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Clinical and Radiological Profile of Pulmonary Tuberculosis Among Patients Having Occupational Exposure to Silica Dust: An Observational Study

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Abstract

Background: Silicotuberculosis, a condition where tuberculosis develops as a complication of silicosis, is a critical public health concern, particularly prevalent in low- and middle-income countries where prolonged exposure to crystalline silica particles is widespread. This dual impact amplifies the complexity of managing these conditions, posing significant challenges for healthcare systems. By leveraging a combination of radiographic techniques and clinical expertise, healthcare providers can optimize the diagnostic process, enabling timely intervention and improving outcomes for individuals affected by silicosis-associated tuberculosis.

Material & Methods: A hospital-based prospective observational study was done over 18 months with 65 TB patients having occupational exposure to silica dust, who have met the inclusion and exclusion criteria, were included in the study. A detailed demographic, occupational and clinical history were recorded for these patients and all were subjected to chest x-ray imaging to assess their radiological profile.

Results: Among the TB patients with occupational silica dust exposure, the mean age of distribution was 43.56 ± 12.5 years with a greater number of patients between the 31 to 40-year age group (32.3%), males more in proportion (97%) with more population from a rural background (95.4%), about 62% study population belongs to upper lower socioeconomic status. The most common type of occupational exposure was seen in stone drilling (32.3%) and a majority of the patients (47.6%) had duration of exposure >10 years. The most common symptoms experienced by these patients were cough (96.9%) along with fever (90.8%), and shortness of breath (90.8%). Among the clinical signs, pallor (43.1%) and pedal edema (32.3%) were predominantly exhibited by these patients. Among the study population, most patients predominantly exhibit bilateral lung disease (92.3%), with a significant proportion having cavitary disease (60%). Moderate and far advanced disease was more common (46.1% moderate and 43.1% far advanced) in these patients.

Conclusion: A comprehensive, multifaceted approach is needed to better manage TB in the context of occupational silica exposure, which includes active surveillance for early TB detection in individuals with silicosis, and the development of enhanced diagnostic methods.

Keywords: Tuberculosis, Silicotuberculosis, Occupational silica dust exposure.

Introduction

Silicotuberculosis, a condition in which tuberculosis develops as a complication of silicosis, is a significant public health issue, especially in low- and middle-income countries where prolonged exposure to crystalline silica particles is common.[1] This exposure occurs when workers inhale tiny respirable crystalline silica (RCS) particles, typically ranging in size from 5 to 10 microns, which are released

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during activities like mining, quarrying, sandblasting, and construction work involving cutting or drilling into rock or concrete. The most common form of crystalline silica is quartz which is abundantly present in granite, slate, and sandstone.[2] The chronic inhalation exposure of silica dust heightens the vulnerability of workers to tuberculosis infection, exacerbating the already substantial burden of both diseases.[3] This dual impact amplifies the complexity of managing these conditions, posing significant challenges for healthcare systems.[4] The global agencies such as the World Health Organization (WHO) and the International Labor Organization (ILO) are running public awareness and prevention programs to eliminate silicosis from the world by 2030. But because of common symptoms like cough, dyspnea, excessive expectoration, and chest pains between silicosis and TB as often hinder the diagnosis of TB in silicosis patients. Therefore, comprehensive knowledge of clinical symptoms, prevention, treatment, and diagnosis is needed to reduce the burden of silico-TB.[5] Efforts to address silicotuberculosis necessitate a multifaceted approach, encompassing robust workplace regulations to limit silica exposure, enhanced tuberculosis screening protocols tailored to high-risk populations, and improved diagnostic tools capable of differentiating between silicosis and tuberculosis accurately.[6] The utility of chest X-rays extends beyond mere detection, as they enable healthcare providers to identify tuberculosis lesions in silicosis patients at an incipient stage, facilitating timely intervention and potentially averting disease progression.[7] Given the insidious nature of tuberculosis in this population, where symptoms may not be readily apparent, the proactive use of regular radiographic screening emerges as a more effective strategy compared to relying solely on sputum examination for early tuberculosis detection.[8] Chest radiograph and smear examination are crucial for diagnosing pulmonary tuberculosis in patients with silicosis, serving as the cornerstone of the diagnostic process.[9] By leveraging a combination of radiographic techniques and clinical expertise, healthcare providers can optimize the diagnostic process, enabling timely intervention and improving outcomes for individuals affected by silicosis- associated tuberculosis.[10]

