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Relationship Between Glycemic Control And Ct-Based Severity Of Pulmonary Tuberculosis In Diabetics And Non-Diabetics

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Abstract

Tuberculosis (TB) remains a leading infectious killer worldwide. Diabetes mellitus (DM) is a rapidly growing metabolic epidemic. By weakening the body's immune system, diabetes enables TB to spread more aggressively and destroy lung tissue. Poor blood sugar control (HbA1c ≥7%) leads to even higher CT severity scores and greater cavity burden, highlighting the need for combined TB diabetes care. DM impairs immunity, leading to extensive pulmonary TB, and poor glycemic control correlates with severe CT findings including cavitation, consolidation, and lymphadenopathy.

Aim of the Study:

The main aim of this study is to evaluate the relationship between glycemic control and CT- based severity of pulmonary tuberculosis in diabetic and non-diabetic patients, and to determine whether elevated HbA1c levels are associated with increased radiological severity.

Methodology:

This cross-sectional analytical study was carried out at Nawaz Sharif Hospital, Lahore, and included 113 patients with pulmonary tuberculosis. Each participant underwent a contrast-enhanced chest CT examination using a 16-slice Toshiba scanner. Based on clinical history and HbA1c measurements, participants were separated into two main groups: diabetic (47 individuals) and non-diabetic (66 individuals). Non-diabetic status was defined as HbA1c below 5.7%. Diabetic subjects were then subdivided according to their level of glycemic control: good

control (HbA1c between 5.7% and 7%, 8 patients) and poor control (HbA1c between 7% and 10%, 38 patients). A standardized scoring system (ranging from 0 to 20 points) was used to quantify CT severity, taking into account cavity count, cavity diameter, lobar distribution, bilateral involvement, tree-in-bud sign, consolidation, mediastinal lymphadenopathy, pleural effusion, and bronchiectasis. Statistical analysis was performed with SPSS version 25, using descriptive statistics (frequencies, percentages, means). Comparisons of categorical variables were made using Chi-square tests, while linear-by-linear association was applied to assess dose-response trends. A p-value below 0.05 was considered statistically significant.

Results:

Compared to non-diabetics, diabetic patients had significantly higher CT severity scores ($p = 0.004$). Poor glycemic control (HbA1c ≥7%) was strongly linked to bilateral lung involvement, larger cavities, disease affecting multiple lobes, and noticeable lymph node enlargement. In particular, those with poor control had a greater number of cavities ($p = 0.009$); among patients with 3-4 cavities, 80% were poorly controlled diabetics. There was a positive relationship between HbA1c levels and CT severity scores, with a significant dose-response trend confirmed by linear-by-linear association ($p = 0.003$). Furthermore, lower lobe involvement was seen more often (51.3%) than upper lobe involvement (40.7%), pointing to an unusual pattern associated with diabetes.

Conclusion:

Diabetics with poor glycemic control is significantly associated with increased radiological severity of pulmonary TB.

Introduction

Tuberculosis (TB) continues to be one of the world's deadliest infectious diseases, causing widespread illness and death. In 2023 alone, around 10.8 million people fell ill with TB [1]. The lung form of the disease, caused by the bacterium Mycobacterium tuberculosis, spreads through tiny airborne droplets from coughs or sneezes. Once inside the body, it sets off a complicated immune reaction marked by the formation of granulomas, tissue death (caseous necrosis), and sometimes the development of lung cavities [2]. High-resolution CT scans offer
a much clearer look at lung damage, revealing spots, cavities, tree-in-bud patterns, swollen lymph nodes, and areas of consolidation. These features can be given a severity score that reflects how advanced the disease is [3].

On the other hand, diabetes especially type 2 now affects more than 460 million adults worldwide, and that number is expected to climb [4]. Persistently high blood sugar levels weaken the body's defenses, both the fast-acting (innate) and slower, targeted (adaptive) immune systems. Neutrophils, macrophages, and lymphocytes don't work as well the body produces less interferon gamma; cells struggle to move toward infection sites; and granulomas fail to form properly. All of this allows TB germs to multiply more easily and destroy lung tissue [5]. Studies show that diabetes makes a person two to four times more likely to develop active TB, and roughly 10% of all TB cases around the globe are linked to diabetes [6]. The connection goes both ways: having active TB can make blood sugar harder to control due to widespread inflammation, setting off a harmful cycle where each disease worsens the other [7].

