

## RESEARCH PAPER

## ASSOCIATION OF POOR GLYCEMIC CONTROL ON RADIOLOGICAL PATTERNS OF TUBERCULOSIS: A Cross-Sectional Study from a Tertiary Care Centre

Dr Ranjan B N<sup>1\*</sup>, Dr Basavaraju M M<sup>2</sup>, Dr Ravi B Nagarajaiah<sup>3</sup>

<sup>1</sup>Junior Resident, Department of General Medicine, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, 571448, Karnataka, India.

<sup>2</sup>Professor, Department of General Medicine, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, 571448, Karnataka, India.

<sup>3</sup>HOD and Professor, Department of General Medicine, Adichunchanagiri Institute of Medical Sciences, B.G. Nagara, 571448, Karnataka, India.

\*Corresponding Author: Dr Ranjan B N, Junior Resident, Department of General Medicine, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, 571448, Karnataka, India. Email: ranjuraku747@gmail.com

### ABSTRACT

**Background:** Tuberculosis (TB) and diabetes mellitus (DM) represent a significant global health syndemic. Hyperglycemia is known to alter the immune response, leading to more severe clinical presentations and atypical radiological patterns. This study evaluates the association of poor glycemic control with the radiological morphology of TB. **Methods:** A hospital-based cross-sectional observational study was conducted among 90 microbiologically confirmed TB patients with coexisting DM. Glycemic control was categorized by HbA1c levels: good (<7%), moderate (7.0–8.0%), and poor (>8.0%). Chest X-ray (CXR) findings were analyzed in relation to these levels. **Results:** The majority of patients (53.4%) had poor glycemic control (HbA1c >8.0%), with a mean HbA1c of 8.24 ± 1.11. Chest X-rays revealed a range of abnormalities, with infiltrative patterns being the most common (29%), followed by cavitory lesions (18%), upper lobe involvement (16%), bilateral disease (10%), extensive lower lobe involvement (6%), and patchy consolidation (2%). **Conclusion:** Poor glycemic control (HbA1c >8%) is associated with more severe radiological presentations. Integrated management and routine HbA1c screening are essential for improving outcomes in this high-risk population.

**Keywords:** Tuberculosis, Diabetes Mellitus, Glycated Hemoglobin A (HbA1c), Poor Glycemic Control, Pulmonary Tuberculosis, Radiological Pattern, Chest X-ray, Cavitory Lesions, Lower Lobe Tuberculosis, TB–DM Comorbidity.

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### Introduction

Tuberculosis (TB) and diabetes mellitus (DM) represent a significant global health syndemic, with their convergence increasingly observed in vulnerable populations. TB remains one of the leading infectious causes of mortality worldwide, particularly in resource-limited settings, while the rapid global expansion of diabetes—especially in TB-endemic regions—has created a complex public health challenge (1).

The overlap between these diseases is driven primarily by immune dysregulation. Diabetes has emerged as a major independent risk factor for active tuberculosis, with individuals with DM having approximately a threefold increased risk of developing pulmonary TB (relative risk ≈ 3.11) (3). Conversely, the chronic inflammatory stress induced by active TB may unmask previously undiagnosed diabetes or worsen pre-existing glycemic control, further complicating disease outcomes (4).

Poor glycemic control, particularly in uncontrolled type 2 diabetes mellitus, significantly impairs host immune responses against *Mycobacterium tuberculosis*. Chronic hyperglycemia disrupts macrophage phagocytosis and cytokine signaling, promoting a shift toward the M2 anti-inflammatory phenotype that facilitates intracellular persistence of the bacillus (5,6). Although circulating neutrophil counts may be elevated in hyperglycemic individuals, their effective recruitment to infection sites is impaired due to advanced glycation end-product-mediated collagen modification and altered chemotaxis, resulting in reduced bactericidal activity (5).

At the cytokine level, poorly controlled diabetes is associated with diminished production of key pro-inflammatory mediators essential for TB control, including interferon-gamma (IFN- $\gamma$ ) and tumor necrosis factor-alpha (TNF- $\alpha$ ), alongside elevated systemic inflammatory markers such as interleukin-6 (IL-6) and interleukin-18 (IL-18), leading to a dysregulated immune response (6,7).

