N=16) while the normal BMI group was the most affected.

➤ Stroke

Table 2 below shows that the majority of participants who had suffered at least one stroke (N=3) were female with a percentage of 60% (N=3), and the age group most affected by this disease was the 35-64 age group. In this study, it was the normal BMI group that had a higher stroke percentage 60% (N=3).

➤ Coronary artery disease

Table 2 below shows that the majority of participants with coronary artery disease (N=24) were female with a percentage of 70.08% (N=17), and the age group most affected by this disease was the 35-64 years group with a percentage of 70.08% (N=17) of cases. Participants with a duration of diabetes more than 1 to 5 years were the most affected. The normal BMI group was the most affected.

3.3 Distribution of microvascular complications

Table 2 below shows that the majority of participants with microvascular complications (N=6) were male with a percentage of 66.7% (N=6), and the age group 35 to 64 years was the most affected by these diseases. Women were the least affected with a percentage of 33% (N=2). Patients with a duration of 11 to 20 years of diabetes were more affected by these diseases. The normal BMI group was more affected than other BMI groups. Among participants with renal failure, the majority were male with a percentage of 60% (N=3); the groups most affected here were 35 to 64 years, duration of diabetes between 10 and 20 years and normal BMI.

Table 2: Distribution of micro and macrovascular complications

Variables	Terms and Conditions	RF	AN	DF	HF	CVA	PAD	CAD
Sex	Female	2	0	17	1	16	5	17
	Male	3	1	11	4	6	2	7

Age	35-64 years old	3	0	15	3	12	5	17
	65 and over	2	1	13	2	10	2	7
Duration of diabetes	1-5 years	1	0	5	2	8	2	11
	6-10 years old	0	1	11	2	8	3	7
	11-20 years old	3	0	11	1	5	2	6
	21 years and older	1	0	1	0	1	0	0
BMI	Underweight	2	0	3	0	2		1
	Normal	2	1	13	3	11		13
	Overweight	1	0	10	2	6		8
	Obesity	0	0	1	0	3		1

RF: renal failure;**AN:** autonomic neuropathy;**DF:** diabetic foot; **HF:** heart failure; **CVA:** cerebrovascular accident; **PAD:** peripheral arterial disease; **CAD:** coronary artery disease

3.4. Analysis of variations in the levels of biochemical markers associated with endothelial dysfunction and cardiovascular complications

Table 3 below shows the distribution of participants according to normal and abnormal biochemical parameters. It can be seen that out of 100 participants 46% have high uncontrolled glucose (HbA1C); 83% have high LDL cholesterol; 30% have low HDL cholesterol; 29% have high TRIG (triglycerides); 27% have high TC (total cholesterol); 56% have high ET-1; 67% have low endothelial nitric oxide synthase and 53% have elevated troponin I levels.

Table 3: Distribution of participants according to normal and abnormal biochemical parameters

Markers	Staff	Percentage (%)
HbA1C	Normal: 46	46.0
	Abnormal: 54	54.0
	Total: 100	100.0
HDL	Normal: 70	70.0
	Abnormal: 30	30.0

	Total: 100	100.0
LDL	Normal: 17	17.0
	Abnormal: 83	83.0
	Total: 100	100.0
Triglycerides	Normal: 71	71.0
	Abnormal: 29	29.0
	Total: 100	100.0
Total cholesterol (CT)	Normal: 73	73.0
	Abnormal: 27	27.0
	Total: 100	100.0
Endothelin 1 (ET-1)	Normal: 44	44.0
	Abnormal: 56	56.0
	Total: 100	100.0
eNOS	Normal: 33	33.0
	Abnormal: 67	67.0
	Total: 100	100.0
Troponin	Normal: 47	47.0
	Abnormal: 53	53.0
	Total: 100	100.0

3.5 Determination of the correlation between hyperglycemia, lipid imbalance and endothelial dysfunction

3.5.1: Hyperglycemia and lipid imbalance associated with endothelin-1 level

Table 4 shows the association between biochemical markers (HbA1c, HDL, LDL, total cholesterol, triglycerides) and ET-1 status (normal or abnormal), an indicator of endothelial dysfunction. In an univariate binary logistic regression model, the HbA1c marker (a marker of glycemic imbalance) showed a significant association with endothelial dysfunction ($p = 0.02$; OR = 2.6; 95% CI: 1.154–5.858), indicating that patients with high HbA1c levels were 2.6 times more likely to have endothelial dysfunction. Similarly, an increase in LDL-cholesterol is significantly associated with an increased risk ($p = 0.015$; OR = 3.825; 95% CI: 1.232–11.877), as is an increase in total cholesterol (TC) ($p = 0.008$; OR = 3.8; 95% CI: 1.375–10.505).

