

Correlation of spirometry findings and post-six-minute walk test oxygen desaturation in chronic simple silicosis patients with age, duration of silica exposure, smoking pack years, occupation and mean pulmonary artery pressure

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Abstract

Silicosis is associated with preventable but irreversible lung damage. Early quantifiable assessment of silicosis workers would promote early interventional steps to reduce health deterioration. The objectives of this study were to correlate spirometry findings and post-six-minute walk test oxygen desaturation (post-6MWT OD) in chronic simple silicosis with age, duration of silica exposure (DSE), smoking pack years (SPY), occupation, and mean pulmonary artery pressure. Based on occupational exposure to silica and radiologic confirmation of chronic simple silicosis, 104 patients (all males) were enrolled and grouped based on SPY (nil, 1-10, 11-20, and >20) and occupation (drillers and dressers). They were further investigated with spirometry, post-6MWT OD, and transthoracic echocardiography (TTE), and findings were statistically analyzed. Abnormal spirometry findings were seen in 62.5% of total cases (65/104), with the highest percentage in the >20 SPY group (84%; 21/25) and drillers (68.3%; 28/41). The post-6MWT OD was seen in 50.96% of cases (53/104), with the highest percentage in the >20 SPY group (56%; 14/25) and drillers (63.4%; 26/41). Normal and restrictive patterns were predominant among the <20 SPY groups, while obstructive and mixed patterns were prevalent in the >20 SPY group. Normal, obstructive, and restrictive patterns were predominant among dressers, while mixed patterns were in drillers. Mean age and mean DSE were higher for the >20 SPY group and dressers, obstructive and mixed patterns, and patients with post-6MWT OD. Pulmonary hypertension was significantly associated with the presence of abnormal spirometry patterns (69.3%; 45/65) and post-6MWT OD (79.3%; 42/53). Mean forced expiratory volume in one second (FEV1)/forced vital capacity (FVC) was significantly lower for the >20 SPY group. Mean FEV1 had an inverse relation with SPY, and mean FVC was lower for drillers than dressers. Spirometry, post-6MWT OD, and TTE assessment give a complete overview of the cardiopulmonary exercise capacity of chronic silicosis patients and facilitate early interventions with special consideration for workers involved in machine-based mining activity.

Introduction

Silicosis is a preventable but untreatable occupational pulmonary disease. It is an irreversible disease that tends to progress even when the exposure stops [1-3]. Chronic simple silicosis is the most common form of silicosis (other types are acute and accelerated silicosis), and it occurs after long-term exposure to low concentrations of respirable crystalline silica (RCS). Radiologically, it is characterized by small (less than 10 mm) rounded opacities pre-

dominantly in the upper lung zones, and the silicotic nodules are the pathological hallmark in the lungs of these patients. It is associated with the chronic inflammatory changes within the alveoli (chronic alveolitis) through direct cellular toxicity involving macrophages. Subsequently, results in lung fibrosis and emphysema, leading to decreased pulmonary function capacity [4,5].

The higher prevalence of tobacco smoking among stone workers has been observed in various studies [6-8]. Tobacco smoking is a key environmental risk factor for chronic obstructive pulmonary disease (COPD), which is characterized by abnormalities of the airways (bronchitis/bronchiolitis) and/or alveoli (emphysema) that cause persistent, often progressive, airflow obstruction [9]. Tobacco smokers have a higher prevalence of respiratory symptoms and lung function abnormalities, a greater annual rate of decline in forced expiratory volume in one second (FEV1), and a greater COPD mortality rate than non-smokers [10,11].

Spirometry is a physiological test that measures the maximal volume of air that an individual can inspire and expire with maximal effort [12]. The most important variables reported include the volume exhaled in the first second, known as the FEV1, total exhaled volume, known as the forced vital capacity (FVC), and their ratio (FEV1/FVC) [13]. A restrictive spirometry pattern, defined as a reduced FVC in the absence of airflow obstruction, is prevalent in the general population [14]. The main parameter that represents obstructive spirometry pattern is the FEV1/FVC ratio [15].

The six-minute walk test (6MWT) is a low-intensity, submaximal exercise test used to assess aerobic capacity, endurance and oxygen saturation [16,17]. Eclipse study has demonstrated the usefulness of partial oxygen saturation percentage (Spo2) post-6MWT as an important tool for prognostic evaluation in COPD patients [18].

Pulmonary hypertension (PH) was previously defined by mean pulmonary artery pressure (mPAP) ≥ 25 mmHg at rest, measured by right heart catheterization [19]. At the 6th World Symposium on PH (2018), a proposal was made to lower mPAP from ≥ 25 mmHg to >20 mmHg [20]. Transthoracic echocardiography (TTE) is a non-invasive, cheaper, and easily available investigation that qualifies as the best screening tool for the assessment of PH in suspected patients [21].