This immune dysfunction frequently translates into altered clinical and radiological manifestations. Patients with poorly controlled diabetes often demonstrate more extensive pulmonary disease, increased cavitory lesions, bilateral involvement, and atypical lower lung zone predominance compared to normoglycemic individuals (8,9). Given that glycated hemoglobin (HbA1c) reflects long-term glycemic control, evaluating the impact of elevated HbA1c levels (>8%) on radiological patterns of pulmonary tuberculosis is essential for improving diagnostic vigilance and integrated management strategies in TB–DM co-infection (10).

This study evaluated 90 microbiologically confirmed TB patients with coexisting DM, examining the influence of glycemic severity on clinical and radiological disease patterns. Poor glycemic control was observed in 53.4% of patients, with a mean HbA1c of 8.24 ± 1.11. Similar high HbA1c levels among TB–DM patients have been reported in Indian cohorts, reinforcing the contribution of uncontrolled diabetes to disease burden (11,12).

**Aim and Objective**

1. To determine the association between poor glycemic control (HbA1c >8%) and radiological patterns of pulmonary tuberculosis in patients with coexisting diabetes mellitus.

**Materials and Methods**

**Study Setting and duration**

This observational cross-sectional study was conducted in Adichunchanagiri Hospital and Research Centre, a tertiary care teaching hospital. The study duration spanned 18 months, from March 2024 to August 2025.

**Study Design**

The present research was a cross-sectional observational study designed to evaluate the association of poor glycemic control with radiological patterns of pulmonary tuberculosis.

**Study Population**

Patients aged 18–70 years with diagnosed tuberculosis and diabetes mellitus (as per NTEP and WHO guidelines) were included.

**Inclusion Criteria:**

1. Patients aged 18 to 70 years.
2. Newly diagnosed tuberculosis as per NTEP guidelines.
3. Diagnosed with diabetes mellitus as per WHO criteria.

**Exclusion Criteria:**

1. History of previous tuberculosis.
2. Pregnant women.
3. Patients with other comorbid conditions such as HIV, liver failure, cerebrovascular disease, occupational lung diseases, or other immunosuppressive disorders.
4. Patients having any other respiratory illness not related to pulmonary TB.
5. Patients having any other systemic diseases.

**Ethical Considerations**

Institutional Ethics Committee approval was obtained prior to study initiation. Written informed consent was secured from all participants. Privacy and confidentiality were maintained.

**Data Collection and Study Procedures**

Data were recorded using a pre-tested structured proforma.

**Investigations**

1. Complete haemogram
2. Fasting blood sugar and postprandial blood sugar
3. HbA1c
4. Renal function tests and serum electrolytes
5. Liver function tests
6. Chest X-ray

**Special Investigations**

- CBNAAT*
- SPUTUM AFB*
- PLEURAL FLUID ANALYSIS*
- ASCITIC FLUID ANALYSIS*
- FNAC*
- USG ABDOMEN AND PELVIS*
- MRI BRAIN*
- CSF ANALYSIS*
- MRI SPINE*
- MRI HIP*

**Sample Size Determination**

The sample size was calculated based on the prevalence of diabetes mellitus among TB patients reported in previous literature, using the formula  $n = Z^2pq/d^2$ .

Where:

- $Z = 1.96$  (standard normal deviate at 95% confidence interval)
- $p = 35.5\%$  (prevalence of DM in PTB)
- $q = 100 - 35.5 = 64.5\%$
- $d = 10\%$  (absolute precision)

Substituting the values:  $n = (1.96)^2 \times 35.5 \times 64.5 / (10)^2 =$  approximately 90.

Thus, approximately 90 patients were enrolled.