When diabetes isn't well managed meaning HbA1c levels of 7–8% or higher the lung damage from TB tends to be much more severe. Compared to patients with good blood sugar control or those without diabetes, poorly controlled diabetics show more widespread infection, larger and more numerous cavities, disease affecting both lungs and multiple lobes, and higher CT severity scores [8]. What's more, swollen lymph nodes which signal that the infection has spread through the lymphatic system are bigger and more common in diabetic TB patients, a sign that the immune system is failing to keep the bacteria in check [9]. Poor blood sugar management also means it

takes longer for TB bacteria to disappear from sputum tests, raises the risk of treatment failure and relapse, and increases the chance of death [10].

Few studies have used CT severity scores with clear HbA1c cutoffs to compare good versus poor glycemic control within diabetics or examined dose response trends. Almost no such research exits in Pakistan, a high burden country for both diabetes and tuberculosis. This study fills these gaps with quantitative, trend tested evidence linking glycemic control to CT-based TB severity.

MATERIAL AND METHODS

This cross-sectional analytical observational study was carried out at Nawaz Sharif Hospital, Lahore, over a four-month period following synopsis approval. Using convenient sampling, 113 adults over 18 years of age with microbiologically or radiologically confirmed pulmonary

tuberculosis (defined by positive sputum acid-fast bacilli, positive Mycobacterium tuberculosis culture, or characteristic imaging findings) were enrolled. Exclusion criteria included HIV positivity, coexisting respiratory disorders (COPD, asthma, bronchiectasis, ARDS, pulmonary embolism, allergic conditions), immune-mediated diseases (rheumatoid arthritis, systemic lupus erythematosus, sarcoidosis), severe organ dysfunction, pregnancy or lactation, mental illness, cognitive impairment, or incomplete clinical data. All participants underwent contrast- enhanced chest CT on a 16-slice Toshiba Activion scanner. Non-ionic iodinated contrast (1.5– 2.0 mL/kg) was administered through an 18–20G intravenous cannula using a dual-head power injector at a rate of 3 mL/s, with imaging acquired during arterial (25–30 sec), portal venous (60–70 sec), and delayed (3–5 min) phases. Thin-section (≤1 mm) images were reconstructed in axial, coronal, and sagittal planes on PACS. CT scans were assessed for cavitation (count and maximum diameter), consolidation, tree-in-bud pattern, lower lobe predominance, bilateral involvement, pleural effusion, and lymphadenopathy, and each patient received a CT severity score (categorized as mild, moderate, or severe). Glycemic status was evaluated using hemoglobin A1c (HbA1c) well-controlled diabetes was defined as HbA1c <7% and poorly controlled diabetes as HbA1c ≥7%, with disease duration also documented. Clinical and imaging data were extracted from the hospital's Radiology Information System and electronic health records, and all information was anonymized to ensure patient confidentiality. The study complied with the ethical standards of the Ethical Committee of Superior University, Lahore. Written informed consent was secured from all participants, who were advised of their voluntary participation and their right to withdraw at any time without penalty. Statistical analysis was performed using SPSS version 25.0. Descriptive statistics (means ± standard deviations for continuous variables; frequencies and percentages for categorical variables) were calculated. Associations between diabetic status or glycemic control and CT severity scores were examined using the Pearson chi-square test, and linear-by-linear association analysis was used to evaluate dose-response trends. A p-value <0.05 was considered statistically significant.