Table 4: Markers associated with endothelin 1

Endothelin 1					
Variables	Terms and Conditions	Normal	Abnormal	P-value	OR (95 % CI)
HbA1c	Normal	26	20	0.02	2.6(1.154-5.858)
	Abnormal	18	36		
HDL	Normal	27	43	0.095	0.48(0.202-1.144)
	Abnormal	17	13		
LDL	Normal	12	5	0.015	3.825(1.232-11.877)
	Abnormal	32	51		
Total cholesterol	Normal	38	35	0.008	3.8(1.375-10.505)
	Abnormal	6	21		
TRIG	Normal	34	37	0.220	1.746(0.713-4.278)
	Abnormal	10	19		

In multivariate analysis, HbA1c marker; LDL cholesterol and total cholesterol are still significantly associated with high endothelin 1 level; showing that patients with high HbA1c level have 2.7 times the risk of having endothelial dysfunction (**P=0.02; OR=2.73; 95% CI: 1.147-6.500**). Similarly, patients with high LDL-cholesterol have a 3.4-fold increased risk of

endothelial dysfunction ($p = 0.039$; $OR = 3.44$; $95\% CI: 1.067-11.151$), just as an increase in total cholesterol (TC) ($p = 0.025$; $OR = 3.42$; $95\% CI: 1.170-10.028$) in these patients would increase the risk of endothelial dysfunction 3.42 times. This is shown in Table 5

Table 5: Multivariate analysis of markers significantly associated with endothelin1 levels

Endothelin 1					
Variables	Terms and Conditions	Normal	Abnormal	P-value	aOR(95% CI)
HbA1c	Normal	26	20	0.0232	2.730(1.147-6.500)
	Abnormal	18	36		
LDL	Normal	12	5	0.039	3.449(1.067-11.151)
	Abnormal	32	51		
Total cholesterol	Normal	38	35	0.025	3.425(1.170-10.028)
	Abnormal	6	21		

3.5.2: Hyperglycemia and lipid imbalance associated with the Endothelial rate nitric oxide synthase

Endothelial status nitric oxide synthase(normal or abnormal), is an indicator of endothelial dysfunction. In a univariate binary logistic regression model, the HbA1c marker ($p = 0.192$; $OR = 1.70$ (0.764–3.781)) does not show a statistically significant association. There is a trend towards an increased risk of endothelial dysfunction, but the confidence interval contains 1, making the result inconclusive. The HDL marker ($p = 0.710$; $OR = 0.452$ (0.189–1.078)) has a non-significant effect. Although HDL shows a protective trend against endothelial dysfunction, the result remains statistically insignificant. LDL ($p = 0.012$; $OR = 4.026$ (1.295–12.514)) shows a significant association. High LDL is associated with a 4-fold increased risk of endothelial dysfunction, demonstrating a deleterious effect of LDL on the vascular wall. Total cholesterol ($p = 0.005$; $OR = 9.697$ (2.681–35.075)) shows a highly significant result. High total cholesterol is associated with an almost 10-fold increased risk of endothelial dysfunction. Triglycerides($p = 0.272$; $OR = 1.650$ (0.673–4.044)) is not significantly associated while LDL and total cholesterol are significantly associated with endothelial dysfunction. Other markers (HbA1c, HDL, TG) do not show a significant association in this analysis.

Table 6: Factors of associated diabetes *Endothelial nitric oxide synthase*

Enos		Normal	Abnormal	P-value	OR (95% CI)
HbA1c	Normal	23	20	0.192	1.7(0.764-3.781)
	Abnormal	23	34		
HDL	Normal	26	17	0.71	0.452(0.189-1.078)
	Abnormal	44	13		
LDL	Normal	12	31	0.012	4.026(1.295-12.514)
	Abnormal	5	52		
CT	Normal	40	3	0.005	9.697(2.681-35.075)
	Abnormal	33	24		
TRIG	Normal	33	10	0.272	1.650(0.673-4.044)
	Anormal	38	19		

In multivariate analysis between LDL, total cholesterol and Enos, only total cholesterol showed a significant association with low eNOS level, marker of endothelial dysfunction ($p = 0.001$; $OR = 8.858$; $95\% CI: 2.411-32.542$); this is shown in Table 7

Table 7: Multivariate analysis of the factor associated with *endothelial rate nitric oxide synthase*

