JOURNAL OF SCIENCE & DISEASES

The Impact of Diabetes Mellitus on Treatment Outcomes of hospitalized Patients with Active Pulmonary Tuberculosis: A 5-Year Retrospective Study at the Laquintinie Hospital Douala

Impact du diabète sucré sur l'issue thérapeutique des patients hospitalisés pour tuberculose pulmonaire active : étude rétrospective sur 5 ans à l'Hôpital Laquintinie de Douala.

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Article Original

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Keywords: Tuberculosis, Diabetes mellitus, Treatment outcomes, Cameroon

Mots-clés : Tuberculose, Diabète sucré, Résultats du traitement, Cameroun

Date de soumission: 17/05/2025
Date d'acceptation: 04/09/2025

ABSTRACT

Background: Pulmonary tuberculosis–Diabetes mellitus (PTB-DM) co-morbidity is a rising global health concern. This study aimed to determine the prevalence of diabetes mellitus among pulmonary TB patients and assess its impact on treatment outcomes.

Methods: A retrospective study was conducted over a five-year period at Laquintinie Hospital. Medical records of patients diagnosed with pulmonary tuberculosis and hospitalized between 2016 and 2021 were reviewed using a structured data collection tool. Chi-square test was used to test for categorical variables. Logistic regression analyses were used to identify factors associated with unsuccessful PTB treatment outcomes among PTB-DM patients.

Results: A total of 411 patients with active pulmonary tuberculosis (PTB) were included in this study. The mean age (± SD) of the participants was 44.3 ± 11.6 years. There were 263 (64.9%) males. All patients (100%) were on the RHEZ treatment regimen. Out of 411 active pulmonary TB patients, 117 (29%) patients were diabetic. Diabetic TB patients had significantly higher odds (OR = 10.2) of unsuccessful treatment than non-diabetic patients (35.2% vs. 15.4%, $p < 0.0001$). Delayed sputum conversion (4–5 months; COR = 4.48, $p = 0.032$) and non-compliant diabetic status (COR = 8.4, $p = 0.005$) were associated with poor outcomes.

Conclusion: Diabetes is common among TB patients in our setting and is associated with worse treatment outcomes. Delayed sputum conversion and poor glycemic control significantly contribute to treatment failure.

RESUME

Introduction : La comorbidité diabète-tuberculose (DT-TB) est une préoccupation croissante mondiale. Cette étude visait à évaluer l'impact du diabète sur les résultats du traitement antituberculeux.

Méthodes : Une étude rétrospective a été menée sur une période de cinq ans à l'Hôpital Laquintinie. Les dossiers médicaux des patients diagnostiqués avec la tuberculose pulmonaire entre 2016 et 2021 ont été examinés. Le test du Chi-deux a été utilisé pour les variables catégorielles. Des analyses de régression logistique ont été employées pour identifier les facteurs associés aux échecs de traitement de la TP chez les patients atteints de TP-DT.

Résultats : Au total, 411 patients atteints de tuberculose pulmonaire active (TPA) étaient inclus. L'âge moyen des participants était de 44,3 ± 11,6 ans avec une prédominance masculine (64,9 %). Tous les patients suivaient le schéma de traitement RHEZ. Sur les 411 patients atteints de TPA, 117 (29 %) étaient diabétiques. Les patients tuberculeux diabétiques présentaient une probabilité d'échec de traitement plus élevée (OR = 10,2) que les patients non diabétiques (35,2 % contre 15,4 %, $p < 0,0001$). La conversion tardive des crachats (4-5 mois ; COR = 4,48, $p = 0,032$) et un statut diabétique non compliant (COR = 8,4, $p = 0,005$) étaient associés à de mauvais résultats.

Conclusion : Les patients tuberculeux diabétiques présentaient une probabilité d'échec de traitement plus élevée. La conversion tardive des crachats et un statut diabétique non compliant étaient associés à de mauvais résultats.

Introduction

Tuberculosis (TB) is a chronic infection caused by the gram-positive, acid-fast bacillus Mycobacterium tuberculosis, primarily affecting the lungs, but also capable of causing extrapulmonary disease1. TB remains a significant source of mortality and morbidity globally, with about one-third of the world's population infected with Mycobacterium tuberculosis 2. In 2019, an estimated 10 million cases of TB were diagnosed 3. Among people with human immunodeficiency virus (HIV) infection, about 920,000 incident TB cases were recorded in 2017, accounting for 9% of all TB cases 4.

