



Association between hypertension and microvascular and macrovascular complications among patients with type 2 diabetes: a cross-sectional study

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Abstract

Background. Hypertension frequently coexists with type 2 diabetes (T2D) and may contribute to the development of diabetic complications.

Objective. This study aimed to assess the association between hypertension and microvascular and macrovascular complications in patients with type 2 diabetes (T2D).

Methods. We conducted a retrospective cross-sectional study based on a review of medical records, including 500 patients with T2D followed in the Department of Endocrinology, Diabetology, and Nutrition. Patients were grouped according to the presence of hypertension, with 204 patients in the hypertension group and 296 patients in the non-hypertension group. Clinical, biological, and complication-related data were collected and analyzed using appropriate statistical methods.

Results. The mean age was 58.3 ± 12.8 years, and hypertension was present in 40.8% of cases. Poor glycemic control (glycated hemoglobin [HbA1c] >10%) was observed in 52.2%. Patients with hypertension had higher frequencies of several microvascular and macrovascular complications compared with patients without hypertension. Nephropathy was more frequent among patients with hypertension than among those without hypertension (32.8% vs. 14.2%; OR = 2.96, 95% CI: 1.91–4.58; $p < 0.001$). Higher grades of hypertension were significantly associated with peripheral arterial disease and cerebrovascular accident. Longer diabetes duration was associated with retinopathy, neuropathy, and cerebrovascular accident, whereas longer hypertension duration was significantly associated with peripheral arterial disease.

Conclusions. Hypertension is significantly associated with a higher prevalence of both microvascular and macrovascular complications in patients with T2D. These findings support the importance of early identification and integrated management of hypertension, glycemic control, and other cardiovascular risk factors to reduce the burden of diabetic complications.

Keywords: diabetes mellitus type 2, hypertension, diabetes complications, diabetic angiopathies, cross-sectional studies

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Introduction

Diabetes mellitus is widely recognized as a global epidemic affecting nearly all countries and populations across diverse age and socioeconomic groups. Recent estimates indicate that approximately 40% of individuals living with diabetes remain undiagnosed, thereby increasing the risk of delayed diagnosis and the subsequent development of severe chronic complications. Diabetes is characterized by chronic hyperglycemia resulting from defects in insulin secretion, insulin action, or both, and is associated with substantial morbidity and mortality [1,2].

The long-term complications of diabetes are traditionally classified into microvascular and macrovascular complications. Macrovascular complications include coronary artery disease, cerebrovascular accidents (CVA), and peripheral arterial disease, whereas microvascular complications encompass diabetic neuropathy, nephropathy, and retinopathy [3]. Among these, diabetic retinopathy remains one of the most frequent and clinically significant microvascular complications.

Hypertension (HTN) is a highly prevalent comorbidity in patients with type 2 diabetes mellitus and represents a major modifiable cardiovascular risk factor. Its coexistence with diabetes substantially amplifies cardiovascular risk and contributes to both the development and progression of chronic complications. In particular, elevated blood pressure exacerbates endothelial dysfunction, promotes vascular inflammation, and accelerates atherosclerotic and microvascular damage, thereby affecting multiple organ systems [4].

Evidence from major clinical trials has highlighted the importance of risk factor control in diabetes-related complications. The DCCT (Diabetes Control and Complications Trial) and UK Prospective Diabetes Study (UKPDS) demonstrated that intensive metabolic control reduces the risk of microvascular complications, establishing glycemic control as a cornerstone of management [5,6].

However, evidence regarding blood pressure control has been more heterogeneous. While studies such as UKPDS and ADVANCE reported significant reductions in both microvascular and macrovascular outcomes with tighter blood pressure control, other trials, including ACCORD, showed more limited or context-dependent cardiovascular benefit, underscoring the complexity of HTN management in diabetic populations [7–11].

Despite advances in the management of both diabetes and HTN, diabetic complications remain a major public health burden worldwide. Furthermore, data from North African populations remain limited, particularly regarding the combined impact of HTN on both microvascular and macrovascular complications in type 2 diabetes (T2D), highlighting an important gap in the literature.