Table 4.1: **Comparison of** Glycemic Control (HbA1c) vs. Duration of Diabetes, Cavity Diameter, and Number of Cavities**.**

Glycemic control (HBA1c level)	**Duration of Diabetes (years)**	**MAX. Cavity Diameter (cm)**	**NO. Of Cavities**	**Total**
Below 5.7 (non-diabetics)				**66**
	0-3 years: 56	0-3 cm: 50	0-2: 65	
	4-6 years: 3	3.1-6 cm: 16	3-4: 1	

	7-10 years: 4			
	11-14 years: 3			
Above 5.7 (diabetics)				**1**
	0-3 years: 1	0-3 cm: 0	0-2: 1	
	4-6 years: 0	3.1-6 cm: 1	3-4: 0	
	7-10 years: 0			
	11-14 years: 0			
5.7-7 (diabetic, good control)				**8**
	0-3 years: 6	0-3 cm: 4	0-2: 7	
	4-6 years: 2	3.1-6 cm: 4	3-4: 1	
	7-10 years: 0			
	11-14 years: 0			
7-10(diabetic,poor control)				**38**
	0-3 years: 16	0-3 cm: 25	0-2: 30	
	4-6 years: 5	3.1-6 cm: 13	3-4: 8	
	7-10 years: 11			
	11-14 years: 6			
Total	**113**	**113**	**113**	**113**

Table 4.1: Comparison of **Glycemic Control (HbA1c) vs. Duration of Diabetes, Cavity Diameter, and Number of Cavities**.

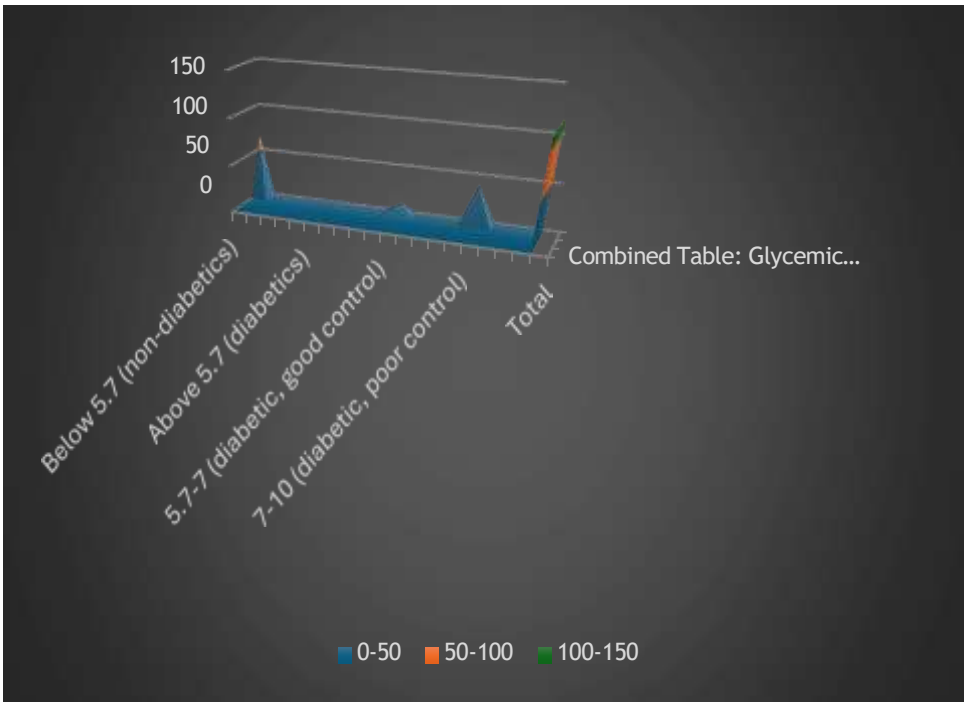


Table 4.2: Frequency of Lobe Involvement

Lobe Involvement	Below 5.7 (non-diabetics)	5.7–7 (Good Control)	7–10 (Poor Control)	Above 5.7 (other)	Total
Both lobes	**4**	**1**	**4**	**0**	**9**

Both lobes involved: 4 in poor control, 4 in non-diabetics, 1 in good control. No clear association with glycemic control.