Endothelial nitric oxide synthase					
Variables	Terms and Conditions	Normal	Abnormal	P-value	aOR (95 % CI)
LDL	Normal	12	31	0.059	3.448(0.995-11.259)
	Abnormal	5	52		
CT	Normal	40	3	0.001	8.858(2.411-32.542)
	Abnormal	33	24		

3.6: Determine the association between endothelial dysfunction parameters and cardiovascular diseases

Table 8 examines the association between ET-1 and eNOS levels (markers of vascular endothelial status) and troponin, a marker of myocardial damage. In a univariate binary logistic regression model, the ET-1 marker ($p = 0.000$; $OR = 4.916$)

(2.096–11.531)) shows a highly significant result. High endothelin-1 levels are associated with a 4.9-fold increased risk of cardiac damage, suggesting a strong involvement of this marker in the link between endothelial dysfunction and cardiovascular disease. The eNOS marker ($p = 0.000$; OR = 4.488 (1.93–10.477)) also shows a highly significant result. Altered eNOS is strongly associated with elevated troponin, highlighting the direct impact of endothelial dysfunction on the myocardium. These results confirm that endothelial dysfunction, as evidenced by an increase in ET-1 and a decrease in eNOS, is significantly linked to the occurrence of cardiovascular diseases in diabetic patients.

Table 8: Correlation between endothelial dysfunction and cardiovascular complications

		Troponin			
		Normal	Abnormal	P-value	OR (95% CI)
ET-1	Normal	30	14	0,000	4.916(2.096-11.531)
	Abnormal	17	39		
eNOS	Normal	23	10	0,000	4.488(1.93-10.477)
	Abnormal	24	43		

In a multivariate binary logistic regression model (Table 9); markers of endothelial dysfunction showed a significant association with the cardiac injury marker, meaning that patients with high endothelin 1 and low *endothelial nitric oxide synthase* have a high risk of developing cardiovascular disease, i.e. 4.5 times for those with a high level of endothelin1 ($p = 0.001$; OR = 4.5; 95% CI: 1.90-10.70) and 4.7 times for those with a low level of eNOS ($p = 0.002$ OR = 4.7; 95% CI: 1.88-10.50).

Table 9: Multivariate analysis between factors associated with myocardial injury

		Troponin			
Variables	Terms and Conditions	Normal	Abnormal	P-value	aOR (95 % CI)
Endothelin-1	Normal	30	14	0.001	4.5(1.90-10.70)
	High	17	39		
Endothelial nitric oxide synthase	Normal	23	10	0.002	4.7(1.88-10.50)
	Low	24	43		

4. Discussion

The study was conducted on 100 type 2 diabetic patients, selected according to well-defined criteria at the Bafoussam Regional Hospital and aimed to evaluate the effect of chronic hyperglycemia on the variability of endothelial biochemical parameters (endothelin-1, endothelial nitric oxide synthase), lipid profile and analyze their link with the occurrence of cardiovascular diseases in type 2 diabetic patients. The descriptive analysis helped to describe the distribution of patients according to their sociodemographic characteristics, which allowed to see that the cohort was made up mainly of women (63%) against 37% of men of average age equal to 58.87 (35-90 years); the age group namely the group of 35 to 64 was more represented in the cohort. Most of our participants had a normal BMI 52% against 27% overweight and 15% obese.

Of the 100 participants, 92% had a microvascular (6%) or macrovascular (86%) complication or both already diagnosed. For microvascular complications, 5% had renal failure and 1% autonomic neuropathy; for macrovascular complications, 28% had diabetic foot; 24% coronary artery disease; 22% peripheral arterial disease; 7% stroke and 5% heart failure.

Statistical analysis following a univariate logistic regression model of the markers Hb1Ac, HDL, LDL, TC, Triglycerides, ET-1, eNOS, troponin according to the factors: sex, age group, BMI, and duration of diabetes, did not reveal any statistically significant association. These results corroborate those of several recent previous works which have highlighted this same type of non-association after adjustment. Notably, in the ARIC study conducted by Hamo et al in 2022 it was demonstrated that the duration of diabetes was not an independent factor associated with an elevation of troponin T in type 2 diabetic patients [11].

The association observed in crude analysis disappeared after multivariate adjustment, suggesting that it is not the time of diabetes progression alone, but rather the quality of metabolic and vascular control that influences the risk of myocardial injury. Similarly, an analysis based on the NHANES 1999–2004 cohort [12] found no significant association between diabetes duration or HbA1c with cardiovascular biomarkers (NT- proBNP , troponin), once variables such as age, sex, comorbidities and lipid status were taken into account. These results suggest that the severity of vascular and myocardial involvement in diabetics is multifactorial and depends more on the quality of current metabolism (glycemic

and lipid control, inflammation, endothelial function) than on the absolute duration of the disease.

