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Diffusing capacity of the lung for carbon monoxide (dlco) Pattern in Old Treated Asymptomatic Cases of Drug Sensitive Pulmonary Tuberculosis and it's Correlation with Spirometry & 6 minute walk test.

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Abstract: *Introduction: Pulmonary function abnormalities may persist after completion of treatment for pulmonary tuberculosis, including in individuals without significant respiratory symptoms. This study evaluated pulmonary function and exercise capacity in asymptomatic individuals after completion of treatment for drug-sensitive pulmonary tuberculosis, with particular emphasis on diffusing capacity of the lung for carbon monoxide (DLCO).*
Methodology: This clinical study evaluated 45 recovered, asymptomatic cases who completed treatment for drug-sensitive pulmonary tuberculosis. Lung function was measured using standard spirometry, haemoglobin-corrected single-breath carbon monoxide diffusing capacity (DLCO), and a six-minute walk test (6mwt).
Results: Impaired DLCO was present in 75.6%(N=34) of the asymptomatic patients. Notably, 76.2%(N=16/21) of participants with entirely normal spirometry had reduced gas transfer, demonstrating that diffusion defects occur independently of mechanical airflow changes. Statistically, DLCO percentages correlated positively with both FEV 1 ($r=0.332$, $p=0.026$) and FVC ($r=0.295$, $p=0.049$), showing that a reduction in lung volumes also led to lower gas transfer efficiency. Furthermore, six-minute walk distances showed a strong positive correlation with DLCO levels ($r=0.729$, $p<0.001$), this signifies that decreased gas exchange also decreases the exercise tolerance.
Conclusion: DLCO is a sensitive marker that detects early lung membrane damage when standard spirometry tests appear normal. Combining DLCO and walk tests provides a reliable screening protocol to help guide early patient care and pulmonary rehabilitation.
Keywords: *diffuse lung capacity for carbon monoxide (dlco), functional capacity, post-tubercular lung disease, six minute walk test, spirometry*

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I. Introduction

Tuberculosis (TB) continues to be a major public health problem worldwide. Although modern antitubercular therapy achieves microbiological cure in a large proportion of patients, cure does not necessarily imply restoration of normal pulmonary structure or function. Survivors of pulmonary tuberculosis frequently continue to experience persistent respiratory abnormalities long after completion of treatment [1]. Recognition of these long-term consequences has led to the concept of post tuberculosis lung disease (PTLD). PTLD encompasses a spectrum of sequelae involving the lung parenchyma, airways, pleura and pulmonary vasculature, and may present as airflow obstruction, restrictive defects, impaired gas transfer, exercise limitation and reduced quality of life [2]. Post-infectious obliterative bronchiolitis (PIOB), a form of small airway disease, represents an important yet under-recognized component of post-tuberculosis lung disease. Therefore, pathogenesis of PTLD is multifactorial. Even after successful treatment, structural abnormalities like cavitation, fibrosis, bronchiectasis change, parenchymal destruction, small airway involvement and vascular remodeling may persist and translate into long-term functional impairment. Routine post-treatment follow-up has traditionally focused on bacteriological cure, treatment completion and radiological resolution. However, this approach may fail to identify a substantial proportion of patients who remain physiologically compromised despite apparent clinical recovery. This gap is particularly important in asymptomatic individuals, because absence of overt respiratory complaints does not exclude the presence of residual pulmonary damage. Spirometry is the most widely available pulmonary function test and remains the standard initial tool for assessment of ventilatory defects. ATS/ERS defines its role in identifying obstructive, restrictive and mixed ventilatory patterns [3]. However, spirometry primarily reflects mechanical abnormalities of airflow and lung volume; it does not detect abnormalities in alveolar-capillary gas transfer. Therefore, a patient with preserved spirometric

