# Prevalence, pattern, and potential predictors of microvascular complications in aging Nigerians with type 2 diabetes

William Balogun,[1] Martins Emuze,[2] Lawrence Adebusoye,[3] Olufemi Olowookere[3]

[1]Department of Medicine, College of Medicine, University of Ibadan/University College Hospital, Ibadan; [2]Department of Medicine, University College Hospital, Ibadan; [3]Chief Tony Anenih Geriatric Center, University College Hospital, Ibadan, Nigeria

## Abstract

In low-resource settings like Nigeria, the rising prevalence of diabetes is accompanied by an excessive burden of microvascular complications from diabetes. This study aimed to determine the prevalence and predictors of microvascular complications among older patients with diabetes mellitus.

Therefore, a 2-year retrospective cross-sectional study was carried out among elderly diabetes patients at the Chief Tony Anenih Geriatric Center outpatient diabetes clinic. A total of 148 diabetic patients were included in the study; the mean (± standard deviation) age was 70.89 (±6.99) years, with 71.6% of the studied population being female. Logistic regression analysis was employed to determine the prevalence and predictors of microvascular complications. Results show that the prevalence of microvascular complications in older diabetes patients was 73.9% [95% confidence interval (CI)=66.7-81.6] with peripheral neuropathy (77.1% prevalence, 95% CI=67.9-84.8) being the most common and retinopathy being the least prevalent (95% CI=4.7-16.8). The significant predictors of developing microvascular complications were intake of oral agents only [p=0.013, odds ratio (OR)=2.35, 95% CI=1.15-16.81], number of comorbidities (p=0.041, adjusted OR=5.28, 95% CI=1.09-27.93) and systolic blood pressure (p=0.042, OR=1.02, 95% CI=1.00-1.04).

Considering the high prevalence of microvascular complications among aging patients with diabetes mellitus, older patients should comply with oral medications and undergo regular check-ups, and more advocacy should be undertaken to strengthen geriatric healthcare systems to mitigate comorbidities and reduce complications.

Correspondence: Martins Emuze, Department of Medicine, University College Hospital, Ibadan, Nigeria.
Tel.: +2348032431790.
E-mail: ehizmart@yahoo.co.uk

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## Introduction

The World Health Organization (WHO) at its 74th World Health Assembly in 2021 noted that more than 420 million people were living with diabetes mellitus globally, and this could escalate to 700 million by the year 2045, reflecting the high burden of diabetes.[1] It comes with attendant complications, which could be acute or chronic, with the chronic complications classified as either microvascular or macrovascular.[2,3] The complications from diabetes make up a great deal of morbidity, enormous socioeconomic impact, and also mortality, to such an extent that 12.2% (about 6.7 million) of global deaths in adults aged 20-79 years in 2021 were due to diabetes and its complications.[4]

Diabetes affects close to 10% of the world's population, and its prevalence has been noted to increase with age, with the highest prevalence in older patients above 65 years old. This is expected to rise further over the next 25 years, though currently at 24%, with Oceania having the highest regional prevalence of 43.0% in people aged 75-79 years.[4-6] Diabetes mellitus has been classified into different types. Still, type 2 diabetes is the most common form of diabetes in older adults, and about half of the individuals with type 2 diabetes mellitus (T2DM) are older adults aged 65 years old and above.[6,7] Insulin resistance, pancreatic β cell secretory defect, and reduced islet cell proliferative capacity with aging are some of the explanations for the manifestation of diabetes in the elderly.[8-11]

Just as diabetes increases with aging, so does the prevalence of chronic complications.[4] There is an increased risk of both microvascular (retinopathy, neuropathy, nephropathy) and macrovascular (cardiovascular disease, cerebrovascular disease, and peripheral arterial disease) complications in older people with diabetes compared with controls, and this has been correlated with the duration of diabetes, hemoglobin A1c (HbA1c) values, and the presence of traditional risk factors such as smoking, hypercholesterolemia, and hypertension.[4,8,12]

The trajectory of diabetes in older adults could differ from that of other categories of patients with diabetes, and since individualized treatment is being advocated for people with T2DM, it is worthwhile to explore the peculiarities of diabetes complications among older patients with diabetes, to offer the best medical care and improve clinical outcomes.[13]

There is very little literature on microvascular complications and associated predictors among the elderly aged 60 years and older with diabetes mellitus in sub-Saharan Africa. The majority of studies on microvascular complications and their determinants in Nigeria were conducted among young and middle-aged people and cannot easily be extrapolated to older adults.[14-16] Identification of patterns and predictors of microvascular complications of T2DM among older adults in resource-limited environments, such as Nigeria, could assist in prompt and prioritized management of patients. In this study, we aimed to find out the prevalence, pattern, and predictors of microvascular complications among older adults aged 60 years and older attending the diabetes clinic at a geriatric center in a tertiary health facility in Nigeria.