Cameroon, a lower-middle-income country with a population of approximately 27.5 million as of 2021, reported 480,250 tuberculosis cases via sputum smear microscopy. According to WHO, the TB case detection rate in Cameroon in 2014 was 52%. While the number of diagnosed but unnotified cases is considered relatively low, there is undoubtedly a number of undiagnosed TB cases in Cameroon 5. In 2019, an estimated incidence of 179 TB cases per 100,000 people was reported 6. Although TB case notifications in Cameroon increased from the 1990s until 2014, they have declined since then; However, treatment coverage remains suboptimal at 53% in 2019 6.

Diabetes mellitus (DM) represents a growing global health concern, with an estimated prevalence of 9.3% in 2019, and approximately 80% of cases occurring in low- and middle-income countries 7–9. In Cameroon, the prevalence of DM is estimated at 6%, largely attributed to increasing rates of obesity, physical inactivity, and poor dietary habits 7,10.

The association between DM and TB is well established. DM is recognized as an independent risk factor for pulmonary TB and has been associated with adverse TB outcomes, including delayed sputum conversion, treatment failure, relapse, and increased mortality 11,12. The rising prevalence of DM in TB-endemic settings has raised significant concerns for TB control efforts, particularly in resource-limited countries 13. Despite these concerns, limited evidence exists from Cameroon regarding the impact of DM and glycemic control on pulmonary TB (PTB) treatment outcomes. This study aimed to assess the prevalence of DM among PTB patients, identify factors associated with poor treatment outcomes, and evaluate the impact of DM on PTB management.

Material and Method

This was a retrospective cohort study conducted at Laquintinie Hospital Douala (LHD), a secondary-level referral and teaching hospital in Douala, Cameroon, between January 2016 and December 2021. All patients newly diagnosed and treated for active pulmonary TB at LHD during the study period were included. For all newly diagnosed pulmonary tuberculosis patients at CMR, antituberculosis treatment is administered systematically according to the WHO protocol. The standard course is RHEZ for two months, followed by RH for four months. A non-probability convenience sampling method was used, reviewing all available medical records that met the inclusion criteria. The study included medical records of patients aged ≥15 years diagnosed with active pulmonary TB and treated at LHD between January 2016 and December 2021. Pulmonary tuberculosis (PTB) referred to active tuberculosis primarily affecting the lungs, diagnosed based on clinical and/or radiological findings. In the study, it encompassed both smear-positive tuberculosis cases (where sputum smears were positive for acid-fast bacilli) and smear-negative cases (where sputum smears were negative). Files for which key information was missing, such as the cause and date of death, past medical history, blood sugar levels, and sputum conversion time, were excluded. Likewise, patients who died before the start of treatment for unknown reasons, or those who were transferred or lost to follow-up, were excluded.

Eligible patient records were retrieved from the hospital archives and reviewed using a structured data extraction form designed to collect relevant information. Sociodemographic variables included age, sex, marital status, employment status, level of education, and smoking habits. Clinical presentation data included common symptoms such as cough, fever, and hemoptysis. The medical history section documented comorbidities, including Human Immunodeficiency Virus (HIV) infection, diabetes mellitus, hypertension, chronic alcohol use, and Bacillus Calmette–Guérin (BCG) vaccination status. Non-compliance to antidiabetic treatment was defined as the self-reported absence of taking the usual protocol (oral and/or injectable) for at least one consecutive month.

Diagnostic and investigative parameters included sputum smear status, time to sputum conversion, and blood glucose levels. Treatment outcomes were recorded and classified as cure, treatment completion, treatment failure, or death. A patient was considered cured if they had initial smear-positive pulmonary TB and became smear-negative by the 5th month, remaining so through the last month of treatment. Treatment Completion applied to patients who finished the full prescribed treatment course without clinical signs of active disease, in the absence of end-of-treatment bacteriological results. Treatment Failure was defined as a patient whose smear remained positive at or after the 5th month of treatment, or who reverted to smear-positive after an initial negative period. Finally, Death referred to any patient who died from any cause during the course of antituberculosis treatment.

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The dataset was initially analyzed using Epi Info version 7.2.4 for basic data preparation and then exported to IBM SPSS Statistics version 25. Descriptive statistics were used to summarize variables; means and standard deviations for continuous data, and frequencies with percentages for categorical variables. Associations between categorical variables were assessed using the Chi-square test. Bivariate and multivariate logistic regression analyses were conducted to identify factors associated with treatment outcomes. Independent variables included sociodemographic characteristics, body mass index (BMI), and comorbidities. The dependent variable was TB treatment outcome.