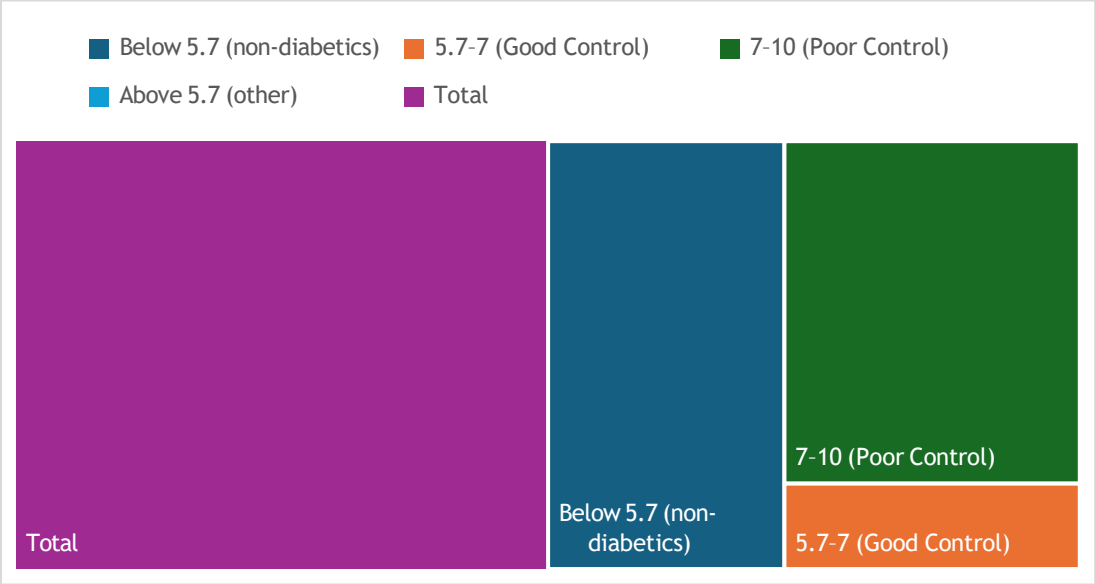


Table 4.3: Frequency of CT SEVERITY SCORE

CT Severity Scoring	N	%
0-5	25	21.7%
6-10	22	19.1%
11-15	44	38.3%
16-20	22	19.1%

The most common CT severity score range was 11-15 (38.3%, n=44), followed by 0-5 (21.7%, n=25). Scores of 6-10 and 16-20 each accounted for 19.1% (n=22). As shown in figure 4.9

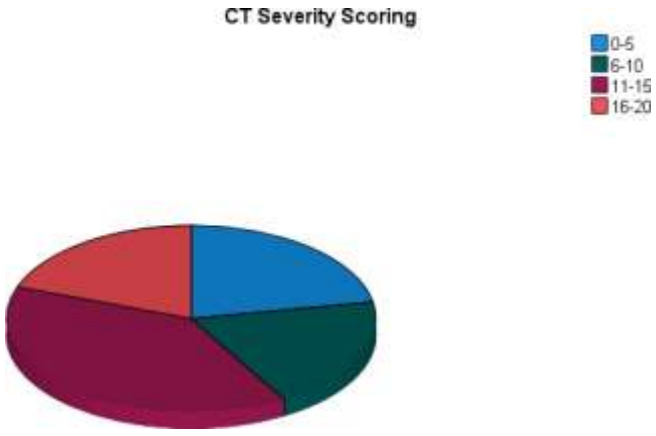


Table4.4: Frequency of Conditions

Radiological Finding	Diabetic (TB Yes = 88)	Non-Diabetic (TB No = 25)	Total
Bronchiectasis	74 (84.1%)	0 (0%)	74
Mediastinal Lymphadenopathy	51 (58.0%)	0 (0%)	51
Consolidation	71 (80.7%)	0 (0%)	71
Tree-in-bud score	46 (52.3%)	0 (0%)	46
Bilateral Disease	48 (54.5%)	0 (0%)	48
Pleural Effusion	26 (29.5%)	0 (0%)	26

All six radiological findings (bronchiectasis, consolidation, mediastinal lymphadenopathy, bilateral disease, tree-in-bud, and pleural effusion) were seen exclusively in diabetic patients (n=88), with zero cases in non-diabetics (n=25). Among diabetics, bronchiectasis (84.1%) and consolidation (80.7%) were most common, while pleural effusion (29.5%) was least common.