This study was conducted to correlate spirometry findings and post-6MWT-oxygen desaturation (post-6MWT OD) in chronic simple silicosis patients with age, duration of silica exposure (DSE), smoking pack years (SPY), occupation and mean pulmonary artery pressure.

Materials and Methods

Study design

This was a cross-sectional analytical study that was conducted over a period of 12 months at the Kamla Nehru Chest Hospital, Jodhpur (a dedicated respiratory center with silicosis screening facility in the western part of Rajasthan, India). The Ethical Committee of Dr. Sampurnanand Medical College, Jodhpur, had approved this study (approval document no. F1/Acad/MC/JU/16/7814 dated May 3, 2016).

Study sample

The inclusion and exclusion criteria were similar to the primary study [22]. In brief, the patients above 18 years of age who were diagnosed with chronic simple silicosis (based on occupational his-

tory and International Labor Office pneumoconiosis radiographs guided screening by a team of two pulmonologists and one radiologist) with no other co-morbid conditions were selected for 6MWT, spirometry (pre- and post-bronchodilator), and TTE.

Six-minute walk test

The 6MWT was performed as per the American Thoracic Society 2002 Guidelines [16]. SpO2 before and after the 6MWT was measured by a finger-tip pulse oximeter and used as a standardized tool to measure exercise-induced desaturation. Post-6MWT OD was defined as a fall in Spo2 of $\geq 4\%$ between the end (post-test) and beginning (pre-test) and an end (post-test) of $<90\%$ [16,23].

Spirometry

A spirometry machine (RMS Medspiror, Recorders and Medicare Systems, Panchkula, Haryana, India) based on a recorder system, which was closer to the profile of the Indian patients, was used. All procedures were carried out according to the American Thoracic Society 2005 Guidelines [24]. The parameters evaluated were FVC, FEV1, and FEV1/FVC ratio. The obstructive pattern was defined by an FEV1/FVC ratio lower than 70; the restrictive pattern was defined by FVC lower than 80%; and the mixed pattern was defined by the presence of both obstructive and restrictive patterns.

Transthoracic echocardiography

The investigation was performed using the GE Vivid E9 echocardiography machine (GE HealthCare, Chicago, Illinois, USA) by the cardiology department to calculate mPAP. A reference value of ≤ 20 mmHg MPAP at rest was considered normal.

Statistics

Statistical analysis was performed using Statistical Package of the Social Sciences (SPSS version 23, IBM, Armonk, NY, USA). Skewness and Kurtosis were used to measure the degree of asymmetry of the distribution for horizontal spread and vertical peakedness, respectively. Mean \pm standard deviation was used as a measure of central tendency using the statistical tool 'compare means', and statistical significance was checked with analysis of variance. Cross-tabulation was used to tabulate and correlate data between two categorical variables, and statistical significance was measured using Pearson's Chi-square. A p-value below 0.05 was considered statistically significant.

Results

A total of 104 participants (all males) were included in this study, with a mean age and mean DSE of 47.1 ± 9.9 years and 21.3 ± 8.6 years, respectively. Significant differences were seen in mean age and mean DSE among SPY-based groups and occupation-based groups. On spirometry, an abnormal spirometry pattern was seen in 62.5% of overall study cases, 53.3% of non-smokers, 60% of 1-10 SPY, 55.2% of 11-20 SPY, 84% of >20 SPY, 68.3% of drillers, and 58.7% of dressers. On spirometry, normal study and restrictive pattern were seen predominantly among below 20 SPY groups (35/39 and 28/29, respectively); while obstructive and mixed patterns were seen predominantly among >20 SPY groups (11/18 and 9/18, respectively). Normal spirometry, obstructive pattern, and restrictive pattern were more common among dressers than drillers, while mixed pattern was more common among drillers

than dressers. On 6MWT, oxygen desaturation was seen in 50.96% of overall study cases, 50% in the non-smoker group, 45% in the 1-10 SPY group, 51.7% in the 11-20 SPY group, 56% in the >20 SPY group, 63.4% in drillers, and 42.85% in dressers. On comparison of post-6MWT OD among SPY-based groups, no conclusive results were seen, while drillers were more at risk for post-6MWT OD than dressers (26/41 against 27/63) (Table 1).

Overall, the mean age was higher for obstructive and mixed patterns than for normal and restrictive patterns. No significant association was seen on comparing spirometry patterns with the mean age in SPY-based groups. Dressers had a higher mean age in all except mixed spirometry findings. Among overall patients (n=104), the mean age was higher for patients who had ≥4% or <90 % post-6MWT OD. Mean age was significantly higher among the >20 SPY group and the dresser group, irrespective of whether desaturation was present or not (Table 2).