Ethical approval was obtained from the Institutional Review Board of the Faculty of Health Sciences, University of Buea (Ref: 1563-01). Administrative clearance was granted by the Littoral Regional Health Delegation and the Director of LHD. Patient confidentiality was strictly maintained throughout the study.

Results

A total of 411 patients with active pulmonary tuberculosis (PTB) were included in this study. The mean age (± SD) of the participants was 44.3 ± 11.6 years. There were 263 (64.9%) males. More than half of the participants (200; 51.2%) were single, and the majority (247; 62.7%) were employed.

All patients (100%) were on the Rifampicin, Isoniazid, Ethambutol, Pyrazinamide treatment regimen. A total of 225 patients (58.4%) had been vaccinated against tuberculosis. The most frequent comorbidities included HIV infection (152; 37.0%), chronic alcohol consumption (106; 26.0%), and hypertension (27; 6.6%) (Table 1).

The prevalence of diabetes mellitus among active PTB patients was 29%. PTB patients with coexisting diabetes mellitus (TB-DM) were significantly older than their non-diabetic counterparts, with a mean age of 51 years compared to 41 years ($p < 0.001$). The majority of TB-DM patients (59.8%) were aged 50 years or older.

Hypertension (HTN) was significantly more prevalent in the TB-DM group (13.7% vs. 3.8%; $p < 0.001$), whereas HIV infection was more frequent in the TB-only group (40.8% vs. 27.4%; $p = 0.012$).

TB+DM patients were significantly more likely to develop the following signs and symptoms, dyspnea (42.7% vs. 31.0%, $p = 0.025$), peripheral adenopathy (3.4% vs. 0.3%, $p = 0.010$).

Also, TB only patients were more like to report more weight loss than TB+DM patients (49.1% vs. 35.0%, $p = 0.001$) (Table 2).

Table 1: socio-demographic characteristics and comorbidities of patients

Characteristic	Frequency (n)	Percentage (%)
Age (Mean ± (SD))	44.3 ± (11.6)	
Age group (years)		
15-29	23	5.6
30-39	143	34.8
40-49	119	29.0
50-59	77	18.7
60-69	39	9.5
≥70	10	2.4
Gender*		
Male	263	64.9
Female	142	35.1
Occupation^		
Employed	247	62.7
Unemployed	93	23.6
Student	23	5.8
Retired	31	7.9
Marital status¥		
Single	200	51.2
Married	163	41.7
Divorced	5	1.3
Widowed	23	5.9
Education[a]		
Primary	61	15.8
Secondary	215	55.8
University	90	23.4
Never	19	4.9
Residence		
Rural	0	0
Urban	411	100
Treatment regiment RHEZ	411	100
BCG vaccination		
Yes	225	58.4
No	90	23.3
Unknown	70	18.1
Alcohol		
Yes	106	26.6
No	292	73.3
HIV		
Yes		
No	259	63.0
HTN	27	6.6
Yes		
No	384	93.4

SD: Standard deviation; Information missing with respect to gender * 6; occupation status ^17; marital status * 20; highest educational status attained [a]26, RHEZ= Rifampicin, Isoniazid, Ethambutol, Pyrazinamid; HIV: Human Immunodeficiency Virus; BCG: Cacille calmette et Guerin vaccine ; HTN: hypertension

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Table 2: Socio-demographic and Clinical Characteristics of PTB Patients Stratified by Diabetes Status