**Statistical Analysis**

Data were entered into Microsoft Excel and analyzed using SPSS 26.0. Frequencies and proportions were calculated for symptoms and radiological findings. Continuous variables such as blood glucose levels and HbA1c were summarized using mean and standard deviation. Correlation analysis was used to examine the relationship between glycemic control and treatment outcomes such as sputum conversion and radiographic resolution. A p-value <0.05 was considered statistically significant.

**Results**

**TABLE 1. HbA1c Distribution**

HbA1c Range (%)	Frequency	Percentage
< 7.0	12	13.3
7.0 – 8.0	30	33.3
> 8.0	48	53.4
Total	90	100
Mean ± SD	8.24 ± 1.11	

HbA1c levels among the diabetic TB patients varied considerably, with the majority (53.4%) having poorly controlled diabetes (HbA1c > 8.0). Around one-third (33.3%) had moderately controlled levels (7.0–8.0), while only 13.3% had

HbA1c levels below 7.0, indicating good glycemic control. The mean HbA1c level was 8.24 ± 1.11, suggesting suboptimal diabetes control in the majority of patients, which may contribute to increased susceptibility or severity of tuberculosis.

FIGURE 1. HbA1c Distribution

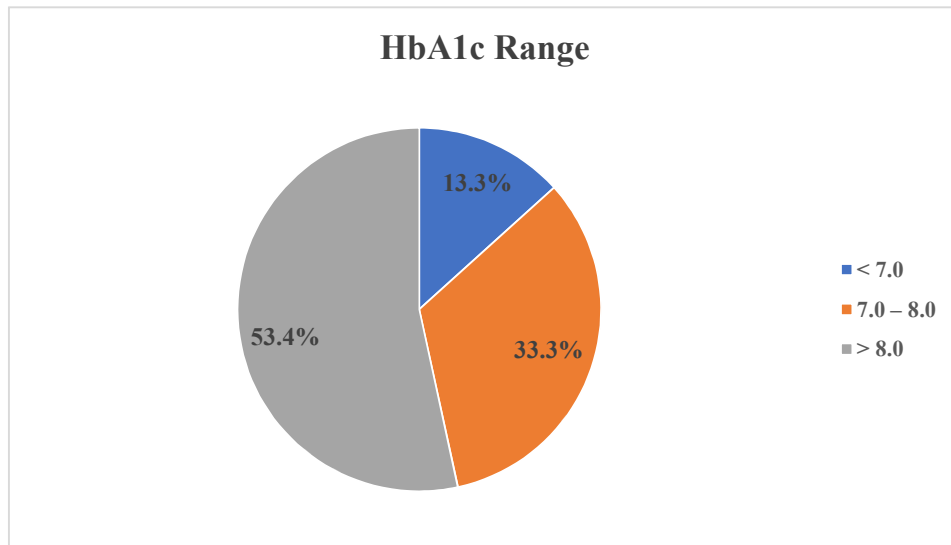
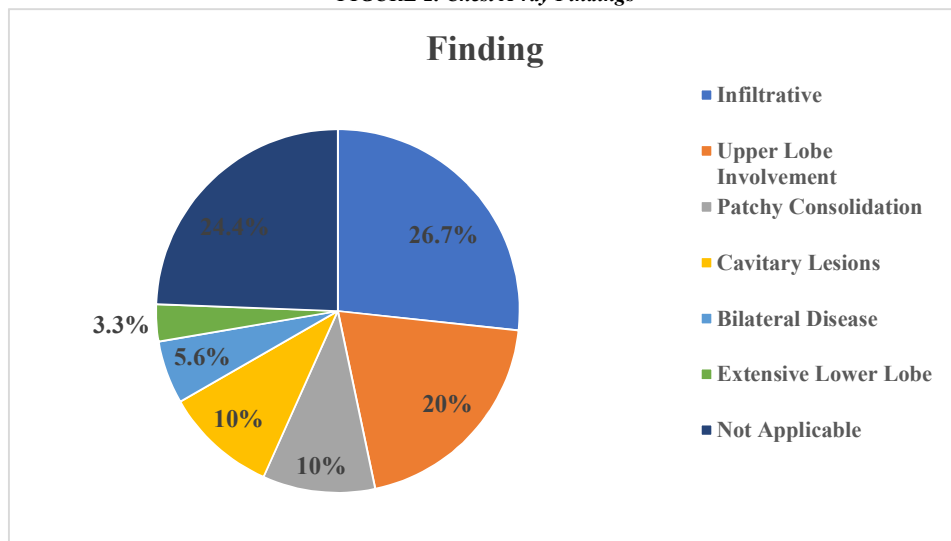