In the overall study, those with obstructive and mixed patterns had a higher mean DSE than the restrictive pattern and normal findings. No significant association was seen on comparing spirometry patterns with mean DSE in SPY-based groups. Mean DSE was higher among dressers in all except the mixed spirometry pattern. Patients with a restrictive pattern had significantly higher mean DSE in the dresser group. There was no significant difference in mean DSE between those who had ≥4% or <90% post-6MWT OD and those with <4% post-6MWT OD. Mean DSE was higher among patients with ≥4% or <90 % post-6MWT OD than other group, but no statistical significance was observed. No statistically significant results were observed among the SPY-based groups for those who had post-6MWT OD; while among occupation-based groups, dressers had significantly higher mean DSE in both ≥4% or <90 % post-6MWT OD and <4% post-6MWT OD patients (Table 3).

Table 1. Baseline characteristics of the study participants.

Parameter	Study sample	Smoking pack years				p	Occupation		p
		Nil	1-10	11-20	>20		Driller	Dresser	
Number of patients (N)	104	30	20	29	25		41	63	
Age (mean±SD)	47.1±9.9	43.6±10.5	42.1±10.3	48.42±8.1	53.8±7.1	0.000	43.7±10.5	49.3±9.1	0.004
DSE (mean±SD)	21.3±8.6	17.40±7.85	19.45±9.4	23.96±8.59	24.28±6.85	0.004	17.7±7.5	23.2±8.1	0.005
Spirometry									
Normal	39	14	8	13	4	<0.0001	13	26	0.156
Obstructive	18	3	2	2	11		5	13	
Restrictive	29	9	10	9	1		12	17	
Mixed	18	4	0	5	9		11	7	
6MWT									
<4 %	51	15	11	14	11	0.906	15	36	0.04
≥4 % or <90 %	53	15	9	15	14		26	27	

SD, standard deviation; DSE, duration of silica exposure; 6MWT, six-minute walk test.

Table 2. Comparison of spirometry findings and post-six-minute walk oxygen desaturation with mean age in overall study cases, and smoking pack years and occupation type-based groups.

Parameter	Study sample	p	Smoking pack years				p	Occupation		p		
			Mean age±SD	Nil	1-10	11-20		>20	Driller		Dresser	
Spirometry												
Normal	45.2±9.7	0.003	44.3±10.4	38.2±7.4	48.6±8.9	50.5±7.6	0.061	41.9±10.6	46.7±9.1	0.148		
Obstructive	53.4±7.7		46.0±5.3	49.0±12.7	56.5±2.2	55.6±7.1		0.195	50.8±7.1		54.4±7.9	0.391
Restriction	43.9±10.6		38.8±10.3	43.8±11.7	48.1±8.2	55.0		0.201	35.9±7.2		49.6±8.7	0.000
Mixed	50.1±8.6		49.7±12.9	-	45.2±5.9	53.0±7.2		0.281	51±8.2		48.7±9.7	0.599
6MWT												
<4%	45.7±9.7	0.171	43.1±9.5	37.6±7.4	49.8±8.7	52.2±6.4	0.000	41.5±10.9	47.5±8.7	0.042		
≥4% or <90%	48.4±10.2		44.1±11.7	47.4±11.2	47.1±7.5	55.2±7.5		0.022	44.9±10.2		51.7±9.2	0.014

SD, standard deviation; 6MWT, six-minute walk test.

Table 3. Comparison of spirometry findings and post-six-minute walk oxygen desaturation with mean duration of silica exposure in overall study cases, and smoking pack years and occupation type-based groups.

Parameter	Overall	p	Smoking pack years				p	Occupation		p		
			Mean age±SD	Nil	1-10	11-20		>20	Driller		Dresser	
Spirometry												
Normal	20.1±8.6	0.599	16.7±7.8	17.6±9.4	23.9±8.6	24.5±3.3	0.087	16.4±6.7	21.9±8.9	0.056		
Obstructive	22.7±8.1		22.3±10.2	17.0±7.1	18.5±4.9	24.7±8.3		0.564	18.6±8.6		24.4±7.6	0.181
Restriction	20.9±9.5		16.0±7.1	21.4±10.3	25.4±9.9	21		0.218	15.2±9.9		25.1±6.9	0.004
Mixed	22.8±7.7		19.3±9.4	-	23.6±8.4	24±7.1		0.601	24.2±7.3		20.7±8.4	0.369
6MWT												
<4%	20.2±8.6	0.193	16.3±7.4	16.8±8.6	24.6±8.6	23.0±7.1	0.016	15.6±6.4	22.1±8.7	0.013		
≥4% or <90%	22.4±8.6		18.4±8.4	22.6±9.9	23.3±8.8	25.3±6.7		0.178	20.0±9.5		24.6±7.1	0.049

SD, standard deviation; DSE, duration of silica exposure; 6MWT, six-minute walk test.