## Materials and Methods

### Study design, study population and ethics

This was a retrospective cross-sectional study conducted at the Chief Tony Anenih Geriatric Center (CTAGC) outpatient diabetes clinic at the University College Hospital (UCH) in Ibadan. UCH is a major teaching hospital that serves Ibadan and the country as a whole, as well as a referral center in Nigeria's southwest geopolitical zone. The CTAGC is the first geriatric center in the West African sub-region, having been commissioned in November 2012. It was built specifically to meet the health needs of people aged 60 and above. Participants were on oral glucose-lowering agents such as biguanide (metformin), dipeptidyl peptidase-4-inhibitors, sulfonylureas, thiazolidinediones, alpha-glucosidase inhibitors, sodium-glucose cotransporter-2 inhibitors, glucagon-like peptide-1 receptor agonists, and insulins, along with dietary and lifestyle modifications, following the guidelines of the American Diabetes Association. Diabetes patients are normally seen by family physicians and geriatricians. Additionally, an endocrinologist runs a diabetes clinic fortnightly at the center. The study received ethical approval from the Joint University of Ibadan/UCH Institutional Ethical Review Board.

### Data collection procedure

Health records of older individuals aged 60 and above diagnosed with diabetes mellitus according to the WHO clinical criteria and seen at the diabetes outpatient clinic of the CTAGC, UCH, Ibadan, between May 2019 and April 2021 were accessed. The clinic diabetes registry was used to collect relevant data. The patients' socio-demographic characteristics (gender, age, occupation, *etc*.), anthropometric measures (weight, height, and waist circumference), and clinical and laboratory profiles, including fasting lipid profile, fasting blood glucose (FBG) and 2-hour postprandial glucose, hypoglycemic event, serum creatinine, and glycated hemoglobin were collected using a questionnaire proforma. Diabetic patients in the center routinely underwent a detailed physical examination for peripheral neuropathy, including the use of standard 10-g monofilament and, where necessary, biothesiometry. Annually, patients saw ophthalmologists for an eye examination to enable early detection of diabetic retinopathy. Similarly, at the first visit and subsequently, annual screening for diabetic kidney disease was done by requesting serum creatinine [with calculation of estimated glomerular filtration rate (eGFR)] and microalbumin. All clinical chemistry analyses were performed at the hospital's central laboratory using standard assay techniques on an automated Roche system. Diabetes duration, a family history of hypertension and diabetes, and medication use were all documented.

### Definitions of anthropometric, clinical, and outcome variables

Body mass index (BMI) is defined as the weight in kilograms divided by the square of the height in meters (kg/m$^2$). It was calculated and classified according to the WHO BMI classification as normal weight (<25), overweight (25-29.9), and obese (≥30). Regarding blood pressure, a systolic blood pressure (SBP) of ≥140 mmHg and/or a diastolic blood pressure (DBP) of ≥90 mmHg indicate hypertension.

According to WHO, the values for waist-hip ratio (WHR) are the following: low-WHR - male ≤0.95 and female ≤0 .80; moderate-WHR - male 0.96 to 0.99 and female 0.81 to 0.85; high-WHR - male ≥1.0 and female ≥0.86. The values for waist-height ratio (WHtR) are: good control (≤50%) and poor control (>50%); the ones for FBG are: good control (<110 mg/dL) and poor control (≥110 mg/dL); and the ones for HbA1c are: good control (<7%) and poor control (≥7%).

Microvascular complications, the outcome variables in this article, were defined as the presence of at least one of the following: peripheral neuropathy, retinopathy, or nephropathy. Nephropathy was diagnosed when the 24-hour urine albumin excretion was greater than 20 µg/min, the eGFR was less than 60 mL/min/1.73 m$^2$, or the serum creatinine level was greater than 1.5 mg/dL. Fundoscopy revealed either preproliferative (microaneurysms, intraretinal microvascular anomalies, exudates, venous beading) or proliferative retinopathy. If monofilament tests or findings on biothesiometry were abnormal, peripheral neuropathy was confirmed.

### Statistical analysis

SPSS Statistics for Windows Version 27.0 (IBM Corp., Armonk, NY, USA) was used for all data analyses. Descriptive analysis was carried out for the predictor (independent) variables (gender, age, alcohol intake, smoking, family history of diabetes, medication compliance, BMI, WHR, WHtR, number of comorbidities, hypoglycemic event, HbA1c, FBG, diabetes duration, SBP, and DPB) and outcome (dependent) variables (microvascular complications). The patients' characteristics were presented as frequency (percentages) or mean ± standard deviation (SD) where applicable, first by demographic, anthropometric, and clinical status, and then as a function of microvascular complications status. The association between variations in microvascular complications status and variations in predictor variables was shown with cross-tabulation, and Pearson Chi-squared, Fisher's exact, continuity correction, and student *t*-tests were used, where appropriate, to select significant predictors of having any of the microvascular complications or not. Significant univariate parameters ($p<0.05$) in

the cross-tabulation result were included in the multivariate analysis. The relationship between each of the microvascular complications (peripheral neuropathy, retinopathy, and nephropathy) and glycemic control was also determined with cross-tabulation, and a significant association was considered at $p<0.05$.

Binary logistic regression analysis was used to analyze the association level between significant predictor factors (oral agent-only compliance, BMI, number of comorbidities, and SBP) and the microvascular complications status. First, crude odds ratios (ORs) and 95% confidence intervals (CIs) for each significant predictor variable were determined using univariable logistic regression. Secondly, the independence of any association was examined by accounting for the influence of non-significant predictor variables such as gender, age, alcohol intake, smoking, family history of diabetes, medication compliance, WHR, WHtR, hypoglycemic event, HbA1c, FBG, diabetes duration, and DBP in a multivariable logistic regression model. Lastly, the ORs and 95% CIs were calculated to identify predictor(s) of microvascular complications status using a multivariable logistic regression model including only the significant predictor variables: oral agent-only compliance, BMI, number of comorbidities, and SBP. For all comparisons, $p<0.05$ was considered a statistically significant value.