TABLE 2 . Chest X-ray Findings

Finding	Frequency	Percentage
Infiltrative	24	26.7
Upper Lobe Involvement	18	20
Patchy Consolidation	9	10
Cavitary Lesions	9	10
Bilateral Disease	5	5.6
Extensive Lower Lobe	3	3.3
Not Applicable	22	24.4

FIGURE 2. Chest X-ray Findings



ASSOCIATION OF POOR GLYCEMIC CONTROL ON RADIOLOGICAL PATTERNS OF TUBERCULOSIS:

Chest X-rays revealed a range of abnormalities, with infiltrative patterns being the most common (26.7%), followed by upper lobe involvement (20%), patchy consolidation (10%), and cavitory lesions (10%). Bilateral disease was seen in 5.6%, while

extensive lower lobe involvement was rare (3.3%). In 24.4% of patients, radiographic findings were not applicable, possibly due to extrapulmonary disease or inconclusive imaging.

TABLE 3 . Poor glyceimic control and radiological pattern

Finding	Frequency	Percentage
Infiltrative	14	29
Upper Lobe Involvement	8	16
Patchy Consolidation	1	2
Cavitory Lesions	9	18
Bilateral Disease	5	10
Extensive Lower Lobe	3	6
Not Applicable	8	16

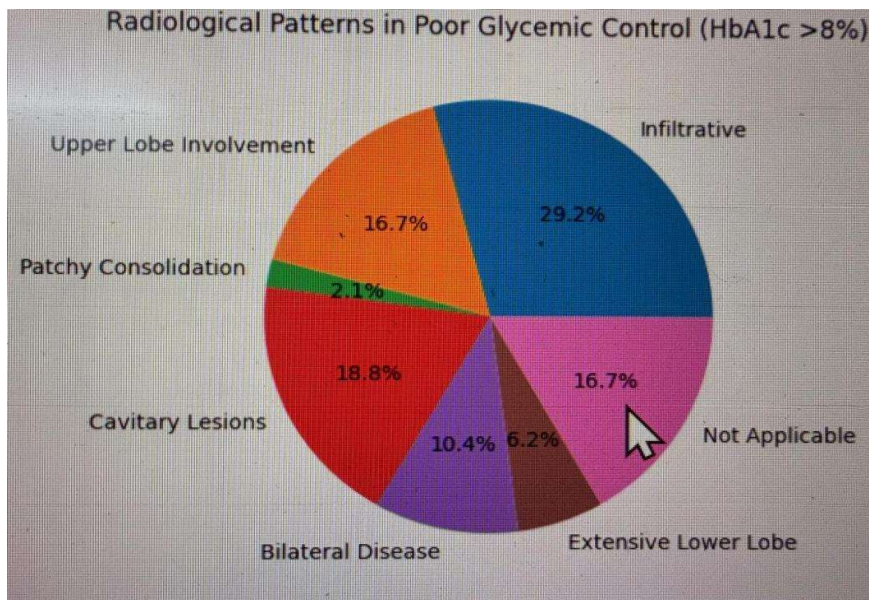


FIGURE 3: Poor glyceimic control and radiological pattern

Infiltrative Patterns were the most frequent finding (29%), consistent with an aggressive inflammatory response in patients with chronic hyperglycemia followed by Cavitory lesions were seen in 18% of patients, indicating significant parenchymal destruction and potentially higher bacillary loads, Upper lobe involvement (16%) remains common, reflecting classical post-

primary tuberculosis, Bilateral disease (10%) and extensive lower lobe involvement (6%) represent atypical and more disseminated patterns of disease. A notable proportion were classified as not applicable (16%), suggesting patterns not included in predefined categories.