Table 4. Comparison of spirometry findings and post-six-minute walk test oxygen desaturation with mean pulmonary artery pressure.

Parameters	mPAP, n (%)		Total (104)	p
	≤20 (42)	>20 (62)		
Spirometry				
Normal	22 (56.4)	17 (43.6)	39	0.000
Obstructive	7 (38.9)	11 (61.1)	18	0.000
Restriction	10 (34.48)	19 (65.5)	29	0.000
Mixed	3 (16.67)	15 (83.33)	18	0.000
6MWT				
<4%	31 (60.78)	20 (39.22)	51	0.000
≥4% or <90%	11 (20.75)	42 (79.25)	53	0.000

mPAP, mean pulmonary artery pressure; 6MWT, six-minute walk test.

Table 5. Comparison of spirometry parameters with smoking pack years and occupation type-based groups.

Spirometry parameter	Study sample	Smoking pack years				p	Occupation		p
		Nil	1-10	11-20	>20		Driller	Dresser	
Mean FEV1/FVC	72.7±14.8	78.5±12.8	81.2±12.5	72.2±12.9	59.7±12.4	0.000	72.8±14.4	72.6±15.3	0.946
Mean FEV1	72.1±18.8	77.9±19.4	75.0±17.4	69.8±16.8	65.1±19.6	0.060	70.2±15.8	73.3±20.5	0.406
Mean FVC	80.5±15.7	80.4±15.6	78.6±19.9	78.3±12.5	84.7±15.7	0.452	78.4±14	81.8±16.7	0.276

FEV1, forced expiratory volume in one second; FVC, forced vital capacity.

On comparison of spirometry findings and mPAP, most patients with normal spirometry had ≤20 mmHg mPAP (56.4%; 22/39), while patients with abnormal findings had most patients with mPAP>20 mmHg (69.3%; 45/65). The majority of patients (60.78%; 31/51) with <4% post-6MWT OD had ≤20 mmHg mPAP, while among patients with ≥4% or <90% post-6MWT OD majority (79.3%; 42/53) had mPAP>20 mmHg (Table 4).

The mean FEV1/FVC was significantly lower for the above 20 SPY group. The mean FEV1/FVC was almost similar for drillers and dressers. The mean FEV1 had an inverse relation with SPY and was lower for drillers than dressers. The mean FVC was higher among the >20 SPY group and lower for drillers than dressers (Table 5).

Discussion

Tobacco smoking has been associated with various pulmonary diseases resulting from damage to airways as well as parenchyma. Like any other industrial laborers, stone workers also have a high prevalence of tobacco smoking (71.2% in this study) [7-9]. Drillers are exposed to higher concentrations of respirable silica dust as compared to dressers owing to their machine-based mining activity. To further elaborate on the role, study patients were grouped on the basis of SPY and occupation type.

Tobacco smoking has shown its concurrent effect in chronic simple silicosis patients, as the above 20 SPY group was strongly associated with obstructive and mixed patterns on spirometry. While study patients with no smoking history (n=30) had normal spirometry (14/30), followed by a restrictive pattern (9/30). Also, the above 20 SPY group had a lower mean FEV1/FVC ratio and mean FEV1 than the other SPY group. These findings are suggestive of additional detrimental effects of tobacco smoking (especially above 20 SPY) in silicosis patients.

Drillers are exposed to finer and higher concentrations of RCS than dressers due to their engagement in machine-based mining activity (drilling, blasting, and cutting) [25]. In this study, significantly lower mean age of presentation and mean DSE were

observed among drillers than dressers.

On 6MWT, a major proportion of drillers had post-6MWT OD (26/41) while a major proportion of dressers had normal post-6MWT OD (36/63). Restrictive pattern on spirometry was associated with significantly lower mean age and mean DSE among drillers than dressers.

In this study, the presence of pulmonary hypertension (defined as mPAP>20 mmHg at rest) has been significantly associated with the presence of abnormal spirometry findings and post-6MWT OD.

Limitations of this study

As inspection of the workplaces of these patients was not part of this study, information regarding silica particle size and concentrations, workplace environment, preventive methods adopted, and worker training could not be collected, and the impact of these factors on the results of this study cannot be evaluated. Also, mPAP was measured through TTE, while right heart catheterization is the gold standard.

Conclusions

Spirometry and post-6MWT OD were found to be useful screening tools for assessment of chronic simple silicosis, and adding TTE gives a complete overview of the patient's cardiopulmonary exercise capacity. All industries that are involved in RCS-generating activities must employ adequate on-site preventive methods and workers' training and screening, with special consideration to the stone workers involved in machine-based activities.

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