values may still have impairment at the level of gas exchange [4]. The diffusing capacity of the lung for carbon monoxide (DLCO) is a more sensitive physiological marker for assessing transfer of gas across the alveolar-capillary membrane. The 2017 ERS/ATS [5] describes the single-breath DLCO test as a standardized method for quantifying pulmonary gas transfer [4]. In post-TB patients, a low DLCO may reflect residual parenchymal scarring, destruction of the alveolar-capillary membrane or loss of effective alveolar volume, even when conventional spirometry is near normal [6,7]. Functional assessment is equally important because physiological impairment should be interpreted in the context of exercise capacity and day-to-day performance. The sixminute walk test (6MWT) is a simple, reproducible and clinically meaningful tool that assesses submaximal functional exercise capacity. The relationship between DLCO and 6MWT is especially relevant in PTLD. A patient may report minimal symptoms at rest, yet demonstrate reduced exercise performance because impaired gas transfer limits oxygen delivery during exertion. This discrepancy may be even more important in asymptomatic postTB patients, in whom physiological testing can unmask occult impairment and identify individuals who may benefit from counseling, follow-up and pulmonary rehabilitation [8,9]. In many centers, patients who are declared cured are not subjected to detailed functional assessment unless they are overtly symptomatic. Consequently, subtle but clinically relevant gas exchange impairment may be overlooked. India carries a substantial TB burden; there is a strong rationale for evaluating DLCO patterns in treated pulmonary tuberculosis and correlating them with spirometry and exercise capacity [1,5].

II. Materials And Methods

The study was conducted after obtaining permission from the Institutional Research Committee and the Institutional Ethics Committee of Dr. S. N. Medical College, Jodhpur.

Study place: Kamla Nehru Chest Hospital, Department of Respiratory Medicine, Dr. S. N. Medical College, Jodhpur, Rajasthan.

Study design: Observational study.

Study period: This study was conducted after approval from the Institutional Ethics Committee. Data collection, analysis, and write up of the report were done over a period of 6 months from November 2025April 2026.

Eligible asymptomatic patients who had completed six months of anti-tubercular treatment for drugsensitive pulmonary tuberculosis, willing to participate were traced through NIKSHAY ID from the NIKSHAY portal through which the patients received their anti tubercular treatment and from their recruited according to the predefined inclusion and exclusion criteria.

Sample size was calculated using the formula $N = (Z\alpha)^2 \times P(100-P) / E^2$, where $Z\alpha = 1.96$ at 95% confidence interval, P = expected proportion of old treated drug-sensitive pulmonary tuberculosis patients with abnormal DLCO, taken as 69% from the previous study conducted by Gupta et al. [6], and E = relative allowable error taken as 20% of P. This yielded a minimum sample size of 43, which was rounded off to 45.

The objectives and procedures of the study were explained to all participants in their preferred language, and written informed consent was obtained before enrollment after which history and physical examination was done followed by chest xray and sputum AFB if indicated then pulmonary function test : DLCO, spirometry and 6 minute walk test was performed.

The six-minute walk test (6MWT) was performed according to the standardized protocol described by Anne E
Holland et al. in the European Respiratory Journal (ERS/ATS Technical Standard) [10]. the grading used in 6MWT are BORG scale [11] and mMRC grading [12].

Inclusion criteria:

Age ≥18 years and <59 years.

Asymptomatic patients or patients with mMRC grade 0 or 1; who were established cases of pulmonary tuberculosis at the time of initiation of treatment.

Patients who had completed treatment for drug-sensitive pulmonary tuberculosis and had been declared cured.

Patients willing to participate and provide written informed consent.

Exclusion criteria:

Active pulmonary tuberculosis, relapse of pulmonary tuberculosis, or patients treated inadequately or incompletely for anti-tubercular therapy.

History of extra-pulmonary tuberculosis.

Patients with poor efforts to do DLCO, spirometry or 6MWT.

Patients with contraindications to spirometry, DLCO testing or six-minute walk test.

Study design:

Asymptomatic old treated patients who completed 6 months of anti-tubercular treatment for drug susceptible pulmonary tuberculosis

↓

History and physical examination

↓

Sputum AFB & CXR (PA view), if indicated

↓

Pulmonary function tests: DLCO, Spirometry & 6MWT

↓

CBC with haemoglobin
↓
Data collection and tabulation
↓
Statistical analysis and conclusion

STATISTICAL ANALYSIS
Continuous data was represented as mean ± S.D. or median with 25th-75th quartiles. Categorical data was presented by numbers and percentage. Pearson and Spearman tests were used for correlation. Categorical data was compared by the Pearson Chi-square test and median was compared with Mann-Whitney U test. P value less than 0.05 is considered significant.