## DISCUSSION

### HbA1c Distribution and Glycemic Control in TB-DM Patients

In the present study, HbA1c levels among 90 microbiologically confirmed TB patients with diabetes mellitus demonstrated a predominance of poor glycemic control. More than half of the patients (53.4%) had HbA1c levels  $>8.0\%$ , while 33.3% had moderately controlled diabetes (7.0–8.0%), and only 13.3% achieved good glycemic control ( $<7.0\%$ ). The mean HbA1c of  $8.24 \pm 1.11$  reflects overall suboptimal metabolic control within this cohort.

These findings are clinically significant, as chronic hyperglycemia has been shown to impair host immune defenses against *Mycobacterium tuberculosis*, increasing both susceptibility to active disease and severity of pulmonary involvement (1,2). Poor glycemic control is associated with defective macrophage phagocytosis, altered cytokine production (reduced IFN- $\gamma$  and TNF- $\alpha$ ), and dysregulated neutrophil

function, which collectively contribute to ineffective containment of infection (2,3).

Gupte et al. reported median HbA1c levels approaching 10% among known diabetics with TB, emphasizing poor metabolic control at the time of TB diagnosis (4). Similarly, Garg et al. demonstrated that a significant proportion of TB-DM patients had HbA1c levels above 8%, and those with higher HbA1c experienced delayed sputum conversion and worse treatment outcomes (5).

In a cohort study by Chiang et al., diabetic TB patients with HbA1c  $\geq 8\%$  had more extensive radiographic disease and higher bacillary load compared to those with better glycemic control (6). Likewise, Kumar et al. demonstrated that elevated HbA1c levels correlated with increased inflammatory cytokine dysregulation and greater disease severity in TB-DM co-morbidity (3).

The high proportion of patients with HbA1c  $>8\%$  in our study (53.4%) aligns with the growing evidence that diabetes remains inadequately controlled in TB populations, particularly in low- and middle-income countries where healthcare access and diabetes monitoring may be inconsistent (1,7).

### Comparative Table: HbA1c Distribution in TB-DM Patients Across Studies

Study	Country	Sample Size	Mean/Median HbA1c	% HbA1c $>8\%$	Key Findings
Present Study	India	90	$8.24 \pm 1.11$	53.4%	Majority poorly controlled; associated with greater disease severity
Gupte et al. (2017) (4)	India	630	Median $\sim 10\%$ (known DM)	High prevalence	Poor control associated with adverse TB outcomes
Garg et al. (2020) (5)	India	124	$8.6 \pm 1.3$	$\sim 50\%$	Higher HbA1c linked to delayed sputum conversion
Chiang et al. (2014) (6)	Taiwan	438	Noted $\geq 8\%$ subgroup	Significant subgroup	HbA1c $\geq 8\%$ associated with extensive radiological disease
Kumar et al. (2019) (3)	India	88	Higher HbA1c in severe cases	Not specified	Elevated cytokine dysregulation with poor control

### Radiological Patterns and HbA1c

Chest X-ray analysis revealed infiltrative lesions in 26.7% of cases, upper lobe involvement in 20%, patchy consolidation and cavitory lesions in 10% each, bilateral disease in 5.6%, and extensive lower lobe involvement in 3.3%, while 24.4% showed no significant findings. These patterns align with observations from other studies highlighting a shift in typical pulmonary TB radiology in diabetic patients.

In the study done by Grover S, 109 TB-DM patients had significantly more lower lobe involvement (38.9% vs. 17.6%;  $p = 0.001$ ), multilobar disease (40.7% vs. 21.3%;  $p = 0.003$ ), and thick-walled cavitory lesions (36.1% vs. 16.7%;  $p = 0.002$ ) compared to TB-only patients. Similarly, Jyotirmoy Ghanta118 observed significantly higher rates of isolated lower lobe lesions (8%), multilobar involvement (42%), and cavitation (20%) in TB-DM patients versus controls. Garg R114 reported that lower zone involvement (67.9%), bilateral lesions (58.4%), and cavity formation (45.3%) were more frequent in poorly controlled diabetics, while better-controlled patients more commonly exhibited classic upper zone disease (52.1%) with unilateral involvement and fewer cavities (28.7%).