Methods

It was aimed to study the clinical and radiological profile of pulmonary tuberculosis among patients having occupational exposure to silica dust. After getting approval from the Institute's Ethical Committee, ensuring adherence to ethical standards and guidelines, it was carried out at our centre under National Tuberculosis Elimination Programme (NTEP) among pulmonary TB attending either inpatient or outpatient basis in the department. It was a prospective and observational type study with a study period from January 2023 to July 2024 (18 months) with a study population of 65 patients.

Inclusion Criteria

- Patients of pulmonary tuberculosis having occupational exposure to silica dust.

Exclusion Criteria

- Patients of pulmonary TB without occupational exposure to silica dust and not willing to participate in the study.
- Patients with extrapulmonary TB were excluded from the study.

Data Collection

The patients were carefully identified and included based on their dual diagnosis. The patient's demographic details documented were age and sex. The patients were classified into rural and urban populations based on the following 2021 census definition. The socio-economic status was assessed by the Modified Kuppuswamy scale. The occupational history provided by the patient was – location of occupational work, nature of work, type of dust exposure, duration of exposure to silica dust, etc. A detailed clinical history included a systemic recording of general symptoms i.e. weakness, fever, weight loss, etc., and respiratory symptoms i.e. cough, expectoration, chest pain, breathlessness, hemoptysis, etc. The history of previous anti-tubercular (ATT) drug treatments was recorded to distinguish between relapse and new cases. All study participants were subjected to a skiagram chest postero-anterior view at our department using the KONICA MINOLTA REGIUS E II machine using a standard protocol. An X-ray film automatic processor "Fuji Film Dry Pix Plus" was the device used. 28 X 17 inches view box with a high brightness of more than 4000 lux was used. A classic-style magnifier 3" precision-ground glass convex magnifies lens objects to 5X with minimal distortion was used. The abnormalities observed on the chest radiographs were recorded in the patient data form as a site of the disease - unilateral/ bilateral involvement, type of the disease- cavitary/non-cavitary disease and extent of disease severity classified as – minimal disease/moderate disease/far advanced disease. They were also assessed for the evaluation of other abnormalities like pleural effusion, pneumothorax, hilar enlargement, etc.

Data Analysis

The data collected was input into MS Excel, and statistical analysis was performed using IBM's Statistical Package for Social Sciences (SPSS) software version 23 (2015).

Results

A total of 65 patients were examined. The mean age of distribution in the patients was 43.56 ± 12.5 years and the median was 42 years within a range of 23 to 77 years. More number of patients were between the 31 to 40-year age group (n = 21, 32.3%) then between 41 to 50 years age group (n-19, 29.3%) then between 51 to 60 years age group (n = 13, 20%) then between 21 to 30 years age group (n = 7, 10.7%). 3 patients (4.6 %) were between the 61 to 70-year age group and 2 patients (3.1%) were >70 years while no patients were of age <20 years (Table 1). Gender distribution in the study population showed males were more in proportion (97%, n = 63) as compared to females (3%, n = 2) with

p-value <0.05. Among the study population, more patients were from rural backgrounds (n = 62, 95.4%) as compared to urban (n = 3, 4.6%). Among the study population, more proportion of patients were of upper lower socioeconomic class (n = 40, 62%) and 38% of patients (n = 25) were of lower socioeconomic class as per the modified Kuppuswamy scale. The most common type of exposure among TB patients with occupational silica dust exposure was stone drilling (32.3%) and then stone cutting (23.1%). Well-digging was also seen in 9 patients (13.5%), while stone grinding (12.4%), stone blasting (10.7%) and stone crushing (7.7%) were also observed in lesser proportions (Figure 1). Among the study population, the majority of the patients had a duration of exposure of >10 years (47.6%, n = 31). 29.3% (n = 19) patients had a duration of exposure between 6 to 10 years and 23.1% (n = 15) patients had a duration of exposure of ≤5 years.

