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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 <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 >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.

Key words: spirometry, six-minute walk test, 6MWT, oxygen desaturation, transthoracic echocardiography, chronic simple silicosis.

Introduction

Silicosis is a preventable but untreatable occupational pulmonary disease. It is an irreversible disease which tends to progress even when the exposure stops [1-3]. Chronic simple silicosis is the most common form of silicosis (other types – acute and accelerated silicosis), occurs after long term exposure to low concentrations of respirable crystalline silica (RCS). Radiologically, characterized by small (less than 10mm) rounded opacities predominantly 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 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 forced expiratory volume in one second (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 forced vital capacity (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 usefulness of partial oxygen saturation percentage (Spo2) post 6MWT as an important tool for prognostic evaluation in COPD patients [18].

Pulmonary Hypertension was previously defined by mean pulmonary artery pressure (mPAP) 25mmhg at rest measured by right heart catheterization (RHC) [19]. At the 6th World Symposium on PH (2018), proposal was made to lower mPAP from 25 mmHg to > 20 mmHg [20]. Trans-thoracic echocardiography (TTE) is non-invasive, cheaper and easily available

investigation which qualifies as best screening tool for assessment of PH in suspected patients [21].

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

Materials and Methods

Study design

This was a cross-sectional analytical study which 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 age who were diagnosed with chronic simple silicosis (on the basis of occupational history 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 transthoracic echocardiography.

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

Spirometry - A spirometry machine (RMS Medspiror) based on 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 FEV1/FVC ratio lower than 70; the restrictive pattern was defined by FVC lower than 80%; and mixed pattern was defined by presence of both obstructive and restrictive patterns.

Transthoracic Echocardiography (TTE) - The investigation was performed using GE Vivid E9 echocardiography machine by the cardiology department to calculate mPAP. The 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). Skewness and Kurtosis were used to measure degree of asymmetry of the distribution for horizontal spread and vertical peakedness; respectively. Mean ± standard deviation (SD) was used as measure of central tendency using statistical tool 'compare means' and statistical significance was checked with Analysis of Variance (ANOVA). 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 .05 was considered statistically significant.

Results

A total of 104 participants (all males) were included in this study, with mean age and mean DSE 47.1 ± 9.9 years and 21.3 ± 8.6 years; respectively. Significant differences were seen in mean age and mean DSE among smoking pack years (SPY) based groups and occupation based groups. On spirometry, abnormal spirometry pattern was seen in 62.5% in overall study cases; 53.3% in non-smokers; 60% in 1-10 SPY; 55.2 % in 11-20 SPY; 84% in > 20 SPY; 68.3% in drillers and 58.7% in 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 group (11/18 and 9/18; respectively). Normal spirometry, obstructive pattern and restrictive pattern were more among dressers than drillers, while mixed pattern was more common among drillers than dressers. On 6MWT, oxygen desaturation was seen in 50.96% in overall study cases; 50% in non-smoker group; 45% in 1-10 SPY group; 51.7 % in 11-20 SPY group; 56% in > 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).

In overall study patients, mean age was higher for obstructive and mixed patterns than normal and restrictive patterns. No significant association was seen on comparing spirometry patterns with mean age in SPY based groups. Dressers had higher mean age in all except mixed

spirometry findings. Among overall patients (n=104), mean age was higher for patients who had >/= 4% or < 90 % post-6MWT OD. Mean age was significantly higher among > 20 SPY group and dressers group irrespective of desaturation was present or not (Table 2).

In overall study patients, those with obstructive and mixed patterns had higher mean DSE than restrictive pattern and normal finding. 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 mixed spirometry pattern. Patients with restrictive pattern had significantly higher mean DSE in 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 statistical significant results were observed among smoking pack years based groups for those who had oxygen desaturation post-6MWT; 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).

On comparison of spirometry finding 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). Majority 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).

Mean FEV1/FVC was significantly lower for above 20 SPY group. Mean FEV1/FVC was almost similar for drillers and dressers. Mean FEV1 had inverse relation with smoking pack years and lower for drillers than dressers. Mean FVC was higher among > 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 labors, stone workers also have 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 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 above 20 SPY group was strongly associated with obstructive and mixed pattern on spirometry. While

study patients with no smoking history (n=30) had normal spirometry (14/30) followed by restrictive pattern (9/30). Also above 20 SPY group had lower mean FEV1/FVC ratio and mean FEV1 than other SPY group. These findings are suggestive of additional detrimental effect of tobacco smoking (especially above 20 SPY) in silicosis patients.

Drillers are exposed to finer and higher concentrations of respirable crystalline silica 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 duration of silica exposure were observed among drillers than dressers.

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

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

Conclusions

Spirometry and post-6MWT oxygen desaturation were found to be useful screening tools for assessment of chronic simple silicosis and adding trans-thoracic echocardiography gives complete overview of patient's cardiopulmonary exercise capacity. All industries, those are involved in respirable crystalline silica 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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Table 1. Baseline characteristics of the study participants.

Parameter		Study sample	Smoking pack years				P value	Occupation		P value
			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; p value – probability value.

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 value	Smoking pack years				p value	Occupation		p value
		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; p value, probability value.

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 value	Smoking pack years				p value	Occupation		p value
		Mean DSE±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; p value, probability value.

Table 4. Comparison of spirometry findings and post-6MWT oxygen desaturation with mean pulmonary artery pressure.

Parameters		mPAP		Total (104)	p value
		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; p value, probability value .

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

Spirometry Parameters	Study sample	Smoking pack years				p value	Occupation		p value
		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; p value, probability value.