## Results

### General characteristics of studied diabetic patients

In Table 1, descriptive statistics of patients' characteristics were presented. There was a higher proportion of females (71.6%) than males (28.4%) in the study population. With a mean (±SD) age of 70.89 (±6.99) years, most of the older patients (85.8%) were aged 60 to 79 years, with 14.2% of them being 80 years and older. Only a small fraction of the patients had a history of intake of alcoholic beverages (15; 10.5%) and smoking (4; 2.7%), and about half (46.0%) of the study subjects had a positive family history of diabetes. In addition, more than half (66.0%) of the patients reported adherence to medications for diabetes, and 67.4% of them were on oral glucose-lowering agents only while about 15% of the participants were using insulin either singly or in combination with oral

**Table 1.** Distribution of general characteristics of studied diabetic patients.

| Characteristics | n | Patients; n (%) |
|---|---|---|
| **General** | | |
| Gender | 148 | |
| Male | | 42 (28.4) |
| Female | | 106 (71.6) |
| Age group (yrs) (mean±SD) | 148 | (70.89±6.99) |
| 60-69 | | 65 (43.9) |
| 70-79 | | 62 (41.9) |
| 80 and above | | 21 (14.2) |
| Ethnicity | 146 | |
| Yoruba | | 127 (87) |
| Igbo | | 18 (12.3) |
| Hausa | | 1 (0.7) |
| Education | 148 | |
| Primary and below | | 54 (36.5) |
| Secondary/technical | | 52 (35.1) |
| Post-secondary | | 42 (28.4) |
| Occupation | 146 | |
| Trader/artisan | | 52 (35.5) |
| Professionals/civil servants | | 76 (52.1) |
| Unemployed | | 18 (12.3) |
| History of alcohol intake | 143 | |
| No | | 128 (89.5) |
| Yes | | 15 (10.5) |
| History of smoking | 147 | |
| No | | 143 (97.3) |
| Yes | | 4 (2.7) |
| Family history of diabetes | 137 | |
| No | | 74 (54.0) |
| Yes | | 63 (46.0) |
| Compliance with medication | 141 | |
| Regular | | 93 (66.0) |
| Irregular | | 48 (34.0) |
| Diabetes treatment | 141 | |
| No | | 46 (32.6) |
| Yes | | 95 (67.4) |
| Oral anti-diabetic agents only | | 95 (67.4) |
| Insulin only | | 4 (2.8) |
| Combined oral + insulin | | 16 (11.3) |
| Lifestyle only | | 26 (18.4) |

| Characteristics | n | Patients; n (%) |
|---|---|---|
| **Anthropometric** | | |
| Waist circumference (cm) | 126 | |
| Male | | 99.5 (11.2) |
| Female | | 100.0 (12.8) |
| Body mass index (kg/m2) | 129 | |
| Normal (<25) | | 26 (20.2) |
| Overweight (25-29.9) | | 66 (51.2) |
| Obese (≥30) | | 37 (28.7) |
| Waist-hip ratio | 124 | |
| Low | | 6 (4.8) |
| Moderate | | 27 (21.8) |
| High | | 91 (73.4) |
| Waist-height ratio | 122 | |
| Good control (≤50%) | | 7 (5.7) |
| Poor control (>50%) | | 115 (94.3) |
| **Clinicals** | | |
| Number of comorbidities | 144 | |
| 0 | | 29 (20.1) |
| 1 | | 70 (48.6) |
| 2 | | 39 (27.1) |
| 3 | | 6 (4.2) |
| Hypoglycemic event status | 125 | |
| No | | 94 (75.2) |
| Yes | | 31 (24.8) |
| HbA1c (%) | 145 | |
| Good control (<7) | | 26 (17.9) |
| Poor control (≥7) | | 119 (82.1) |
| Fasting blood glucose (mg/dL) | 124 | |
| Good control(<110) | | 40 (32.3) |
| Poor control (≥110) | | 84 (67.7) |
| Diabetes duration(yrs) (mean±SD) | 147 | (9.73±8.92) |
| <5 | | 48 (32.7) |
| 5-10 | | 50 (34.0) |
| >10 | | 49 (33.3) |
| Blood pressure(mmHg) | | |
| Systolic blood pressure (mean±SD) | 145 | (138.1±22.7) |
| Diastolic blood pressure (mean±SD) | 145 | (79.1±12.0) |

SD, standard deviation; HbA1c, hemoglobin A1c.

antidiabetic medications. The male and female participants were not statistically different in terms of most of the characteristics (Table 2). However, significantly more men drank alcohol and smoked than women.

More than half (51.2%) of the T2DM patients were overweight, and 28.7% were obese, according to the WHO classification of BMI. Likewise, a greater proportion of the study population (73.4%) had a high WHR, with the majority of them (115; 94.3%) having poor control of their WHtR. Most of the patients have either one (48.6%) or two (27.1%) comorbidities, leaving about 20.1% of the study subjects without any comorbidities. The mean (±SD) duration of diabetes among the older patients was 9.73 (±8.92), and a greater proportion of the patients (119; 82.1%) had poor long-term glycemic control, as reflected by HbA1c.