Multivariate analysis between markers of endothelial dysfunction (endothelin1 and endothelial nitric oxide synthase), and markers of lipid and glycemic imbalance reveal that elevated HbA1c, LDL and total cholesterol are associated with elevated endothelin1, a key indicator of endothelial dysfunction. Multivariate analysis of markers of lipid and glycemic imbalance with eNOS as the dependent variable showed that only abnormal (elevated) total cholesterol remains significantly associated with decreased eNOS, while LDL, although showing a trend, does not remain independent. The objective here was to demonstrate that metabolic dysfunction induces a reduction in NO production, via decreased eNOS, which is confirmed; these results are consistent with the observations of Lu et al. [13], who showed in cell culture that oxidized LDL directly inhibits eNOS expression in endothelium exposed to a hyperglycemic environment.

Multivariate analysis using a logistic regression model on endothelin-1 (ET-1) levels according to the presence or absence of troponin I shows that patients with elevated troponin I had a significant elevation of ET-1. This result is in agreement with several previous studies, including that of Xue et al. [14], which showed that ET-1, a potent vasoconstrictor, is overexpressed in type 2 diabetes under the effect of oxidative stress and chronic hyperglycemia. This elevation promotes vasoconstriction, endothelial inflammation and myocardial ischemia, which can lead to an elevation of troponin I, as we observed in this study. In parallel, the analysis on eNOS reveals a significant decrease in its level in patients with elevated troponin I. This decrease in endothelial nitric oxide is a major indicator of endothelial dysfunction, because eNOS is responsible for the production of NO, a vasodilator essential for vascular homeostasis. These results are consistent with those of Scheen, who pointed out that diabetes impairs eNOS function, thereby reducing vasodilation, increasing vascular permeability and promoting the progression of atherosclerosis [15]. Compared to the study of Wang et al. [16], which reported an inverse correlation between eNOS and the risk of major cardiovascular events, our data reinforce the idea that eNOS deficiency constitutes a marker of vascular severity in diabetics.

The common points of our study with previous studies are therefore multiple: alteration of eNOS, elevation of ET-1, association with troponin I, disruption of the lipid profile, and aggravation under the effect of poor glycemic control. However, some studies have focused only on inflammatory markers (CRP, IL-6), and in most cases several of these

studies do not consider specific endothelial markers, or the exclusive use of clinical markers. For example, several research studies only examine the body mass index, blood pressure or ECG (Electrocardiogram), without dosage of ET-1 or eNOS, which limits the mechanistic understanding of the link between diabetes and cardiovascular diseases. This study partly fills this gap by providing a mechanistic analysis based on objective biological data; also providing new elements, notably through the combined approach of biochemical markers in a diabetic Cameroonian population, which is poorly documented. This study focuses on functional markers of the endothelium, which constitutes an advance in the screening of cardiovascular risk at an early stage.

However, the present study has limitations. The relatively modest sample size, although sufficient to identify significant trends, limits extrapolation to the general population. In addition, the absence of a non-diabetic control group makes it difficult to estimate the absolute extent of the observed endothelial dysfunction. Since the study is cross-sectional, it does not allow to establish a causal relationship between the measured parameters and cardiovascular diseases. Finally, the lack of measurement of certain inflammatory biomarkers (CRP, IL-6, TNF- α) deprives us of a more complete view of the vascular microenvironment.

5. Conclusion

This study of 100 patients highlights a significant association between glycemic and lipid imbalance, endothelial dysfunction and the occurrence of cardiovascular diseases in patients with type 2 diabetes. Elevated HbA1c, LDL-cholesterol and total cholesterol are correlated with an increase in endothelin-1 and a reduction in eNOS, reflecting a vascular imbalance promoting arterial stiffness and myocardial ischemia. The close relationship observed between these endothelial markers and troponin I elevation suggests that endothelial dysfunction could be an early indicator of cardiac involvement in diabetic patients.

Data Availability Statement: Data supporting the results of this study can be obtained from the corresponding authors upon reasonable request.

Ethics Statement: The research received approval from the Research Ethics Committee

Conflicts of interest: The authors declare that they have no conflicts of interest.

Author Contributions: In this research project, all authors played integral roles across every phase of the work. All authors reviewed and approved the final version of the manuscript for submission.

Funding: No funds were available.

Acknowledgments: The authors express their gratitude to the staff of the clinical biochemistry laboratory of the Bafoussam regional hospital and to the patients who devoted their time and donated their samples for this research.