Given this context, the present study aimed to assess the association between HTN and microvascular and macrovascular complications in patients with type 2 diabetes mellitus (T2D) managed at a tertiary care center. We

hypothesized that HTN is associated with a higher prevalence of both microvascular and macrovascular complications in this population.

Methods

Study design

This was a retrospective cross-sectional study conducted over a 6-year period from January 2020 to December 2025 in the Department of Endocrinology, Diabetology and Nutrition, Oujda, Morocco. The study included 500 patients with T2D. This study design was chosen because it allows the assessment of the association between HTN and the presence of microvascular and macrovascular complications in patients with T2D.

Study population

All eligible patients with T2D who attended the department for the management of poorly controlled or complicated T2D during the study period were consecutively included, provided that complete and retrievable medical records were available.

Exclusion criteria included: other forms of diabetes (type 1, gestational, or secondary), incomplete records, absence of informed consent, inability to perform self-monitoring of blood glucose, unstable psychiatric conditions, uncontrolled severe comorbidities, or insufficient follow-up data. The patient selection and inclusion process is presented in figure 1.

Patients were classified into two groups:

- Group I: patients with T2D and HTN
- Group II: patients with T2D without HTN

Study protocol

In this study, data were retrospectively collected from patients' medical records and included sociodemographic characteristics, lifestyle factors (alcohol consumption, smoking, and physical inactivity), medical history (duration of diabetes and HTN, and family history), and treatment-related data. Information regarding antidiabetic therapy was also collected, including the use of oral antidiabetic drugs (OAD), namely metformin, sulfonylureas, DPP-4 (dipeptidyl peptidase-4) inhibitors, and SGLT2 (sodium-glucose cotransporter 2) inhibitors, as well as insulin therapy when applicable.

Clinical parameters included weight and height, which were used to calculate body mass index (BMI) using the formula $BMI = \text{weight (kg)} / \text{height}^2 (\text{m}^2)$. According to the World Health Organization classification, overweight was defined as a BMI of 25–29.9 kg/m² and obesity as a BMI ≥ 30 kg/m² [12].

Blood pressure was measured using an appropriately sized cuff after 5 minutes of rest in a quiet environment. Two measurements were taken and the average value was recorded. HTN was defined as blood pressure $\geq 140/90$ mmHg or current use of antihypertensive therapy, according to the European Society of Cardiology/European Society of Hypertension guidelines [4].

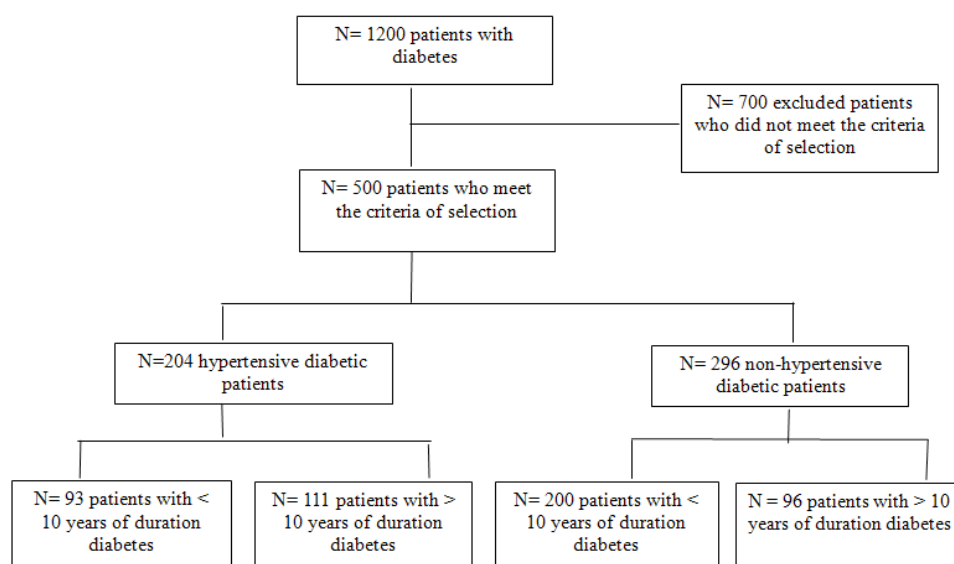


Figure 1. Flow chart of patient selection.