III. Results

The study population in table *1* consisted predominantly of males (88.9% N=40) and participants from rural areas (80.0% N=36). Regarding the history of anti-tubercular treatment (ATT), the highest proportion of participants had completed ATT 1 year and 2 years prior to evaluation (26.7% each N=12), while the lowest proportion had completed ATT 4 years earlier (4.4% N=2).

Variable	Category	Frequency	Percentage (%)
Gender	Male	40	88.9
	Female 5	11.1	
Locality	Rural	36	80.0
	Urban 9	20.0	
Years Since ATT	<1 year	7	15.6
	1 year 12	26.7	
	2 years	12	26.7
	3 years 7	15.6	
	4 years	2	4.4
	5 years 5	11.1	

TABLE 1: STUDY POPULATION DISTRIBUTION AS PER GENDER, LOCALITY AND YEARS SINCE ANTI TUBERCULAR TREATMENT.

ATT- Anti tubercular treatment
In Figure *1*. Flow diagram showing DLCO distribution among participants with normal and abnormal spirometry. Impaired DLCO was therefore seen in both spirometrically normal and spirometrically abnormal participants in approximately equal number of patients.

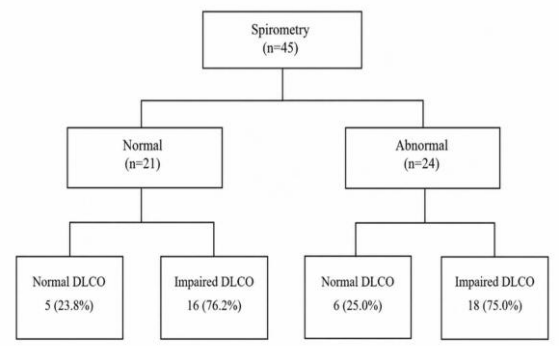

FIGURE 1: Flow diagram showing DLCO distribution among participants with normal and abnormal spirometry.
DLCO- diffusing capacity of lung for carbon monoxide

The mean DLCO % predicted in the study population was 65.76 ± 17.07 and the mean haemoglobin corrected DLCO % predicted was 66.01 ± 16.80; Table2. On paired t-test analysis, the difference between the two values was not statistically significant (p = 0.580). This suggests that haemoglobin correction produced only a modest overall change in DLCO % predicted.

Statistic	DLCO (% Predicted)	Corrected DLCO (% Predicted)
Mean ± SD	65.76 ± 17.07	66.01 ± 16.80
p value (paired t test)	0.580	

TABLE 2: COMPARISON BETWEEN DLCO (% PREDICTED) AND HAEMOGLOBIN CORRECTED DLCO (% PREDICTED) IN THE STUDY POPULATION

Variable compared with DLCO % predicted	Pearson correlation coefficient (r)	p value
FEV1/FVC	-0.126	0.409
FVC % predicted	0.295	0.049
FEV1 % predicted	0.332	0.026

TABLE 3: CORRELATION BETWEEN DLCO AND SPIROMETRIC VARIABLES

FEV1- FORCED EXPIRATORY VOLUME IN 1ST SECOND
FVC- FORCED VITAL CAPACITY
On correlation analysis (TABLE *3*)(figure2) , DLCO % predicted showed a weak negative correlation with FEV1/FVC (r = -0.126, p = 0.409). DLCO % predicted showed a positive correlation with FVC % predicted (r = 0.295, p = 0.049) and with FEV1 % predicted (r = 0.332, p = 0.026). The correlations with FVC and FEV1 were significant, indicating that better spirometric function tended to be associated with better diffusing capacity. Thus, higher lung volumes and expiratory flow were associated with better gas-transfer capacity, whereas FEV1/FVC showed no significant relationship with DLCO, suggesting that diffusion impairment is not solely dependent on airflow obstruction but also reflects parenchymal and vascular components of lung injury.