Among the TB patients with occupational silica dust exposure, 36 patients (55.4%) had a history of previous TB treatment. Out of 36 patients, 23 patients (63.8%) had taken the ATT course 1 time, and 13 patients (36.2%) had taken the course ≥2 times in the past and about 75% of patients (n = 27) had completed at least 6 months of ATT, while 25% patients (n = 9) had completed ATT for at least 9 months duration in the past (Table 2).

Among the study population, the most common symptom experienced was cough (n = 63, 96.9%) along with fever (n = 59, 90.8%) and shortness of breath (n = 59, 90.8%). Chest pain (n = 55, 84.6%), weight loss (n = 44, 67.7%) and body aches (n = 37, 56.9) are also frequently reported. Less common symptoms include anorexia (n = 22, 33.8%) and blood in sputum (n = 5, 7.7%) (Table 3).

Also, among the study population, most patients exhibit pallor (n = 28, 43.1%) and pedal edema (n = 21, 32.3%), suggesting these are the more common clinical signs in this population. Rare signs include clubbing (n = 1, 1.5%). Notably, several potential signs like icterus, cyanosis, raised JVP, and lymphadenopathy were absent in these patients (Table 4). Among the study population, most patients predominantly exhibit bilateral lung disease (n = 60, 92.3%), with a significant proportion having cavitary disease (n = 39, 60%). Moderate and far advanced disease was more common (n = 30, 46.1% moderate and n = 28, 43.1% far advanced),

Table 1: Distribution of TB patients with occupational exposure to silica dust according to age group

Age range (in years)	*Tb patients with silica exposure*	
	Number	*Percent (%)*
<20	0	0
21–30	7	10.7
31–40	21	32.3
41–50	19	29.3
51–60	13	20
61–70	3	4.6
>70	2	3.1
Total	65	100
Mean ± SD (in years)	43.56 ± 12.5	
Median (Range) (in years)	42 (23-77)	

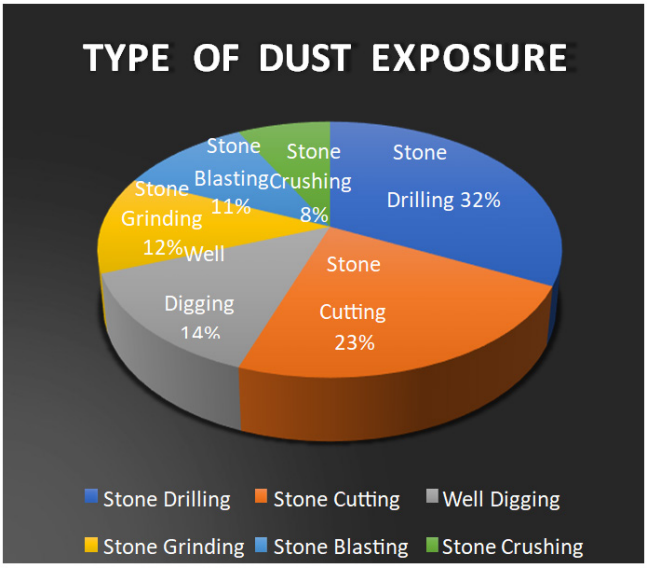

Figure 1: Pie chart showing the distribution of type of dust exposure among TB patients with silica dust exposure

Table 2: Description of past anti-tubercular treatment (ATT) among TB patients with occupational exposure to silica dust

	Parameter	*TB patients with silica exposure*	
		Number	*Percent (%)*
Past history of ATT	Present	36	55.4
	Absent	29	44.6
Number of ATT courses	1	23	63.8
	≥ 2	13	36.2
In past	At least 6	27	75
Duration of past ATT course	months		
	At least 9 months	9	25

Table 3: Clinical profile among TB patients with occupational exposure to silica dust

Clinical profile	*Frequency of symptoms*	*Percent*
Fever	59	90.8
Bodyache	37	56.9
Weight loss	44	67.7
Anorexia	22	33.8
Cough	63	96.9
Expectoration	55	84.6
Shortness of breath	59	90.8
Chest pain	55	84.6
Blood in sputum	5	7.7

Table 4: Distribution of clinical signs among TB patients with occupational exposure to silica dust

Clinical signs	*Frequency*	*Percent*
Pallor	28	43.1
Pedal edema	21	32.3
Clubbing	1	1.5
Icterus	0	0
Cyanosis	0	0
Raised JVP	0	0
Lymphadenopathy	0	0

indicating significant disease progression in such patients. While complications such as pleural effusion (n = 2, 3.1%), pneumothorax (n = 5, 7.7%), pleural thickening (n = 5, 7.7%) and progressive massive fibrosis (n = 27, 41.5%) are also notable. Enlarged calcified hilar lymph nodes were observed in about a quarter of the patients (n = 16, 24.6%), highlighting the involvement of hilar lymph nodes (Table 5).