Variables	Category	TB-DM (n = 117)	TB only (n = 287)	p-value
Age group n (%)	< 50 years	47 (40.2%)	47 (40.2%)	< 0.001
	≥ 50 years	70 (59.8%)	70 (59.8%)	
Gender n (%)	Male	72 (62.6%)	187 (66.1%)	0.511
	Female	43 (37.4%)	96 (33.9%)	
Occupation n (%)	Employed	65 (59.1%)	178 (64.3%)	< 0.001
	Unemployed	18 (16.4%)	73 (26.4%)	
	Student	5 (4.5%)	18 (6.5%)	
	Retired	22 (20.0%)	8 (2.9%)	
Marital Status n (%)	Single	41 (37.6%)	156 (56.7%)	0.010
	Married	55 (50.5%)	110 (38.2%)	
	Divorced	1 (0.9%)	4 (1.5%)	
	Widowed	12 (11.0%)	10 (3.6%)	
Education n (%)	Primary	20 (18.5%)	39 (14.4%)	0.700
	Secondary	61 (56.5%)	151 (55.9%)	
	University	22 (20.4%)	66 (24.4%)	
	Never attended	5 (4.6%)	14 (5.2%)	
Alcohol Use		33 (29.7%)	71 (25.3%)	0.367
Comorbidity n (%)	HIV	32 (27.4%)	117 (40.8%)	0.012
	Hypertension	16 (13.7%)	11 (3.8%)	< 0.001
Symptom n (%)	Cough	98 (83.8%)	260 (90.6%)	0.051
	Hemoptysis	21 (17.9%)	46 (16.0%)	0.642
	Dyspnea	50 (42.7%)	89 (31.0%)	0.025
	Fever	70 (59.8%)	179 (62.4%)	0.626
	Weight loss	41 (35.0%)	141 (49.1%)	0.001
	Night sweats	24 (20.5%)	82 (28.6%)	0.094
	Adenopathy	4 (3.4%)	1 (0.3%)	0.010
BMI n (%)	Underweight	40 (36.0%)	113 (40.2%)	0.443
	Normal	60 (20.9%)	158 (55.1%)	< 0.001
	Overweight	7 (2.4%)	7 (2.4%)	1.000
	Obese	4 (1.4%)	3 (1.0%)	0.734

DM: diabete mellitus, TB: Tuberculosis; BMI: Body mass index; BCG: Cacille calmette et Guerin vaccine

Of 411 PTB patients, 73.5% had successful treatment outcomes. Success was significantly higher in TB-only patients (88.2%) than in those with diabetes (40.2%), while unsuccessful outcomes were more common in TB+DM patients (59.8% vs. 11.8%). TB+DM patients had over 10 times the odds (OR = 10.2) of poor outcomes (Table 3).

Table 3. Treatment Outcomes of All TB Patients vs. TB-DM Patients

Treatment Outcome	Total (N=411)	TB-DM n (%)	TB-only n (%)
Successful outcome* (n = 117)			
Cured	120 (29.2)	15 (12.8)	105 (35.7)
Treatment completed	172 (41.9)	32 (27.4)	140 (47.6)
Unsuccessful outcome** (n = 294)			
Treatment failure	46 (11.2)	35 (29.9)	11 (3.7)
Death	63 (15.3)	35 (29.9)	23 (7.8)

DM: diabete mellitus, TB: Tuberculosis

Bivariate logistic regression showed that sputum conversion at 4–5 months (COR 4.48, p = 0.032) and non-compliant DM status (COR 8.4, p = 0.005) were significantly associated with unsuccessful TB treatment outcomes (Table 4).

Table 4: Binary Regression Analysis of Factors Associated with Unsuccessful PTB Treatment Outcome

Variable	Category	COR	95% CI	p-value
Age (years)		0.996	0.967 – 1.026	0.791
Gender	Male (Ref)	1	-	-
	Female	1.175	0.553 – 2.496	0.675
Education	Primary	0.556	0.077 – 4.009	0.560
	Secondary	1.704	0.262 – 11.058	0.577
	University	0.667	0.094 – 4.733	0.685
	Never(Ref)	1	-	-
Occupation	Retired	0.554	0.214 – 1.436	0.224
	Student	2.419	0.256 – 22.827	0.441
	Unemployed	1.411	0.482 – 4.126	0.530
	Employed (Ref)	1	-	-
Marital Status	Single	1.837	0.520 – 6.485	0.345
	Married	1.214	0.362 – 4.069	0.753
	Divorced	1.36E-10	a	1.000
	Widowed (Ref)	1	-	-
BCG Vaccination	Yes (Ref)	1	-	-
	No	1.890	1.280 – 4.883	0.126
Alcohol Status	Yes	1.545	0.669 – 3.573	0.309
	No (Ref)	1	-	-
Smoking Status	Yes (Ref)	1	-	-