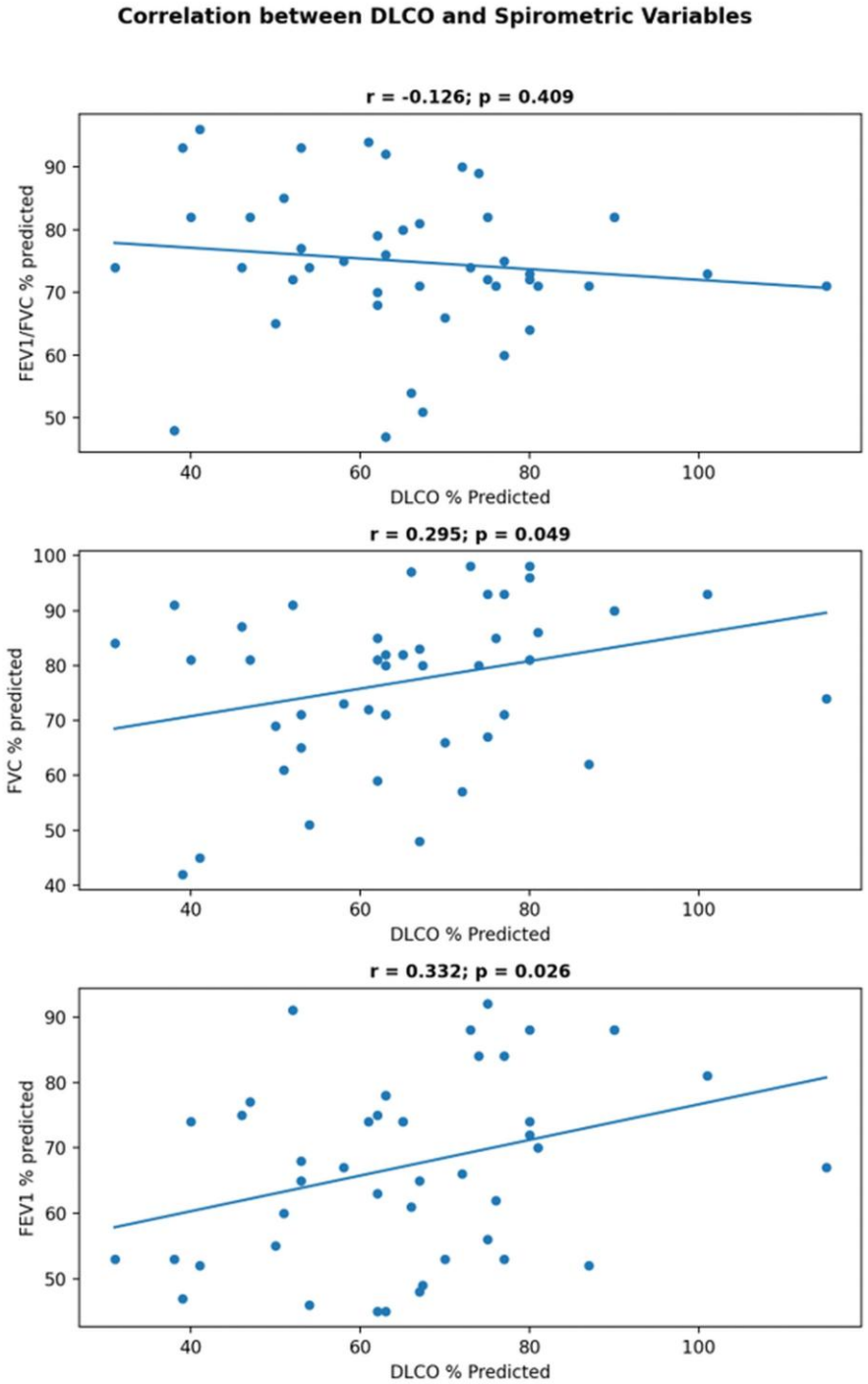

FIGURE 2: Scatter plots showing correlation between DLCO % predicted and spirometric variables (FEV1/FVC, FVC and FEV1).

In Table *4*, patients with normal DLCO had a higher mean 6MWT distance (468.2 m) compared with those with impaired DLCO (392.6 m). This indicates that impaired DLCO was associated with reduced functional exercise capacity, with the difference being statistically significant ($p < 0.001$). The median 6MWD was 450.0 m in participants with normal DLCO and 400.0 m in participants with impaired DLCO. Mann-Whitney U test (in figure *3*.) showed p = <0.001, therefore the difference in 6MWT distance between normal and impaired DLCO groups was significant.