Discussion

The present study reveals that the mean age of distribution of TB patients with occupational silica exposure was 43.56 ± 12.5 years (median age of 42 years) within a range of 23 years to 77 years. Males were more in proportion (97%) than the females (3%) with *p-value* < 0.05, suggesting silicotuberculosis more significantly affects males. According to ICMR Annual Report 2022-2023[11] the mean age of mine/quarries workers with TB working in the sandstone belt of Jodhpur, Rajasthan in Western India was 36.44 ± 11.23 years and observed male: female ratio of 332:3. Rajavel *et al.*,[12] reported the mean age of mine workers 39.13 ± 11.09 years with three workers aged 18 years and nine workers elderly and among 174 study patients, 128 (73.6%) were males and 46 (26.4%) were females. Tyagi *et al.*[13] reported mean age of the workers was 40.7 years within a range of 15 to 84 years. Almost 28.6% of workers were below the age of 30 years. Rupani *et al.*[14] also report the median age of 42 years within a range of 30 years to 55 years among 2748 TB patients with silicosis and among them 66% were males and 34% were females in Khambhat block in western India. Thus, these observations suggest that the age group from 20 years to 60 years is more involved in activities like mining, stone crushing, and well digging making them more prone to silica dust exposure at an early age and are more commonly prone to silicotuberculosis. The occurrence of silicotuberculosis in males as compared to females probably reflects the gender inequality in silica dust-related occupations like mining, stone drilling, well digging, etc. as it requires manual work with power and strength for which females are less preferred.

Table 5: Distribution of radiological profile among TB patients with occupational exposure to silica dust

Chest x ray abnormalities		*TB patients with silica exosure (group a) (n = 65)*	
		Number	*Percent*
Site of the disease	Unilateral disease	5	7.6
	Bilateral disease	60	92.3
Type of the disease	Cavitary disease	39	60
	Non-cavitary disease	26	40
Extent of the disease	Minimal disease	7	10.8
	Moderate disease	30	46.1
	Far advanced	28	43.1
Others	Pleural effusion	2	3.1
	Pneumothorax	5	7.7
	Enlarged calcified hilar lymph nodes	16	24.6
	Pleural thickening	5	7.7
	Progressive massive fibrosis	27	41.5

In the present study, TB patients with occupational silica dust exposure more population belong to rural (95.4%) backgrounds compared to urban (4.6%). According to socioeconomic status as per the modified Kuppuswamy scale, more proportion of patients were from upper lower socioeconomic class (62%) and 38% belonged to lower socioeconomic class. The most common type of occupational exposure in the TB patients exposed to silica dust was stone drilling (32.3%) followed by stone cutting (23.1%), well digging (13.5%), stone grinding (12.4%), stone blasting (10.7%) and stone crushing (7.7%). The majority of TB patients with occupational silica dust exposure (47.6%) had been exposed for more than 10 years. Out of 29.3% of patients had 6 to 10 years duration of exposure and 23.1% of patients had ≤5 years of duration of exposure in 23.1%. In a study conducted by Rajavel *et al.*[12] on 174 patients over 167 patients (96%) had worked 8 hours per day in a mine, with a mean of 7.09 (SD = 1.42) hours per day, ranging from 2 to 12 hours. The study also found that the majority (94.5%) of male workers were involved in stone cutting, drilling, or both, while most female workers (93.4%) were engaged in loading stones, cleaning stone waste, or both. Additionally, nearly half (49.4%) of the workers were illiterate, and 82.2% came from lower or lower-middle socioeconomic backgrounds. Thus, these observations suggest that the majority of patients worked in highly silica dust-exposed environments, such as stone drilling, stone cutting, well digging, stone blasting, crushing, and related activities which are more common in rural settings and largely involve male workers. The workers having occupational silica dust exposure belong mainly to the lower or upper socioeconomic class reflecting poor living standards, lack of proper education, etc., forcing them to engage in this occupation and making them more prone to diseases like silicosis and tuberculosis. The present study also revealed a clear trend that longer durations of exposure to silica dust are associated with a higher frequency of TB cases

this emphasizes that both moderate to long-term exposures are significant risk factors.