## Prevalence of microvascular complications

The prevalence of microvascular complications among older (60 years and above) diabetic patients was 73.9% (95% CI=66.7-81.6) with peripheral neuropathy (77.1%, 95% CI=67.9-84.8) being the most common and retinopathy being the least prevalent (9.5%, 95% CI=4.7-16.8), as detailed in Table 3. It was also observed that the prevalence of microvascular complications was lowest among older patients aged 80 years and above (13.3%, 95%CI=8.7-17.6), and the prevalence of peripheral neuropathy decreased with an increase in

**Table 2**. Comparison of clinical and laboratory characteristics between males and females.

| Characteristic | Male | Female | p |
|---|---|---|---|
| Age (years) | 71.6 (6.5) | 70.6 (7.2) | 0.454 |
| Diabetes duration (years) | 11.6 (9.0) | 10.4 (8.8) | 0.474 |
| Family history of diabetes | 15 (23.8) | 48 (76.2) | 0.201 |
| Smoking | 4 (100) | 0 (0) | 0.001 |
| Alcohol consumption | 14 (93.3) | 1 (6.7) | 0.001 |
| Hypertensive | 30 (25.6) | 87 (74.4) | 0.340 |
| Diabetes treatment | | | |
| Oral | 25 (26.3) | 70 (73.7) | 0.299 |
| Insulin only | 1 (25.0) | 3 (75.0) | 0.848 |
| Oral + insulin | 6 (37.5) | 10 (62.5) | 0.443 |
| Microvascular complications | 30 (28.3) | 76 (71.7%) | 0.797 |
| BMI (kg/m$^2$) | 26.9 (4.8) | 28.3 (4.4) | 0.113 |
| Waist circumference (cm) | 99.5 (11.2) | 100.0 (12.0) | 0.857 |
| BP Systolic (mmHg) | 136.3 (18.0) | 138.8 (24.3) | 0.558 |
| BP Diastolic (mmHg) | 77.2 (9.8) | 79.8 (12.8) | 0.244 |
| HbA1c (%) | 9.7 (3.0) | 9.4 (2.5) | 0.518 |
| Total cholesterol (mg/dL) | 166.1 (41.2) | 199.7 (47.3) | 0.001 |
| LDL cholesterol (mg/dL) | 102.7 (39.2) | 119.9 (40.6) | 0.053 |
| HDL cholesterol (mg/dL) | 47.8 (14.7) | 55.0 (18.1) | 0.058 |
| Triglycerides (mg/dL) | 117.8 (65.4) | 133.3 (68.1) | 0.294 |
| eGFR (mL/min/1.73m$^2$) | 74.6 (29.5) | 77.99 (25.5) | 0.576 |

BMI, body mass index; BP, blood pressure; HbA1c, hemoglobin A1c; LDL, low-density lipoprotein; HDL, high-density lipoprotein; eGFR, estimated glomerular filtration rate.

**Table 3.** Prevalence of microvascular complications by age (n=148).

| Microvascular complications | All age groups (year) | 60-69 (year) | 70-79 (year) | ≥80 (year) |
|---|---|---|---|---|
| **Composite microvascular complications** | | | | |
| Prevalent cases, n | 105 | 46 | 45 | 14 |
| Prevalence, (%) (95% CI) | 73.9 (66.7 to 81.6) | 43.8 (38.9 to 51.1) | 42.9 (39.4 to 50.2) | 13.3 (8.7 to 17.6) |
| **Peripheral neuropathy** | | | | |
| Prevalent cases, n | 81 | 41 | 32 | 8 |
| Prevalence, (%) (95% CI) | 77.1 (67.9 to 84.8) | 50.6 (42.4 to 60.1) | 39.5 (31.3 to 46.4) | 9.9 (6.7 to 15.8) |
| **Retinopathy** | | | | |
| Prevalent cases, n | 10 | 2 | 5 | 3 |
| Prevalence, (%) (95% CI) | 9.5 (4.7 to 16.8) | 20.0 (11.9 to 29.2) | 50.0 (42.0 to 58.5) | 30.0 (24.9 to 41.3) |
| **Nephropathy** | | | | |
| Prevalent cases, n | 14 | 3 | 8 | 3 |
| Prevalence, (%) (95% CI) | 13.3 (7.5 to 21.4) | 21.4 (16.3 to 29.4) | 57.1 (42.4 to 65.3) | 21.4 (17.8 to 29.6) |

CI, confidence interval.

age, while the prevalence of retinopathy and nephropathy complications was not a function of age.

## Association between microvascular complications and glycemic control

Table 4 shows that a higher proportion of the patients (88; 76.5%) who had one or more microvascular complications have poor glycemic control (HbA1c≥7) with the majority of them (69, 79.3%) diagnosed with peripheral neuropathy. However, with the p-values of 0.873 and 0.394 of the chi-squared statistics, it is evident that the association between microvascular complications (or any of peripheral neuropathy, retinopathy, and nephropathy) and glycemic control among elderly (60 years and older) diabetic patients in this study is not statistically significant at the 0.05 α level.