Prasanna A116 noted that lower zone opacities were more common in patients with moderate to poor glycemic control (64.7%), supporting the association between hyperglycemia and

atypical radiographic presentations. In Dev AKC's110 study, chest X-rays showed nodular opacities (43%), consolidation (38%), cavitation (14%), and fibrotic changes (17%). CT findings provided further detail with high prevalence of nodules (93%), consolidation (64%), and cavitation (38%), along with pleural effusion (21%) and bronchiectasis (22%). Sharma A 111 reported that multiple lesions, fibrosis, and cavitations were more prevalent in patients with HbA1c  $>7.5\%$ , while pleural effusion was more common in those with renal dysfunction. Female patients exhibited more multiple lesions, whereas cavitory lesions were more frequent among males.

Mood N120 observed that upper zone involvement, especially in the right lung, was predominant overall, but middle zone involvement was more common among diabetics. Bishnoi SK112 provided strong evidence that lower lung field involvement was significantly higher in diabetic patients (60% vs. 8%;  $p = 0.001$ ), with much less upper zone involvement (2% vs. 55%). Radiological severity and bilateral involvement also correlated strongly with poor glycemic control.

Taken together, these findings suggest that diabetes, particularly when poorly controlled, is associated with atypical and more severe radiological manifestations of tuberculosis, including lower lobe and multilobar involvement, cavitation, and bilateral disease. These deviations from classical TB radiographic patterns underscore the need for heightened diagnostic vigilance in diabetic patients.

## ASSOCIATION OF POOR GLYCEMIC CONTROL ON RADIOLOGICAL PATTERNS OF TUBERCULOSIS:

### Comparison of Radiological Features

Study	Key Radiological Findings
Our Study	Infiltrates (26.7%), Upper lobe (20%), Patchy consolidation & cavities (10% each), Bilateral (5.6%), Lower lobe (3.3%)
Ghanta J	Lower lobe lesions (8% in DM), Multilobar (42%), Cavities (20%) – all significantly higher in DM group ( $p < 0.05$ )
Grover S	Lower lobe (38.9% in DM vs. 17.6%), Upper lobe more in non-DM; Cavities (36.1% in DM), Multilobar (40.7% in DM) – all significantly higher in TB-DM
Bishnoi SK	Lower lung field (60% in DM vs. 8% in non-DM), Upper field drastically reduced in DM (2%); Cavities more common in DM (70%), Multiple cavities in 75% of DM
Dev AKC	Chest X-ray: Nodular opacities (43%), Consolidation (38%), Cavitation (14%); CT: Nodules (93%), Consolidation (64%), Cavities (38%), Pleural effusion (21%)
Sharma A	Cavities, fibrocavitary lesions, pleural effusion, hilar shadows; multiple lesions in patients with HbA1c >7.5%; cavities more common in non-comorbid TB
Mood N	Right upper zone most frequent; Middle zone more in DM; Cavities more in DM (66% vs. 54%); Lung abscess seen only in diabetics
Kuruva P	Consolidation (68.3%), Cavities (42.9%), Infiltrates (22.2%); Lower zone involvement seen in 46%

### Radiological Patterns in Poor Glycemic Control (HbA1c >8%)

In our cohort of 48 TB-DM patients with poor glycemic control (HbA1c >8%), radiological patterns varied widely, with infiltrative lesions, cavitary disease, upper lobe involvement, bilateral disease, and extensive lower lobe disease. These findings underscore the impact of hyperglycemia on pulmonary pathology in tuberculosis.

### Key Findings from the Present Data

Infiltrative patterns were the most frequent finding (29%), consistent with an aggressive inflammatory response in patients with chronic hyperglycemia. Cavitary lesions were seen in 18% of patients, indicating significant parenchymal destruction and potentially higher bacillary loads. Upper lobe involvement (16%) remains common, reflecting classical post-primary tuberculosis. Bilateral disease (10%) and extensive lower lobe involvement (6%) represent atypical and more disseminated patterns of disease. A notable proportion were classified as not applicable (16%), suggesting either normal X-rays or patterns not included in predefined categories.