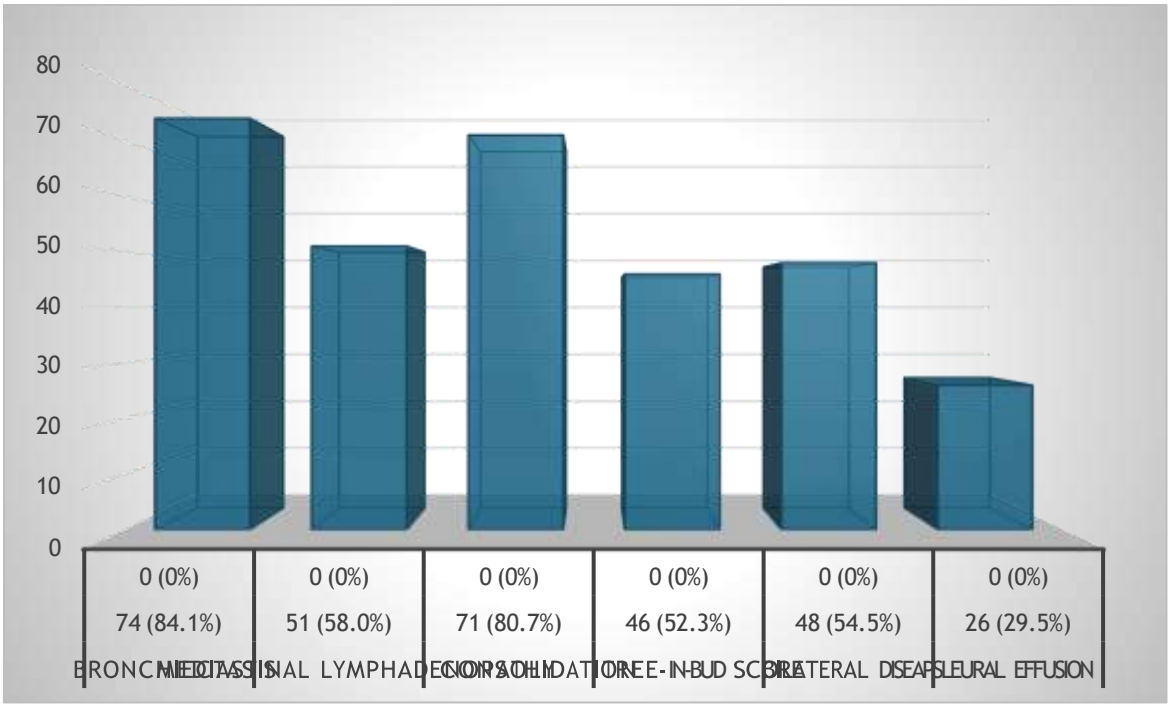


Table 4.11:

Glycemic control HB1AC level * CT Severity Scoring Crosstabulation

Glycemic control HB1AC level * CT Severity Scoring Crosstabulation

		CT Severity Scoring				
		0-5	6-10	11-15	16-20	Total
Glycemic control HB1AC level	below 5.7 non-diabetics	19	16	24	7	66
	above 5.7 diabetics	0	0	1	0	1
	5.7-7 diabetic but good glycemic control	0	1	4	3	8

	7-10 diabetic but poor glycemic control	6	5	15	12	38
Total		25	22	44	22	113

Table 10.12 shows that non-diabetics (n=66), CT severity scores were distributed across all ranges, with the highest proportion in the 11-15 range (n=24, 36.4%). In contrast, among poorly controlled diabetics (n=38), the 11-15 (n=15, 39.5%) and 16-20 (n=12, 31.6%) ranges were most common, indicating a trend toward higher severity scores. Well-controlled diabetics (n=8) showed scores predominantly in the 11-20 range (n=7, 87.5%).