Electrocardiography (ECG) was performed using a 12-lead system to assess cardiac abnormalities.

Laboratory assessments included glycated hemoglobin (HbA1c) and lipid profile (triglycerides, LDL (low-density lipoprotein) cholesterol, and HDL (high-density lipoprotein) cholesterol), measured using standard laboratory methods for evaluation of glycemic control and cardiovascular risk. Serum creatinine and uric acid levels were also measured using standard biochemical assays, and the urine albumin-to-creatinine ratio (UACR) was calculated.

Assessment of complications

Macrovascular complications included coronary artery disease, CVA, and peripheral arterial disease. Coronary artery disease was diagnosed using electrocardiography, transthoracic echocardiography, and exercise stress testing. Peripheral arterial disease was assessed using Doppler ultrasound. Clinical assessment was performed in accordance with established cardiovascular guidelines [4].

Microvascular complications included: Diabetic retinopathy, assessed by fundus examination according to standardized ophthalmologic criteria [13]. Diabetic neuropathy, assessed using the DN4 (Douleur Neuropathique 4) questionnaire and a 10-g monofilament test [14]. Diabetic nephropathy was defined using estimated glomerular filtration rate (eGFR) calculated by the CKD-EPI (chronic kidney disease epidemiology collaboration) equation [15] and UACR, according to Kidney Disease Improving Global Outcomes (KDIGO) and American Diabetes Association criteria [16].

Statistical analysis

Data were analyzed using IBM SPSS Statistics

version 21.0. Continuous variables were expressed as mean $\pm$ standard deviation (SD), and categorical variables as frequencies and percentages. Normality of continuous variables was assessed using the Shapiro–Wilk test. Comparisons between groups were performed using the Student’s t-test or Mann–Whitney U test for continuous variables, as appropriate. Associations between categorical variables were assessed using the Chi-square test or Fisher’s exact test when appropriate.

A p-value < 0.05 was considered statistically significant.

All comparisons between groups were performed using unadjusted bivariate analyses. Multivariable analyses were not performed because complete individual-level data were not available for retrospective model reconstruction.

Missing data handling

Patients with incomplete medical records were excluded from the analysis. No data imputation was performed.

Sample size consideration

The sample size was based on the number of eligible patients available during the study period in the department. A formal sample size calculation was not performed due to the retrospective design of the study.

Ethical approval

The study was approved by the Ethics Committee of Biomedical Research of our faculty (CERBO, reference number: 16/2020) and registered in the Research Registry (researchregistry7745). All data were anonymized. Informed consent was obtained or waived according to institutional ethics approval for this retrospective study.

Results

A total of 500 patients with T2D were included, comprising 325 women and 175 men (sex ratio M/F = 0.53). The mean age was 58.3 ± 12.8 years. The mean duration of diabetes was 10 ± 9 years, and 46% of patients had a duration of less than 5 years. HTN was present in 40.8% of patients, with a mean duration of 28 ± 5 years; 77.6% of patients with HTN had grade I HTN.

Regarding anthropometric characteristics, 30% of patients were overweight, 21.4% had grade I obesity, 6% had grade II obesity, and 3.6% had morbid obesity. The mean HbA1c was $10.6 \pm 2.7\%$, and 52.2% of patients had HbA1c $>10\%$.

Three or more cardiovascular risk factors (CVRF) were present in 24.6% of patients. Concerning treatment, 21% received oral antidiabetic drugs (OAD), 29.4% received a combination of OAD and insulin, and 49.1% were treated with insulin alone.

The frequencies of microvascular and macrovascular complications according to hypertension status are presented in Table I. Among patients without HTN, the frequencies of retinopathy, nephropathy, and neuropathy were 19.9%, 14.2%, and 12.2%, respectively, compared with 30.9%, 32.8%, and 22.5% among patients with HTN. The frequencies of coronary artery disease, peripheral arterial disease and cerebrovascular accident were 19.9%, 3.4%, and 2.4%, respectively, in patients without HTN, and 34.3%, 6.4%, and 9.3%, respectively, in patients with hypertension (Table I).