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Variable	Category	COR	95% CI	p-value
	No	1.135	0.441 – 2.921	0.793
TB Case Category	New case (Ref)	1	-	-
	Recurrent case	1.077	0.463 – 2.504	0.864
Sputum Conversion Time	2–3 months (Ref)	1	-	-
	3–4 months	0.960	0.4241 – 2.189	0.923
	4–5 months	4.480	1.142 – 17.577	0.032
BMI Category	Underweight (Ref)	1	-	-
	Normal weight	0.762	0.345 – 1.681	0.501
	Overweight	0.429	0.085 – 2.161	0.305
	Obese	0.571	0.073 – 4.456	0.593
Diabetes	Non-compliant	8.400	1.927 – 36.619	0.005
	New case	1.338	0.496 – 3.610	0.565
	Compliant (Ref)	1	-	-
DM Duration (years)	>10	1.667	0.210 – 13.223	0.629
	5–10	1.389	0.216 – 8.916	0.729
	0–4 (Ref)	1	-	-

* The procedure models Unsuccessful as the response, treating Unsuccessful as the reference category; a set missing due to overflow; COR = crude odds ratio, CI = confidence interval; DM: diabete mellitus, TB: Tuberculosis; BMI: Body mass index; BCG: Bacille calmette et Guerin vaccine

Multivariate analysis assessed various socio-demographic and clinical factors for their association with unsuccessful TB treatment outcomes among TB-DM patients. However, none showed a statistically significant association ($p > 0.05$) (Table 5).

Table 5: Multivariate Regression Analysis of Factors Associated with Unsuccessful PTB Treatment Outcome

Variable	Category	AOR	95% CI	p-value
Year of Diagnosis	2016	1.036	0.13 – 8.244	0.973
	2017	0.544	0.086 – 3.46	0.519
	2018	0.907	0.105 – 7.862	0.93
	2019	1.055	0.158 – 7.046	0.956
	2020	0.544	0.06 – 4.957	0.589
	2021 (Ref)	1	-	-
Age Category	20–29	0.765	0.045 – 13.016	0.853
	30–39	0.781	0.143 – 4.255	0.775
	40–49	1.504	0.282 – 8.019	0.632
	50–59	0.576	0.121 – 2.741	0.488
	60–69	0.743	0.141 – 3.913	0.726
	≥70 (Ref)	1	-	-
Occupation	Employed	1.729	0.569 – 5.256	0.334
	Unemployed	2.203	0.532 – 9.127	0.276
	Student	3.037	0.211 – 43.698	0.414
	Retired (Ref)	1	.	.
Marital Status	Single	1.325	0.313 – 5.607	0.702
	Married	1.142	0.295 – 4.417	0.848
	Divorced	3.19E-10	0 – a	1
	Widowed (Ref)	1	.	.
Education Level	Primary	0.753	0.092 – 6.183	0.792
	Secondary	1.733	0.239 – 12.543	0.586
	University	0.693	0.082 – 5.836	0.736
	Never (Ref)	1	.	.
BCG Vaccination Status	Yes	0.598	0.257 – 1.392	0.233
	No (Ref)	1	.	.
Alcohol Use	Yes	2.334	0.889 – 6.13	0.085
	No (Ref)	1	.	.
Tobacco Use	Yes	0.881	0.342 – 2.269	0.793
	No (Ref)	1	.	.
TB Case Category	New	1.017	0.377 – 2.746	0.973
	Recurrent (Ref)	1	.	.
Sputum Conversion Time	2–3 months	0.241	0.058 – 1.008	0.051
	3–4 months	0.23	0.052 – 1.028	0.054
	4–5 months (Ref)	1	.	.
BMI Category	Underweight	2.888	0.236 – 35.406	0.407
	Normal weight	1.989	0.168 – 23.581	0.586
	Overweight	0.425	0.014 – 12.911	0.623
	Obese (Ref)	1	.	.
Diabetes Classification	Compliant	0.104	0.009 – 1.251	0.075
	New case	0.035	0.001 – 1.103	0.057
	Non-compliant (Ref)	1	.	.
DM Duration	0–4 years	1.839	0.085 – 39.825	0.698
	5–10 years	0.71	0.055 – 9.256	0.794
	>10 years (Ref)	1	.	.

* The procedure models Unsuccessful as the response, treating Unsuccessful as the reference category; a set missing due to overflow; AOR = Adjusted odds ratio, CI = confidence interval; DM: diabete mellitus, TB: Tuberculosis; BMI: Body mass index; BCG: Cacille calmette et Guerin vaccine

Discussion

The increased prevalence of TB-DM comorbidity is becoming a major public health concern, especially in resource-limited settings where TB remains endemic, such as in Cameroon.