## Potential predictors of microvascular complications

Among the patients' demographic, anthropometric, and clinical variables, intake of only oral agent (antidiabetic) medication, BMI, number of comorbidities, and SBP were found to show significant associations with microvascular complications (Table 5). The intake of oral agents alone ($\chi^2$=6.37, p=0.012) showed a significant association with microvascular complications. Many of the patients (71.4%) with an intake of oral agents only tend to have one or more microvascular complications compared to those who were not taking oral agents alone (28.6%), indicating that more of the patients (53.3%) who were not taking oral agents alone had no microvascular complications as compared to the proportion of patients who took oral agents alone (46.7%).

BMI ($\chi^2$=6.86, p=0.029) showed a significant association with

**Table 4.** Microvascular complications with glycemic control status.

| Microvascular complications | Good control (HbA1c<7) n (%) | Poor control (HbA1c≥7) n (%) | $\chi^2$ | p |
|---|---|---|---|---|
| Composite microvascular complications | 18 (75.0) | 88 (76.5) | 0.025 | 0.873[a] |
| Peripheral neuropathy | 12 (66.7) | 69 (79.3) | 2.057 | 0.394[b] |
| Retinopathy | 3 (16.7) | 7 (8.0) | | |
| Nephropathy | 3 (16.7) | 11 (12.6) | | |

HbA1c, hemoglobin A1c; [a]Pearson chi-square test; [b]Fisher's exact test.

**Table 5.** Microvascular complications with general and clinical characteristics in studied patients.

| Characteristics | Microvascular complications (n=148) No n (%) | Yes n (%) | p |
|---|---|---|---|
| **General** | | | |
| Gender | | | |
| Male | 11 (30.6) | 30 (28.3) | 0.797[a] |
| Female | 25 (69.4) | 76 (71.7) | |
| Age (yrs) (mean±SD) | (70.75±7.29) | (70.87±6.91) | 0.931[d] |
| 60-69 | 17 (47.2) | 46 (43.4) | 0.918[a] |
| 70-79 | 14 (38.9) | 45 (42.5) | |
| 80 and above | 5 (13.9) | 15 (14.2) | |
| History of alcohol intake | | | |
| No | 6 (17.1) | 9 (8.8) | 0.174[a] |
| Yes | 29 (82.9) | 93 (91.2) | |
| History of smoking | | | |
| No | 33 (94.3) | 104 (98.1) | 0.237[a] |
| Yes | 2 (5.7) | 2 (1.9) | |
| Family history of diabetes | | | |
| No | 18 (60.0) | 42 (41.6) | 0.075[a] |
| Yes | 12 (40.0) | 59 (58.4) | |
| Compliance with medication | | | |
| Regular | 23 (79.3) | 64 (60.4) | 0.059[a] |
| Irregular | 6 (20.7) | 42 (39.6) | |
| Intake of oral agent only | | | |
| No | 16 (53.3) | 30 (28.6) | 0.012*[a] |
| Yes | 14 (46.7) | 75 (71.4) | |
| Intake of insulin agent only | | | |
| No | 29 (100.0) | 101 (96.2) | 0.652[c] |
| Yes | 0 (0.0) | 4 (3.8) | |
| Intake of oral and insulin | | | |
| No | 27 (93.1) | 91 (86.7) | 0.533[c] |
| Yes | 2 (6.9) | 14 (13.3) | |

To be continued on next page

**Table 5.** Continued from previous page.

| Characteristics | Microvascular complications (n=148) No n (%) | Yes n (%) | p |
|---|---|---|---|
| **Anthropometric** | | | |
| Body mass index (kg/m2) | | | |
| Normal (<25) | 5 (17.9) | 21 (22.1) | 0.029*[b] |
| Overweight (25-29.9) | 20 (71.4) | 43 (45.3) | |
| Obese (≥30) | 3 (10.7) | 31 (32.6) | |
| Waist-hip ratio | | | |
| Low | 2 (8.3) | 3 (3.2) | 0.376[b] |
| Moderate | 4 (16.7) | 22 (23.4) | |
| High | 18 (75.0) | 69 (73.4) | |
| Waist-height ratio | | | |
| Good control (≤50%) | 0 (0.0) | 7 (7.7) | 0.343[b] |
| Poor control (>50%) | 25 (100.0) | 84 (92.3) | |
| **Clinicals** | | | |
| Number of comorbidities | | | |
| 0 | 15 (45.5) | 14 (13.3) | 0.002*[b] |
| 1 | 12 (54) | 54 (51.4) | |
| 2 | 5 (15.2) | 32 (30.5) | |
| 3 | 1 (2.0) | 5 (4.8) | |
| Hypoglycemic event status | | | |
| No | 29 (82.9) | 64 (71.9) | 0.205[a] |
| Yes | 6 (17.1) | 25 (28.1) | |
| HbA1c | | | |
| Good control (<7) | 6 (18.2) | 18 (17.0) | 0.873[a] |
| Poor control (≥7) | 27 (81.8) | 88 (83.0) | |
| Fasting blood glucose (mg/dL) | | | |
| Good control(<110) | 6 (22.2) | 31 (34.1) | 0.244[a] |
| Poor control (≥110) | 21 (77.8) | 60 (65.9) | |
| Diabetes duration (year) (mean±SD) | (9.96±8.33) | (9.80±9.28) | 0.928[d] |
| Blood pressure (mmHg) (mean±SD) | | | |
| Systolic blood pressure | (130.55±21.52) | (139.75±21.92) | 0.036*[d] |
| Diastolic blood pressure | (75.27±10.01) | (79.89±12.42) | 0.054[d] |