In the present study, a higher proportion of TB patients with occupational silica dust exposure (55.4%) had a history of tuberculosis treatment. Moyo *et al.*[15] similarly reported that over 50% of patients with silicosis had a history of previous tuberculosis treatment. Rajavel *et al.*[12] observed that, among the 47 mine workers who received anti-tuberculosis treatment (ATT), the average treatment duration was 6.78 months, with 36.2% receiving category II treatment due to treatment failure or relapse. Tyagi *et al.*[13] found that 45% of mine workers had a history of tuberculosis treatment, and 83.92% had either completed the treatment or received it for a minimum of six months. Rupani *et al.*`[16] noted that 51% of silica-exposed patients had a history of TB treatment. Thus, this reflects a strong link between silicosis and tuberculosis, highlighting the presence of silicosis substantially elevates the risk of developing tuberculosis even among previously treated patients. This may be due to impaired immune response, suboptimal treatment adherence, high bacterial load, resistance development, or delayed diagnosis. The impaired immune response is because inhaled silica particles are phagocytosed by pulmonary alveolar macrophages that cause lysosomal damage and activate an inflammatory cascade leading to fibrosis. Another theory suggests that silicate particles serve as a reservoir for iron, which is essential for the growth of mycobacteria. The iron released from silica-iron complexes may activate dormant bacilli, leading to reactivation of the infection. Additionally, tubercle bacilli can remain encapsulated within silicotic nodules, contributing to disease reactivation. To prevent these relapses, susceptibility testing and regular follow-up during treatment are crucial to avoid interruptions in treatment. The present study showed that among TB patients with occupational silica dust exposure, the most common symptom experienced was cough (96.9%) along with fever (90.8%) and shortness of breath (90.8%). Chest pain (84.6%), weight loss (67.7%) and bodyache (56.9) are also frequently reported. Less common symptoms include anorexia (33.8%) and blood in sputum (7.7%). In a study by Chopra *et al.*[17], cough with expectoration (80%) was a predominant symptom, followed by dyspnea (70%), chest pain (52.6%), hemoptysis (43%), fever (40%) and hoarseness of voice (1%)among the mine workers with TB. In a study by Tyagi *et al.*[13], breathlessness was the most prevalent symptom among TB patients with silicosis, affecting 32.1%, followed by cough in 31.7% and chest pain in 24.4%. These findings are consistent with the present study, particularly the occurrence of expectoration and shortness of breath, reflecting that these symptoms are exaggerated in TB patients due to silica dust exposure. The differences in symptom occurrence, such as chest pain, observed in the present study compared to other studies could be attributed to several factors. This is because in our study majority of patients had bilateral disease (92.3%), cavitary disease (60%) and moderate to advanced disease (89%) at presentation. This might explain why chest pain is highlighted as a common symptom in tuberculosis (TB) patients with silica exposure in this study. In contrast, other studies might have included patients with less severe conditions or from different healthcare settings, leading to variations in symptom reporting.

The present study also showed the profile of clinical signs among TB patients with occupational silica dust exposure. Most patients exhibit pallor (43.1%) and pedal edema (32.3%), suggesting these are the more common clinical signs in this population. Rare signs include clubbing (n = 1, 1.5%). Notably, several potential signs like icterus, cyanosis, raised JVP, and lymphadenopathy were absent in these patients. In a study by Chopra *et al.*[17] among silicotuberculosis patients, 30 % had clubbing, 10% had cyanosis, and 9% had pedal edema. Pedal edema was notably more common in the silica-exposed group suggesting possibilities of systemic involvement like right heart failure or protein-losing enteropathy along with malnutrition that warrants careful investigation to ensure comprehensive care and address underlying issues, if any effectively. Clubbing was less frequent in TB patients with the silica dust exposed group which showed a difference from other studies, this might be due to the small sample size. These findings alongside comparisons with other studies, underscore the varying clinical presentations associated with silica dust exposure in TB patients. This emphasizes the need for tailored clinical assessment and management strategies based on occupational exposure history.