In this study, the prevalence of DM among PTB patients was 29%. This finding is consistent with results from Mexico (29.63%) and South Texas (27.8%) 14,15. This rate is significantly higher

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than the estimated DM prevalence in the general Cameroonian population (6.82%) and the global TB–DM comorbidity estimate (16%) 16,17. This may reflect the urban lifestyle factors of the patients and hospital's referral role and the with greater access to DM screening. In contrast, Nwachukwu et al. in Nigeria reported a higher prevalence of 38%, likely due to a larger sample and regional differences in DM burden 18. Conversely, Mi et al. in China reported a lower prevalence of 12% 19. This difference might be explained by the lower prevalence of comorbid conditions such as HIV/AIDS in China compared to our setting (3.7% vs. <1%) 20.

Our study found that PTB patients with DM were significantly older than without DM, with 59.8% of TB–DM cases occurring in individuals aged 50 years and above. This is consistent with findings from studies conducted in Southeast Ethiopia 21, China 22, and India 23. The higher prevalence in this age group may be due to reduced physical activity and the natural increase in non-communicable disease risk, including type 2 DM, with age. Additionally, HIV was the most common comorbidity among all PTB patients in our study. Since HIV is more prevalent among younger individuals, this may partly explain the predominance of DM in older patients.

In our study, diabetic PTB patients showed higher frequencies of certain symptoms – dyspnea and lymphadenopathy - compared to non-diabetic patients. However, no significant overall difference in clinical presentation was observed between the two groups. This finding aligns with studies conducted by Alisjahbana et al, in Indonesia 24, Nissapatorn et al, in Southeast Asia 25, and Alladin et al, in Guyana 26. Furthermore, Chiang et al reported poor glycemic control was associated with more symptoms and higher smear positivity 27. Several studies suggest that diabetic patients are more prone to severe forms of PTB, including diffuse or bilateral lung involvement which explains the difficulties in breathing, disseminated TB which would explains the observed lymphadenopathy and a reduced febrile response due to impaired immune function.

In our study, diabetic PTB patients had significantly higher rates of unsuccessful treatment outcomes compared to non-diabetic patients (59.8% vs. 11.8%, $p < 0.001$). This aligns with findings by Dooley et al. in Maryland, who reported higher mortality among diabetic patients (9.5% vs. 3.5%) 28 and Jimenez-corona et al, in Mexico who reported increased rates of treatment failure, mortality, and recurrence in diabetic PTB patients 14. Poor outcomes in diabetics may be linked to medication non-adherence due to polypharmacy, reduced bacteriological response.

Our analysis showed that delayed sputum conversion (4–5 months) and poor diabetes control were independently associated with unsuccessful PTB treatment outcomes among diabetic patients, consistent with findings by Mboussa et al. in Congo 29. This is due to the impaired immune function in diabetics, leading to prolonged bacterial clearance. Additionally, uncontrolled diabetes results in hyperglycemia, which increases pulmonary glucose levels, creating a favorable environment for Mycobacterium tuberculosis growth.

Our study has several limitations. First, its retrospective design led to missing data, which may have influenced the results. Second, as a single-center, hospital-based study, the findings may not accurately reflect the true prevalence in the broader population. Nonetheless, this is the first study on DM–TB comorbidity conducted in the Littoral Region of Cameroon, offering valuable baseline data to inform future research.

Conclusion

DM is highly prevalent among pulmonary TB patients in our setting and is associated with poorer treatment outcomes. Routine screening for diabetes in TB patients is recommended to optimize glycemic management and improve outcomes. Further prospective studies are needed to better understand this co-morbidity and inform national guidelines for integrated TB-DM management at both policy and clinical levels.

Conflict of interest: *The authors declare no conflicts* of interest regarding the publication of this paper

Authors contribution: Laurent-Mireille Endale Mangamba: Conception development, project execution, manuscript writing; Francine Mendane Mekobe: Manuscript writing and revision. Georges Denis Tewaffeu and Vincent Verla Ssissy: Conception development and manuscript revision; Manuscript revision. Linda Ayaba: Data collection, and manuscript revision. Hugo Bertrand Mbatchou Ngahane: Conceptualization, project supervision, data analysis, and manuscript revision.

Aknowlegment

Our deepest gratitude goes to the participants of this study and to the staff of the respiratory diseases center. We also thank the Direction of Laquintinie Hospital of Douala and Regional Delegation of Public Health for granting us permission to conduct this work.

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