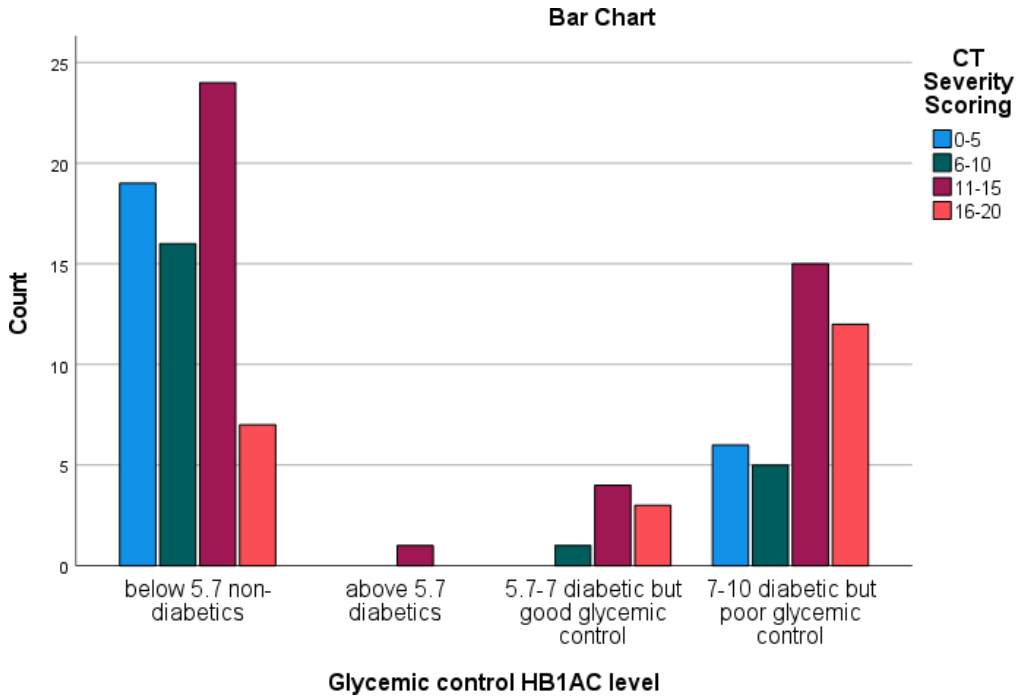


Table 4.12:

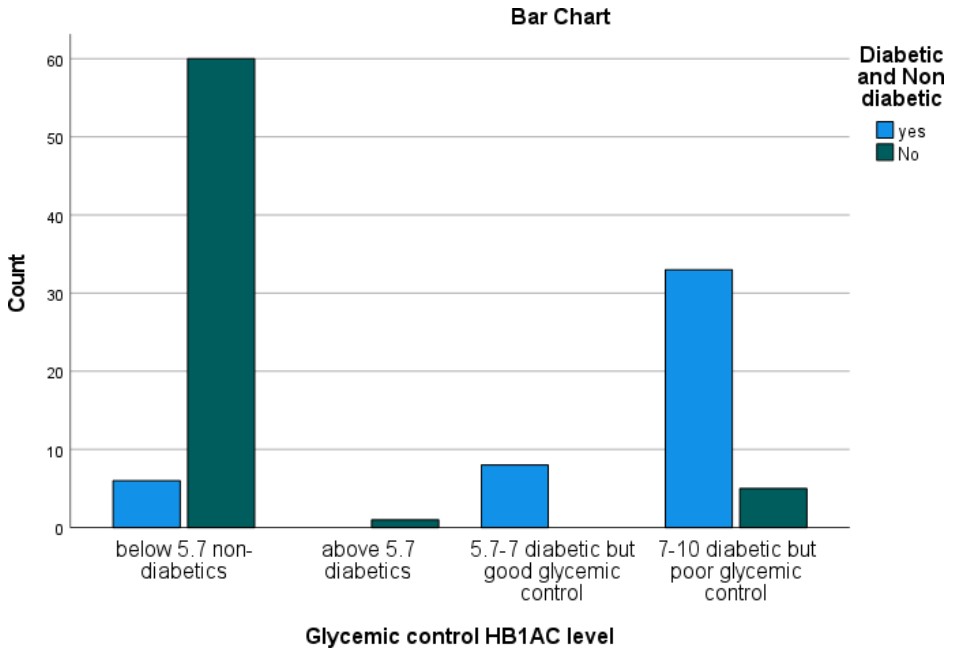
Glycemic control HB1AC level * Diabetic and Non diabetic Crosstabulation

Glycemic control HB1AC level * Diabetic and Non diabetic Crosstabulation

Diabetic and non-diabetic yes			No	Total
Glycemic control HB1AC level	below 5.7 non-diabetics	6	60	66
	above 5.7 diabetics	0	1	1
	5.7-7 diabetic but good glycemic control	8	0	8
	7-10 diabetic but poor glycemic control	33	5	38
	Total	47	66	113

Table 10.14 shows that 47 diabetic patients, the majority had poor glycemic control (HbA1c 7- 10%) (n=33, 70.2%), followed by good control (HbA1c 5.7-7%) (n=8, 17.0%). Among 66 non-

diabetic patients, 60 (90.9%) correctly had HbA1c below 5.7%, while 6 (9.1%) were misclassified as diabetic despite having HbA1c below 5.7%.