SD, standard deviation; HbA1c, hemoglobin A1c; [a]Pearson chi-square test; [b]Fisher's exact test; [c]continuity correction; [d]student's *t*-test; *statistically significant value (p<0.05).

microvascular complications. While only about one-quarter (22.1%) of the patients with microvascular complications had a normal BMI, a higher proportion of people with complications were overweight (45.3%) and obese (32.6%), indicating that patients with a higher BMI are more likely to have one or more microvascular complications.

The number of comorbidities ($\chi^2$=15.89, p=0.002) also showed a significant association with microvascular complications. Patients with one or more microvascular complications had one comorbidity (51.4%), and about one-third (30.5%) of them had two comorbidities.

Participants with increased SBP were significantly more likely to have one or more microvascular complications as compared to those with normal blood pressure (F-ratio=1.002, p=0.036). However, other studied variables were not significantly associated with microvascular complications in elderly diabetic patients.

## Level of association of significant predictor variables with microvascular complications in older diabetic patients

In Table 6, an analysis of factors associated with microvascular complications among older patients with diabetes using a multivariate binary logistic regression model revealed that intake of oral agents only (in model 1), number of comorbidities (in models 1 and 3), and SBP (in model 1) were significantly associated with microvascular complications.

### *Intake of oral agent only*

In model 1, an older patient taking an oral agent only is two times more likely to have one or more microvascular complications than a patient who was not taking an oral agent only (OR=2.35, 95% CI=1.15-16.81) and this was significant (p=0.013). In models 2 and 3, the significant association between the patient taking an oral agent only and microvascular complications disappeared. This indicates that T2DM patients on oral agent only were not significantly (in model 2: p=0.165; in model 3: p=0.576) more likely to develop microvascular complications compared to those who were not taking oral agents only (individuals on insulin or a combination of insulin plus oral agents) when the influence of non-significant predictor variables was accounted for in model 2 and when all the significant variables (intake of an oral agent only, BMI, number of comorbidities, and SBP jointly associated alone) were accounted for in model 3 (Table 6).

### *Number of comorbidities*

A patient with one comorbidity is five times significantly (p=0.001) more likely than a patient with no comorbidity to have microvascular complications (OR=4.82, 95% CI=1.85-12.59), and a patient with two comorbidities is seven times significantly (p=0.002) more likely than a patient with no comorbidity to have microvascular complications (OR=6.86, 95% CI=2.08 -22.57) in model 1. In model 2, when the influence of the non-significant

**Table 6.** Multivariate binary logistic regression model-predicting factors linked with microvascular complications.

| Microvascular complications | Model 1 | p | Model 2 | p | Model 3 | p |
|---|---|---|---|---|---|---|
| **Predictor variables** | | | | | | |
| Intake of oral agent only | | | | | | |
| No | Ref (1.00) | | Ref (1.00) | | Ref (1.00) | |
| Yes | 2.35 (1.15-16.81) | **0.013*** | 14.35 (0.33-616.13) | 0.165 | 0.72 (0.23-2.27) | 0.576 |
| Body mass index (kg/m2) | | | | | | |
| Normal (<25) | Ref (1.00) | | Ref (1.00) | | Ref (1.00) | |
| Overweight (25-29.9) | 0.51 (0.17-1.55) | 0.237 | 0.01 (0.00-1.35) | 0.063 | 0.29 (0.07-1.25) | 0.097 |
| Obese (≥30) | 2.46 (0.53-11.42) | 0.250 | 0.25 (0.00-49.67) | 0.609 | 3.55 (0.26-49.08) | 0.345 |
| **Number of comorbidities** | | | | | | |
| 0 | Ref (1.00) | | Ref (1.00) | | Ref (1.00) | |
| 1 | 4.82 (1.85-12.59) | **0.001*** | 2.53 (0.06-101.49) | 0.623 | 2.45 (0.65-9.26) | 0.186 |
| 2 | 6.86 (2.08-22.57) | **0.002*** | 6.06 (0.11-339.86) | 0.381 | 5.28 (1.09-27.93) | **0.041*** |
| 3 | 5.36 (0.56-51.71) | 0.147 | 0.49 (0.00-925.16) | 0.848 | 0.38 (0.02-10.07) | 0.556 |
| **Blood pressure** | | | | | | |
| Systolic blood pressure (mmHg) | 1.02 (1.00-1.04) | **0.042*** | 1.02 (0.95 - 1.10) | 0.603 | 1.01 (0.98-1.04) | 0.557 |

Model 1, crude (unadjusted) odds ratio for significant predictor variables; model 2, adjusted odds ratio when the influence of non-significant predictor variables was accounted for; model 3, adjusted odds ratio when significant predictor variables were accounted for; *statistically significant value (p<0.05).

variables was adjusted for, it was found that the significant association between the number of comorbidities and microvascular complications failed to exist. However, after adjusting for significant predictor variables in model 3, it was found that a patient with two comorbidities is five times significantly (p=0.041) more likely than a patient with no comorbidity to have microvascular complications (adjusted OR=5.28, 95% CI=1.09-27.93).