Microvascular and macrovascular complications were present in 55.3% and 65.6% of patients with more than three CVRF, respectively. No significant differences were observed between CVRF and treatment type ($p = 0.06$ for antidiabetic treatment; $p = 0.15$ for antihypertensive treatment).

Table I. Association between hypertension and microvascular and macrovascular complications in patients with type 2 diabetes.

Type of complication	Patients without hypertension (n= 296)	Patients with hypertension (n= 204)	P value
Microvascular complications	Retinopathy	59 (19.9%)	0.005
	Nephropathy	42 (14.2%)	<0.001
	Neuropathy	36 (12.2%)	0.002
Macrovascular complications	Coronary artery disease	59 (19.9%)	<0.001
	Peripheral arterial disease	10 (3.4%)	0.116
	Cerebrovascular accident	7 (2.4%)	<0.001

n: number of patients. Data are expressed as percentages. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate.

Table II. Association between hypertension grade and microvascular and macrovascular complications.

Type of complication	Grade I hypertension	Grade II hypertension	Grade III hypertension	P value
Microvascular complications	Nephropathy	34.28%	52.63%	0.228
	Retinopathy	30%	34.21%	0.694
	Neuropathy	12.85%	43.24%	0.638
Macrovascular complications	Coronary artery disease	37.14%	31.75%	0.410
	Peripheral arterial disease	7.14%	5.26%	<0.001
	Cerebrovascular accident	8.75%	15.70%	0.008

Data are expressed as percentages. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate.

Table III. Frequency of microvascular and macrovascular complications based on the duration of diabetes and hypertension.

Type of complication		Duration of diabetes			Duration of HTN		
		<10 years	>10 years	P value	<10 years	>10 years	P value
Microvascular complications	Retinopathy	15.33%	35.42%	<0.001	21.92%	26%	0.543
	Nephropathy	15.95%	32.75%	0.112	35.84%	37%	0.392
	Neuropathy	12.88%	22.85%	0.001	15.44%	28%	0.414
Macrovascular complications	Coronary artery disease	18.50%	21.80%	0.303	24.98%	40%	0.291
	Peripheral arterial disease	6.12%	8.25%	0.07	5.01%	6.06%	< 0.001
	Cerebrovascular accident	2.02%	9.70%	0.001	8.69%	20%	0.144

Data are expressed as percentages. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate. HTN: hypertension.

Peripheral arterial disease and cerebrovascular accident showed significant differences across hypertension grades ($p < 0.001$ and $p = 0.008$, respectively). No significant differences were observed for nephropathy, retinopathy, neuropathy, or coronary artery disease across hypertension grades (Table II).

Retinopathy, neuropathy, and cerebrovascular accident were significantly more frequent among patients with a diabetes duration >10 years ($p < 0.001$, $p = 0.001$, and $p = 0.001$, respectively). Regarding hypertension duration, peripheral arterial disease was significantly associated with longer hypertension duration ($p < 0.001$), whereas no significant differences were observed for the other complications (Table III).

Discussion

The present study highlights a high prevalence of HTN among patients with T2D and demonstrates a significant association between HTN and both microvascular and macrovascular complications. Overall, our findings indicate that the coexistence of HTN and T2D is associated with a higher burden of both microvascular and macrovascular complications in diabetic patients.

The predominance of female patients in our cohort is consistent with previous reports [17]. This pattern may be related to postmenopausal hormonal changes, increased healthcare utilization among women, and longer life expectancy. The mean age of our population reflects the typical age group affected by T2D and its complications, where cumulative vascular damage becomes more evident over time.