Group	n	Mean ± SD	Median	IQR
NORMAL	11	468.2 ± 25.2	450.0	450.0–500.0
IMPAIRED	34	392.6 ± 35.1	400.0	400.0–400.0

TABLE 4: COMPARISON OF 6MWT DISTANCE WITH DLCO STATUS

SD- standard deviation
IQR - inter quartile range

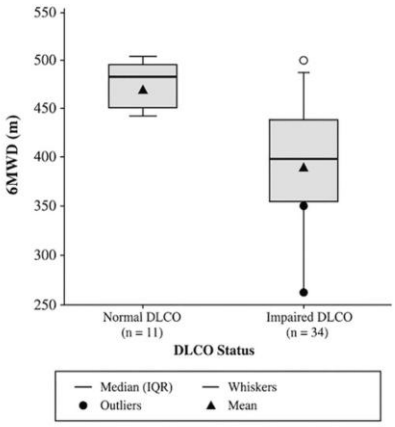

FIGURE 3: The median 6MWD was 450.0 m in participants with normal DLCO and 400.0 m in participants with impaired DLCO.

6MWD- 6 minutes walk distance

As per Table *5*, the 6-minute walk distance showed a positive correlation with DLCO % predicted (r = 0.729, p = <0.001) and with hemoglobin corrected DLCO % predicted (r = 0.718, p = <0.001). This indicates that participants with better diffusing capacity tended to achieve better exercise performance on the 6-minute walk test.

Pulmonary variable	6MWT variable	Pearson r	p value
DLCO % predicted	6MWD (m)	0.729	<0.001
DLCO % predicted	6MWD % predicted	0.806	<0.001
Corrected DLCO % predicted	6MWD (m)	0.718	<0.001
Corrected DLCO % predicted	6MWD % predicted	0.816	<0.001

TABLE 5: RELATIONSHIP OF 6-MINUTE WALK TEST WITH DLCO AND CORRECTED DLCO

The mean 6MWT (in table *6*) distance was similar in patients with normal and abnormal spirometry (416.7 m vs. 406.2 m), with both groups having a median distance of 400 m. Thus, 6MWT performance did not differ significantly according to spirometry status (p = 0.656). The box plot shows (figure *4*) the median 6MWT distance was similar in patients with normal and abnormal spirometry (400 m in both groups).

Group	n	Mean ± SD	Median	IQR
NORMAL	21	416.7 ± 42.8	400.0	400.0–450.0
ABNORMAL	24	406.2 ± 49.6	400.0	400.0–412.5

TABLE 6: COMPARISON OF 6MWT DISTANCE WITH SPIROMETRY STATUS

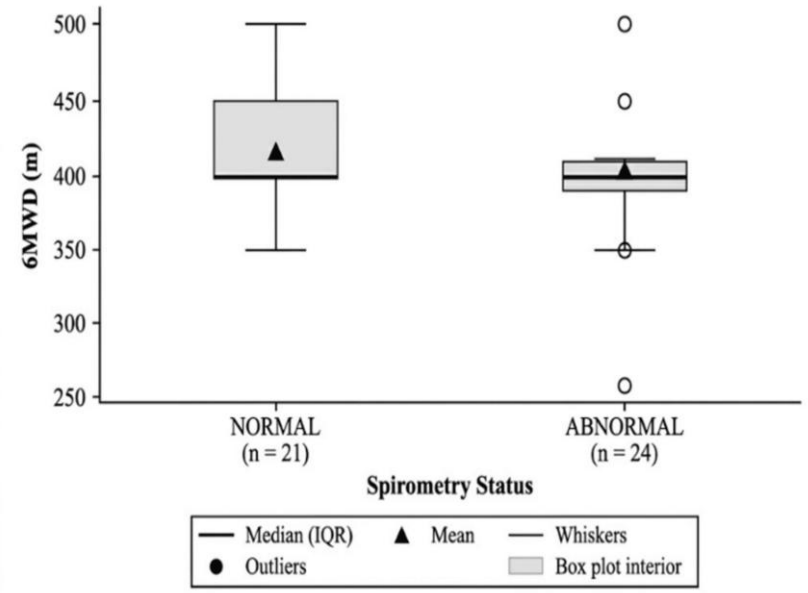

FIGURE 4: The median 6MWD was 400.0 m in participants with normal spirometry and 400.0 m in participants with abnormal spirometry. (p = 0.656,not significant).