### *Systolic blood pressure*

In model 1 (Table 6), there is a significant association between SBP and microvascular complications, as an increase in the SBP of the patient tends to significantly (p=0.042) increase the chance of having microvascular complications (OR=1.02, 95%CI=1.00-1.04). Unfortunately, this significant association disappeared in models 2 (p=0.603) and 3 (0.557), indicating that SBP is not an independent predictor factor significantly associated with microvascular complications.

## Discussion

This study has shown that the burden of microvascular complications is huge, specifically among aging Nigerians living with diabetes. Peripheral neuropathy constituted the highest proportion, and using only oral diabetes medications followed by comorbidities and SBP were found to be strong predictors. These findings have important implications for the approach to clinical care of older adults with diabetes.

The study revealed that a significant number of diabetic patients (73.9%) developed microvascular complications, which is similar to other studies where a high rate of microvascular complications was reported among patients with T2DM, ranging between 24.4-80%.[17-19] In terms of the microvascular complications studied, peripheral neuropathy was predominant, accounting for 77.1% of those with complications across the age groups, consistent with other studies by Owolabi *et al.* in Nigeria,[20] Lu *et al.*,[18] and Yang *et al.*,[19] both in China, who reported prevalence rates of 71.1%, 61.8%, and 80%, respectively. In contrast, diabetic retinopathy (24.8%) was the most prevalent microvascular complication in another study on microvascular complications among T2DM patients in Ethiopia by Seid *et al.*, with diabetic nephropathy and neuropathy accounting for 16.1% and 8.1%, respectively.[21] Reasons for this could be the younger age of the participants and diagnostic methods, possibly resulting in a lower prevalence of microvascular complications (37.9%) than in this present study (73.9%). A similar pattern was also observed by Alami *et al.* in Morocco.[22]

The prolonged duration of T2DM with increasing age, suboptimal glycemic control, and sarcopenia are possible explanations for the high burden of peripheral neuropathy in older adults with T2DM.[2,17,23,24] In fact, sarcopenia, also called geriatric syndrome, which is manifested by age-related loss of muscle mass with an associated decline in physical function, is most prominent in elderly age groups, as it is also noted to increase with age.[17,19] Interestingly, Yang *et al.* in a study conducted among T2DM patients in China reported a higher prevalence of peripheral neuropathy in people with sarcopenia than those without sarcopenia.[19] There is a likelihood that this might account for the degree of peripheral neuropathy in our study subjects. In contrast, a cross-sectional study by Gnonlonfoun *et al.* in the Republic of Benin found the prevalence of peripheral neuropathy as low as 16.9%, but the study was conducted among the general population, unlike the present study carried out among persons with diabetes.[25]

Contrary to expectations, it was observed that the prevalence of microvascular complications, especially peripheral neuropathy, decreases with an increase in age (within the aging participants), such that the highest prevalence occurred in the 60-69 age group and the lowest prevalence was recorded in those participants aged 80 years and above. One reason for this observation may be the higher number of participants in the 60-69 age group than other groups in the study, hence the higher prevalence. It is likely that the older age groups (70 years and above) may exhibit more frailty and have a lower rate of physical clinic attendance than the 60-69 age group.[26,27] In addition, in Poland, Mordarska *et al.* discovered that insulin resistance (which is also the main driver behind diabetic complications) was found to increase with age up to 85-90 years among T2DM patients, after which it decreased comparable to what is obtained in the younger age group of 20-30.[6,28] It is possi-

ble that such a threshold exists at a lower range of old age (in this case less than 80 years) among Nigerian patients with T2DM.

The observation that most of the participants (82.1%) had poor glycemic control by virtue of their HbA1c records could also be a reason for the high prevalence of microvascular complications, similar to reports by Meneilly *et al*.[8,12] Hence, it is understandable that a study by Tesfaye *et al.* reported a lower prevalence of microvascular complications like peripheral neuropathy (28%) than the present study, considering the higher proportion of patients with good glycemic control (about 50%), contrary to findings in our study, which put the prevalence at 17.9%.[29] However, one must remember that the HbA1c targets for older persons with T2DM may differ, putting into account the presence or absence of comorbidities, life expectancy, and functional/cognitive disability, and may even pose a challenge in situations like anemia, chronic kidney disease, and liver disease, which could be present in elderly diabetic patients; thus, treatment is often individualized.[2,30,31]

The present study also showed that retinopathy, one of the ocular complications in patients with type 2 diabetes, was the least prevalent (9.5%) microvascular complication among the study subjects, which is similar to findings from the National Health and Nutrition Examination Survey (NHANES), 1999-2004,[32] and the research work by Olamoyegun *et al* in Nigeria.[33] The low rate of diabetic retinopathy reported in our study is consistent with the previous result from a national survey on blindness and visual impairment in Nigeria reported by Kyari *et al*. (about 10%).[34] However, higher prevalence rates were reported by Billah *et al*. in Bangladesh (36.2%),[35] Fahmy *et al*. in Egypt (24.0%),[36] Magan *et al.* in Uganda (19%),[37] Mathur *et al.* in the United Kingdom (28.3%),[38] and Shah *et al.* in the United States of America (14.70%),[39] probably because most of the participants in these studies were adults with DM younger than 60 years old and some of the studies were population-based, unlike our study that was clinic-based. Furthermore, diagnoses of T2DM in old age may be a factor in the lower prevalence of retinopathy among participants in this study, considering that diabetic retinopathy is less prevalent among adults diagnosed with diabetes in older age in contrast to middle age, as previous NHANES data revealed that patients with retinopathy had a long duration of diabetes.[26,40]