Obesity remains a central modifiable risk factor for both diabetes and hypertension. In our cohort, obesity was observed in 31% of patients, including 21.4% with grade I obesity, 6% with grade II obesity, and 3.6% with morbid obesity. This prevalence was lower than that reported in several cohorts of patients with type 2 diabetes from other regions. In Europe, obesity prevalence ranged from 39.4% to 56.7% across different countries and clinical settings [18], while a large US electronic medical record study reported obesity in 62.6% of patients with type 2 diabetes [19]. In a recent study from Abha, Saudi Arabia, obesity was reported in 46.0% of patients with type 2 diabetes [21]. These differences may reflect variations in demographic characteristics, lifestyle and dietary patterns, socioeconomic conditions, healthcare settings, and study populations. Nevertheless, the substantial prevalence of obesity in our cohort reinforces the importance of population-specific strategies for weight management and cardiometabolic risk reduction [12,20].

Similar findings have been reported in African populations, where long-standing diabetes is strongly associated with microvascular complications [21].

In our unadjusted analyses, longer duration of diabetes was associated with a higher frequency of selected

diabetic complications, particularly retinopathy, neuropathy, and cerebrovascular accident, which may be explained by progressive vascular remodeling, endothelial dysfunction, and the cumulative effects of chronic hyperglycemia.

Importantly, HTN was significantly associated with an increased frequency of both microvascular and macrovascular complications in patients with diabetes. This association is biologically plausible, as HTN exacerbates endothelial injury, increases vascular permeability, and promotes atherosclerotic progression. These mechanisms are well documented and consistent with previous evidence, including the UKPDS trial, which demonstrated the protective effect of blood pressure control on diabetic complications [6].

However, the associations observed according to HTN grade and duration were more selective. Higher grades of HTN were significantly associated with peripheral arterial disease and cerebrovascular accident, whereas no significant differences were observed for the other complications. Similarly, longer duration of HTN was significantly associated with peripheral arterial disease, while no significant associations were observed for the other complications.

Taken together, these results support the importance of considering hyperglycemia and HTN as interconnected cardiovascular risk factors in patients with T2D, rather than isolated disease processes. However, these findings should not be interpreted as evidence of a causal or synergistic interaction between hyperglycemia and HTN.

Our findings have important clinical and research implications. From a clinical perspective, they highlight the need for early and systematic screening of CVRF in patients with T2D, particularly HTN, in order to reduce the burden of both microvascular and macrovascular complications. These results also support an integrated management approach targeting glycemic control, blood pressure, and other modifiable risk factors simultaneously rather than treating each condition in isolation.

From a research perspective, further prospective longitudinal studies are needed to explore associations between HTN and diabetic complications and to evaluate the long-term impact of intensive multifactorial intervention strategies in this population.

Strengths and limitations

This study has several strengths, including its real-world clinical setting and a well-characterized cohort of patients with T2D. The detailed assessment of both microvascular and macrovascular complications enhances the clinical relevance of the findings.

However, several limitations should be acknowledged. The retrospective and cross-sectional design limits the ability to establish causal associations. In addition, potential information bias due to reliance on medical records and missing data may have influenced the results. The single-center design, relatively small

sample size, and socioeconomic factors may also limit the generalizability of the findings.

Larger multicenter prospective studies are needed to confirm and extend these results.

Furthermore, the reported associations were based on unadjusted bivariate analyses, and complete individual-level data were not available to perform multivariable adjustment. Therefore, potential confounding, particularly by age and diabetes duration, cannot be excluded.

Conclusion

Hypertension was associated with a higher prevalence of microvascular and macrovascular complications in patients with type 2 diabetes. These findings underscore the importance of blood pressure control and comprehensive cardiovascular risk management in this population. Further studies using multivariable analyses are warranted to determine whether these associations are independent of potential confounding factors.

Author's contributions

AS: Conception and design of the study, acquisition, analysis and interpretation of data, wrote the manuscript. **HB:** Worked on the conceptualization, design, helped in the writing of manuscript. **REA:** revised the work critically. **BL:** critically revised and edited the manuscript. **NB:** Conception and design of the study, supervised the redaction, revised the work critically. **SR:** Conception and design of the study, supervised the redaction, revised the work critically. **HL:** Conception and design of the study, supervised the redaction, revised the work critically.

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