These patterns collectively suggest that poor glycemic control is associated with both classical (upper lobe, infiltrative, cavitary) and atypical (bilateral, lower lobe) manifestations of pulmonary tuberculosis.

Moodley et al. (2019) reported that diabetic TB patients had significantly higher rates of cavitary and bilateral disease compared to non-diabetics, particularly when glycemic control was poor (13). This aligns with our findings that cavitation and bilateral involvement are relatively prominent in poorly controlled TB-DM. Kuruva et al. (2019) demonstrated a higher frequency of infiltrative and cavitary lesions in TB patients with diabetes compared to non-diabetics (15). Although their study did not categorize by HbA1c levels, the general trend of more extensive radiological disease mirrors our observations. Chiang et al. (2014) reported that patients with higher HbA1c values tended to have more extensive lower lobe and mixed-pattern disease, supporting our observation of lower lobe involvement (6). Garg et al. (2020) showed that elevated HbA1c was associated not only with delayed sputum conversion but also with more extensive radiographic abnormalities, including cavitation (5).

In contrast, Jeon and Murray (2008) found that diabetes increases TB risk but noted variability in radiological patterns across studies, with some showing no significant difference in cavitation between diabetics and non-diabetics (16). This suggests that while glycemic status influences pathology, it may not uniformly affect all radiological features. Restrepo (2016) concluded that the association between diabetes and atypical radiological presentations, such as lower lobe disease, was inconsistent across populations, possibly due to ethnic, nutritional, or genetic differences (2). Our finding of lower lobe involvement in a minority of cases (6%) supports the notion that such atypical patterns are present but not universal.

### Comparative Table — Radiological Patterns in Poor Glycemic Control

Radiological Feature	Present Study (HbA1c >8%, n=48)	Moodley et al. (2019)	Kuruva et al. (2019)	Chiang et al. (2014)	Jeon & Murray (2008)
Infiltrative Patterns	29%	Higher in DM	Higher in DM	Not specified	Variable
Upper Lobe Involvement	16%	Common	Common	Present	Not significantly different
Cavitary Lesions	18%	Increased	Increased	Present	Mixed results
Bilateral Disease	10%	Increased	Increased	Present	Variable
Lower Lobe Involvement	6%	Not specifically reported	Not specified	Elevated in high HbA1c	Not consistent

### Limitations of the Study

As this was a cross-sectional study, causality between poor glycemic control and radiological severity cannot be definitively established. The study was conducted in a single tertiary care center, which may limit generalizability to other populations, particularly primary care settings or rural healthcare facilities.

Although microbiologically confirmed cases were included, the relatively modest sample size may reduce statistical power, particularly in subgroup analyses such as drug-resistant TB. Radiological assessment was based on chest X-ray findings. HbA1c was measured at baseline only; fluctuations in glycemic control during treatment were not assessed. Treatment outcomes such as relapse rates, mortality, and long-term radiological resolution were not evaluated, limiting conclusions regarding prognostic implications.

**Conclusion**

The present study demonstrates that poor glycemic control (HbA1c >8%) is significantly associated with more severe and atypical radiological manifestations of pulmonary tuberculosis in patients with coexisting diabetes mellitus. The higher frequency of cavitary lesions, infiltrative patterns, bilateral disease, and lower lung zone involvement observed among patients with

elevated HbA1c levels is consistent with previous radiological studies in TB-DM populations. Mechanistically, reduced macrophage activation, diminished IFN- $\gamma$  and TNF- $\alpha$  responses, and dysregulated cytokine signaling in hyperglycemic states may compromise granuloma integrity, thereby promoting parenchymal destruction and cavitation. In conclusion, optimizing metabolic control may represent a critical intervention point to improve clinical outcomes and limit disease progression in this vulnerable population.

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