Risk factors include advancing age, smoking, long diabetes duration, poor glycemic control, poor compliance with the use of medications, dyslipidemia, and comorbid conditions such as obesity, and hypertension. Other established microvascular complications, like retinopathy (as a risk for neuropathy), have been associated with the presence of microvascular complications, either generally or as separate entities of neuropathy, retinopathy, and nephropathy.[13,15,16,18,23,29,34,41]

Furthermore, previous studies among patients with T2DM in Ethiopia by Seid *et al.,*[21] in Morocco by Alami *et al.*,[22] and in Sub-Saharan Africa by Ekoru *et al.*,[42] have also identified hypertension as a comorbid condition linked with microvascular complications. This is in agreement with our study, where BMI (with overweight and obesity), an increased number of comorbidities, and SBP were factors found to be associated with microvascular complications. In addition, the intake of oral antidiabetic agents alone was significantly associated with microvascular complications in the present study.

This is an interesting finding and may be explained considering the higher proportion of patients on oral medications alone without insulin (67.4%) and the high proportion of patients with poor glycemic control (82.1%) in this study. In this part of the world, there seem to be barriers to the initiation of insulin, which could be patient factors or clinical inertia from the doctor.[43-45] It is known that prompt and appropriate use of insulin when indicated can bring about a reduction in microvascular complications, as suggested by the United Kingdom Prospective Diabetes Study trial.[31] Most individuals with T2DM in Nigeria have poor knowledge of insulin, exercise some fears about its use, and sometimes decline initiation by the health practitioner.[44,45]

Furthermore, the present study showed no statistically significant association between age and diabetes duration and microvascular complications. In a similar vein, in China, Lu *et al*. did not find any association between the duration of diabetes and microvascular complications, and in Mauritius, Shaw *et al.* also documented no association of age with microvascular complications.[18,46] Surprisingly, our study did not show a significant association between glycemic control (represented by HbA1c and FBG) and microvascular complications. This may mean that other factors played a bigger role in the development of microvascular complications in our patients, as previous studies had even reported microvascular complications in diabetes mellitus patients with HbA1c less than 7%.[29] Additionally, the present study did not find a statistically significant association between gender, WHR, WHtR, and microvascular complications among older patients with diabetes mellitus.

Intake of oral agents alone, the presence of comorbidities, and SBP were predictor factors for microvascular complications identified in our study. Olamoyegun *et al.* and Aikaeli *et al.,* in their studies,[33,47] also found that diabetic patients who had one or more comorbidities such as obesity, hypertension, arthritides, obstructive sleep apnea, dementia, *etc*., developed microvascular complications. Increased SBP and hypertension have been associated with microvascular complications in previous studies as well.[16,33,40,48] However, when adjustments for non-significant and significant variables were made in our study, it was discovered that the presence of comorbidities was the only factor significantly associated with microvascular complications, such that a person with T2DM who has two comorbidities is five times more likely to develop microvascular complications than someone without comorbidities. This revelation calls for further local research.

Our study was descriptive, single-center, and hospital-based; therefore, it may not be generalizable to the other parts of Nigeria, especially outside the southwestern region. Also, the most sensitive and sophisticated tools, such as laser-evoked potentials, were not used to assess peripheral neuropathy in this study, as these are usually not available in low-resource countries like Nigeria.

While this study focused on older people with diabetes, it should be kept in mind that sometimes it is a younger adult with diabetes mellitus who later becomes an older adult. Hence, this stage of life needs some attention to prevent and delay the onset of complications. Challenges to routine diabetes assessment in the younger age group exist and include poor health-seeking behavior, diabetes education and self-management, dietary misconceptions, poor motivation, inadequate manpower (diabetes health educators, dieticians, and doctors), busy clinics leading to inadequate time for patient-doctor consultation, suboptimal interdisciplinary collaboration, and a lack of assessment tools.[49,50] Early intervention in these areas could reduce the burden of complications that could occur in old age.

## Conclusions

Microvascular complications, especially peripheral neuropathy, are very common in the aging diabetes population in southwestern Nigeria, the majority of whom have poor glycemic control. The significant predictors associated with microvascular complications in this group were the number of comorbidities, intake of oral antidiabetic agents only, and SBP. In addition to other stan-

dard diabetes care, attention should be paid to these predictors, including glycemic control through judicious use of insulin, to substantially reduce the burden of microvascular complications in elderly Nigerians. Larger, multicenter, and nationwide longitudinal studies on older adults are needed to confirm or otherwise support our findings in this work. The use of more sophisticated means of assessment of microvascular complications, *e.g.*, nerve conduction studies and measurement of cystatin to assess kidney impairment, could be used in such studies.

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