Correlations

Glycemic control HB1AC level				CT Severity Scoring
Spearman's rho	Glycemic control HB1AC level	Correlation Coefficient	1.000	.290**
		Sig. (2-tailed)	.	.002
		N	113	113
	CT Severity Scoring	Correlation Coefficient	.290**	1.000
		Sig. (2-tailed)	.002	.
		N	113	113

A Spearman's correlation analysis (N=113) revealed a significant positive relationship between HbA1c levels and CT severity scores ($\rho = 0.290$, $p = 0.002$). This indicates that poorer glycemic control is moderately associated with more extensive lung damage on CT imaging in patients with pulmonary tuberculosis

ANOVA Effect Sizes

		Point Estimate	95% Confidence Interval	
			Lower	Upper
Glycemic control	Eta-squared	.598	.481	.678

HB1AC level	Epsilon-squared	.594	.477	.675
	Omega-squared Fixed-effect	.592	.475	.673
	Omega-squared Random-effect	.592	.475	.673

The effect size measures (eta-squared = 0.598, epsilon-squared = 0.594, omega-squared = 0.592) all indicate a large association between HbA1c levels and CT severity scores. The 95% confidence intervals (ranging from approximately 0.48 to 0.68) confirm that this strong relationship is statistically reliable.

DISCUSSION

In this study of 113 pulmonary tuberculosis patients, diabetes was found in 41.6%, which is substantially higher than general population figures. Among diabetic patients, 68.7% had a diabetes duration of only 0–3 years, suggesting that tuberculosis may act as an early indicator of undiagnosed diabetes. Diabetic patients had significantly higher CT severity scores ($p = 0.004$), with 29.8% of diabetics showing severe scores (16–20) compared to only 12.1% of non-diabetics. Poor glycemic control was responsible for 80.0% of patients with 3–4 cavities, and a clear linear trend ($p = 0.003$) demonstrated that worse glycemic control leads to progressively increasing CT severity. However, the overall categorical relationship between glycemic control groups and CT severity did not reach statistical significance ($p = 0.111$), likely because most participants had short-standing diabetes, which may limit the impact of blood glucose variations on total disease burden. When individual CT features were analyzed separately, no notable differences were observed between well-controlled and poorly controlled groups for cavity presence ($p = 0.47$), consolidation ($p = 0.85$), lower lobe involvement ($p = 0.88$), bilateral disease ($p = 0.90$), or pleural effusion ($p = 0.67$). An unusual radiological pattern emerged, with lower lobe involvement (51.3%) being more common than upper lobe involvement (40.7%), differing from typical post-primary tuberculosis and indicating diabetes-related changes in disease distribution. The overall radiological disease burden was largely mild to moderate, with 89.6% of patients having 0–2 cavities and 68.7% showing a maximum cavity diameter of 0–3 mm. These findings align with recent literature from 2020–2025, which consistently shows that poor glycemic control worsens radiological features of pulmonary tuberculosis, particularly cavitary disease. Taken together, these results highlight the critical need for routine two-way screening for tuberculosis and diabetes at the time of TB diagnosis, as achieving good glycemic control may help reduce cavity burden, lower CT severity scores, and improve treatment outcomes.

CONCLUSION:

Diabetes mellitus is highly prevalent among pulmonary tuberculosis patients and is significantly associated with higher CT severity scores and increased cavitary burden. Poor glycemic control strongly correlates with multiple cavities, and a linear trend confirms that worse control leads to greater disease severity. Atypical lower lobe predominance suggests diabetes modifies TB radiological patterns. The short diabetes duration in most patients indicates TB may be a sentinel event for undiagnosed diabetes. These findings emphasize the urgent need for bidirectional screening and strict glycemic management.

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