Comparison of 6MWT distance with history of ATT (years since treatment) was seen in table *7*, in which the mean 6MWT distance was highest in patients 1 year after treatment (433.3 m) and lowest in those 5 years after treatment (370.0 m). Overall, 6MWT distance tended to decrease as the time since completion of ATT increased, suggesting a decline in functional exercise capacity over time. Spearman (in figure *5*.) correlation between 6MWD and past history of ATT showed rho = -0.381, p = 0.010. This indicates that 6MWD tended to decrease as the number of years since Anti-tubercular treatment increased.

Group	n	Mean ± SD	Median	IQR
<1 yr	7	421.4 ± 26.7	400.0	400.0–450.0
1 yr	12	433.3 ± 44.4	400.0	400.0–462.5
2 yrs	12	412.5 ± 48.3	400.0	400.0–412.5
3 yrs	7	392.9 ± 18.9	400.0	400.0–400.0
4 yrs	2	400.0 ± 0.0	400.0	400.0–400.0
5 yrs	5	370.0 ± 75.8	400.0	350.0–400.0

TABLE 7: COMPARISON OF 6MWT DISTANCE WITH HISTORY OF ATT (YEARS SINCE TREATMENT)

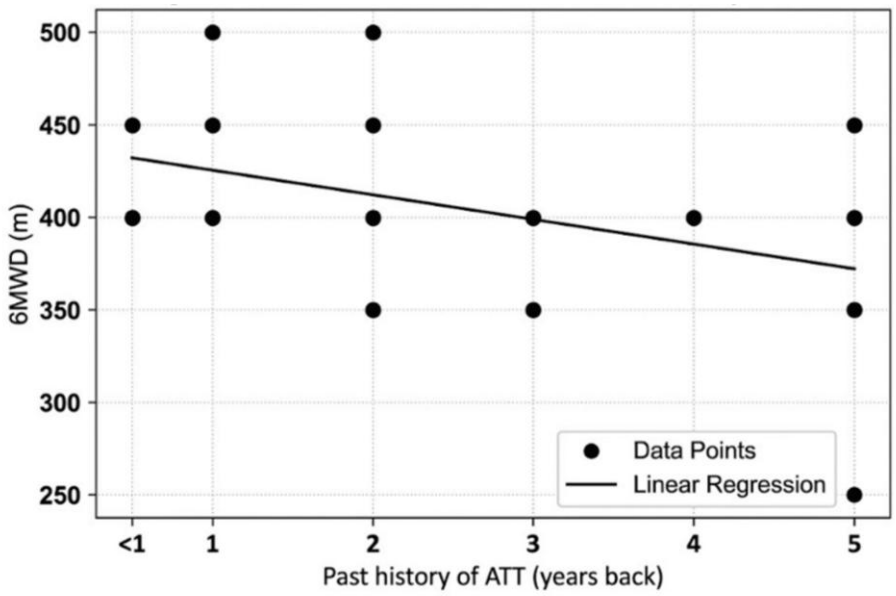

FIGURE 5: COMPARISON OF 6MWT DISTANCE WITH HISTORY OF ATT (YEARS SINCE TREATMENT)

In this study population, 6MWT distance showed DLCO status: significant (p = <0.001); spirometry status: not significant (p = 0.656); past history of ATT: significant (p = 0.010). Thus, 6MWT was significantly lower in the impaired DLCO group, was not significantly different between normal and abnormal spirometry groups, and showed a significant negative correlation with past history of ATT on Spearman analysis.

IV. Discussion

This observational study was conducted at Kamla Nehru Chest Hospital, Dr. S.N. Medical College, Jodhpur, Rajasthan, to evaluate the pattern of diffusing capacity of the lung for carbon monoxide (DLCO) in old treated asymptomatic patients with drug-sensitive pulmonary tuberculosis, and to assess its correlation with spirometry and six-minute walk test (6MWT). The study specifically focused on individuals who were either asymptomatic or had minimal symptoms (mMRC grade 0 or 1), thereby aiming to identify subclinical pulmonary impairment in post-tuberculosis lung disease (PTLD).

Key observation in this study was that a substantial proportion of patients with normal spirometry exhibited impaired DLCO. Mohan Bandhu Gupta et al [7]. reported that more than half of patients with normal spirometry had reduced DLCO, emphasizing its sensitivity. Similarly, Byrne et al. [13] and Nidhi Bansal et al.