References

- [1]. Sun H, Saeedi P, Karuranga S, et al. (2022). IDF Diabetes Atlas: global and regional diabetes prevalence estimates for 2021 and projections for 2045. *Diabetes Research and Clinical Practice*, 183, 109119. <https://doi.org/10.1016/j.diabres.2021.109119>
- [2]. Scheen , A. J. (2018). Cardiovascular Effects of New Oral Glucose-Lowering Agents: DPP-4 and SGLT-2 Inhibitors. *Circulation Research*, 122 (10), 1439–1459. <https://doi.org/10.1161/circresaha.117.311588>
- [3]. Medjahdi K, et al. (2022). Diabetes in Africa: Public Health Issues. *Pan African Medical Journal* , 43:234 .<https://doi.org/10.11604/pamj.2022.43.234.35200>
- [4]. Taherian MR, et al. (2025). Diabetes Care Disparities: Impact of Lifestyle and Medication Access. *Journal of Diabetes Research*, Article ID 8029111. <https://doi.org/10.1155/2025/8029111>
- [5]. Sheen YJ, et al. (2021). Diabetes duration and subclinical myocardial injury: the ARIC study. *Journal of the American College of Cardiology*, 77(12), 1526–1537. <https://doi.org/10.1016/j.jacc.2021.01.040>
- [6]. Goligorsky MS. (2021). Endothelial cell dysfunction: new insights from diabetes research. *Cardiovascular Diabetology*, 20, 163. <https://doi.org/10.1186/s12933-021-01379-4>
- [7]. Yamamoto Y, Yamamoto H. (2020). Role of endothelin-1 in atherosclerosis in diabetic patients. *Journal of Atherosclerosis and Thrombosis*, 27(2), 107–118. <https://doi.org/10.5551/jat.49872>

- [8]. Newby LK, Jesse RL, Babb JD, et al. (2019). Troponins in cardiovascular disease: 2019 update. *Journal of the American College of Cardiology* , 74(21), 2717–2738. <https://doi.org/10.1016/j.jacc.2019.08.1057>
- [9]. American Diabetes Association (2015), “2. Classification and Diagnosis of Diabetes,” supplement_1, *Diabetes Care*39, S13–S22, <https://doi.org/10.2337/dc16-S005>
- [10]. Horiba Medical . (2009). ABX Pentra 400 – User Manual (Ref. RAB125EEN).
- [11]. Hamo, CE, Echouffo-Tcheugui , JB, Zhang, S., Florido , R., Pankow, JS, Michos , ED, Goldberg, R., Nambi , V., Gerstenblith , G., Post, WS, Blumenthal, RS, Ballantyne, C., Selvin, E., Coresh, J., & Ndumele , CE (2022). Diabetes Duration and Subclinical Myocardial Injury: The Atherosclerosis Risk in Communities Study (ARIC). *Clinical Chemistry*,68 (10), 1272-1280. <https://doi.org/10.1093/clinchem/hvac117>
- [12]. Denimal , D. (2023). Carbamylated lipoproteins in diabetes. *World Journal of Diabetes* , 14 (3), 159-169. <https://doi.org/10.4239/wjd.v14.i3.159>
- [13]. Lu, Y., Wang, W., Liu, J., Xie, M., Liu, Q., & Li, S. (2023). Vascular complications of diabetes: A narrative review. *Medicine*,102 (40), e35285. <https://doi.org/10.1097/MD.00000000000035285>
- [14]. Xue , C., Chen, K., Gao, Z., Bao, T., Dong, L., Zhao, L., Tong, X., & Li, X. (2023). Common mechanisms underlying diabetic vascular complications: Focus on the interaction of metabolic disorders, immuno-inflammation, and endothelial dysfunction. *Cell Communication and Signaling* , 21 (1), 298.<https://doi.org/10.1186/s12964-022-01016-w>
- [15]. Scheen , A. J. (2018). Cardiovascular Effects of New Oral Glucose-Lowering Agents: DPP-4 and SGLT-2 Inhibitors. *Circulation Research*,122 (10), 1439–1459. <https://doi.org/10.1161/circresaha.117.311588>
- [16]. Wang, C.C.L., Hess, CN, Hiatt, WR, & Goldfine, AB (2016). Clinical Update: Cardiovascular Disease in Diabetes Mellitus: Atherosclerotic Cardiovascular Disease and Heart Failure in Type 2 Diabetes Mellitus – Mechanisms, Management, and Clinical Considerations. *Circulation*,133 (24), 2459-2502. <https://doi.org/10.1161/CIRCULATIONAHA.116.022194>