In the present study, most patients predominantly exhibit bilateral lung disease (92.3%), with a significant proportion having cavitary disease (60%). Moderate and far advanced disease was more common (46.1% moderate and 43.1% far advanced), indicating significant disease progression in such patients. While complications such as pleural effusion (3.1%), pneumothorax (7.7%), pleural thickening (7.7%) and progressive massive fibrosis (41.5%) were also notable. Enlarged calcified hilar lymph nodes were observed in about a quarter of the patients (24.6%), highlighting the involvement of hilar lymph nodes. Rajavel *et al.*[12] in a study on 168 workers, conducted chest X-rays among 134 (79.8%) and detected abnormal X-ray finding in 74 (56%). The abnormalities in X-rays were more prevalent among male workers (67.7%) as compared to female workers. Among the 74 mine workers with abnormal X-ray findings, 81% showed reticulonodular opacity, indicative of silicosis, while 19% had other conditions, including tuberculosis, emphysema, bronchiectasis, lung fibrosis, lung collapse, and pleural effusion. Out of the 81% of workers showing reticulonodular opacity, 20% exhibited progressive massive fibrosis along with smaller opacities. Among them, 15% had large opacities up to 50 mm, 2% had large opacities greater than 50 mm but not surpassing the equivalent area of the right upper zone, and 3% had opacities

that exceeded the equivalent area of the right upper zone. The majority of nodular opacities (86.6%) were bilateral. Of the 60 radiographs showing nodular opacities, 37% fell under category 3 profusion, followed by category 2 and category 1, each at 35%, and 2% had category 0 profusion. Additional chest X-ray findings included hilar lymphadenopathy (12.7%), tuberculosis (11.2%), calcified hilar lymphadenopathy (8.2%), lung fibrosis (6.7%), and emphysema (3.7%). Apart from this, lung collapse, bronchiectasis and pleural effusion were also observed in one case each. In a study by Chopra *et al.*[17] radiological examination of 156 bacteriological confirmed cases of silicotuberculosis revealed that the most frequent pattern was cavitary disease (Fl) in 41.6% of cases, F2 pattern seen in 26.2% of cases, pattern C seen in 12.1% cases, pattern G seen in 7.6% cases and pattern I seen in 5.1%. A significant finding was pattern K seen in 3.2% of cases. Pleural involvement (33.9%) and hilar calcification (11.5%) were observed in a great number of cases. These observations reflect extensive and severe lung involvement, common in TB cases linked to silica dust exposure. Radiological findings, such as evidence of advanced disease on X-ray in silica-exposed patients, highlight the need for comprehensive screening and monitoring strategies to address the unique challenges posed by TB in this population. This also warrants the need for pulmonary rehabilitation in these patients even after completion of TB treatment. The limitation of the present study was that it was a hospital-based time-framed observational study at a single center hence, the findings can't be generalized to the community at large.

Conclusion

The present study showed more TB patients with silica dust exposure were males and from rural backgrounds with more proportion of patients having a duration of exposure >10 years. The present study also showed that TB patients with silica exposure had more chances of TB recurrence therefore indicating the need for treatment extension on follow-up to reduce the chance of recurrence. The present study also revealed shortness of breath, cough with expectoration, chest pain and weight loss as more prominent symptomatology in silicotuberculosis patients. The present also showed bilateral, cavitary and moderate to far advanced disease as more common radiological abnormalities among TB patients with silica exposure.

A comprehensive, multifaceted approach is needed to better manage TB in the context of occupational silica exposure, which includes active surveillance for early TB detection in individuals with silicosis, and the development of enhanced diagnostic methods. Regular radiographic screening is suggested to be more effective for the early detection of tuberculosis in silicosis patients, emphasizing the significance of proactive radiographic monitoring in this population for timely intervention and treatment. A stronger emphasis on occupational health and safety measures to minimize silica dust exposure is essential for primary prevention of both silicosis and TB.

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