[14] reported a high prevalence of DLCO impairment in post-TB patients.

The mean DLCO % predicted in this study was approximately 65.76%, indicating moderate impairment of gas transfer [4]. Notably, correction for hemoglobin did not significantly alter DLCO values, suggesting that the observed impairment was primarily due to structural lung damage rather than hematological factors.The presence of impaired DLCO in patients with normal spirometry can be explained by involvement of the alveolar-capillary membrane and small airways. This is particularly relevant in the context of postinfectious obliterative bronchiolitis (PIOB)[15], a recognized component of PTLD. Patro et al. [16] have highlighted that PIOB following tuberculosis can lead to significant physiological impairment even when spirometry appears normal. Furthermore, structural abnormalities such as fibrosis, vascular remodelling, and loss of alveolar surface area contribute to reduced DLCO [17]. These mechanisms have been described in studies by Kiryukhina et al. [18] and Nishi et al. [8], which demonstrated that diffusion impairment reflects a combination of alveolar-capillary damage and ventilation inhomogeneity.

Correlation analysis in this study demonstrated a significant positive relationship between DLCO % predicted and both FEV1 % predicted (r = 0.332, p = 0.026) and FVC % predicted (r = 0.295, p = 0.049). This indicates that better spirometric function is associated with better gas transfer capacity. Similar correlations have been reported in previous studies, including Nishi et al. [8], where DLCO correlated with spirometric indices and exercise capacity. However, no significant correlation was observed between DLCO and FEV1/FVC ratio, suggesting that diffusion impairment is not solely dependent on airflow obstruction but also reflects parenchymal and vascular components of lung injury.

Another important finding of this study was the association between DLCO impairment and duration since anti-tubercular therapy. A higher proportion of patients with longer duration since treatment (≥2 years) had abnormal DLCO. This suggests that structural lung damage may persist or even progress over time despite microbiological cure. Similar observations have been made by Sreekaanth et al. [19], who demonstrated that delayed diagnosis and longer disease duration are associated with greater functional impairment.The persistence of diffusion abnormalities over time highlights the chronic nature of PTLD and underscores the need for long-term follow-up of treated TB patients.

The clinical relevance of DLCO becomes more evident when interpreted alongside functional capacity. Even asymptomatic patients may demonstrate reduced exercise capacity due to impaired oxygen transfer during exertion. This supports the use of combined physiological assessment, including DLCO and 6MWT, in evaluating post-TB patients.

Previous studies, including Nishi et al. [8], have demonstrated a significant correlation between reduced DLCO and decreased 6MWT performance. This relationship between DLCO and functional capacity supports the concept that diffusion abnormalities can precede overt clinical limitation. Patients with reduced DLCO may have preserved spirometry yet demonstrate early functional compromise during exertion. This finding reinforces the importance of using DLCO and 6MWT together for comprehensive evaluation.Pulmonary rehabilitation has emerged as a key intervention in PTLD. Studies such as Silva et al. [9] have demonstrated improvement in DLCO and exercise capacity following rehabilitation programs.

V. Conclusion

The study demonstrates that a substantial proportion of old treated drug-sensitive pulmonary tuberculosis patients exhibit impaired diffusing capacity (DLCO), despite having normal or near-normal spirometric parameters. This highlights that conventional spirometry alone may not be sufficient to detect early or subtle pulmonary impairment.

The study also demonstrates that reduced DLCO is associated with decreased functional exercise capacity as assessed by the six-minute walk test, emphasizing the clinical relevance of diffusion impairment even in asymptomatic individuals. Early identification of such impairments may facilitate timely interventions, including pulmonary rehabilitation, lifestyle modification, and regular follow-up.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Arti Gupta, Chaina Ram Choudhary, Kshitiz bansal

Acquisition, analysis, or interpretation of data: Arti Gupta

Drafting of the manuscript: Arti Gupta

Critical review of the manuscript for important intellectual content: Arti Gupta, Chaina Ram Choudhary, Kshitiz bansal

Supervision: Chaina Ram Choudhary

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Dr. SNMC IEC issued approval SNMC/IEC/2026/3346-47. ethical clearance taken from institutional ethics committee. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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