

THE SINGLE BREATH DIFFUSING CAPACITY MEASUREMENT AS A PREDICTOR OF EXERCISE INDUCED OXYGEN DESATURATION IN PATIENTS WITH SILICOSIS

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The single breath diffusing capacity at rest is frequently found to be abnormal in patients with silicosis.¹⁻³ Little correlation exists between measurements of diffusing capacity by the steady state method and arterial oxygen tension.⁴ Patients with conglomerate silicosis frequently show a reduced resting single breath diffusing capacity associated with exercise induced hypoxemia.⁵ In patients with chronic obstructive pulmonary disease, a measurement of the resting single breath diffusing capacity greater than 55% of predicted has been shown to be specific in excluding desaturation on exercise.⁶ In shipyard workers exposed to asbestos, a diffusing capacity below 70 percent of predicted was shown to be associated with abnormal arterial oxygen tension and gas exchange. Abnormalities in gas exchange on exercise were found also in some subjects with diffusing capacities greater than 70 percent of predicted.⁷ We undertook the current study to determine the capacity of the single breath diffusing capacity measurement to predict exercise induced hypoxemia in patients with both simple and conglomerate silicosis.

METHODS

We studied nine subjects with silicosis whose diagnosis was based on occupational history, and chest radiography. All subjects had chest roentgenograms showing simple or conglomerate disease. Each subject also had a measured arterial oxygen tension value greater than 55 mmHg at rest. All subjects undertook standard pulmonary function and exercise testing. The pulmonary function tests included flow rates, lung volumes and single breath diffusing capacity measurements using standard techniques. Progressive exercise testing was performed on a treadmill using standard incremental protocols. Indices monitored during exercise in all subjects included the electrocardiogram, workload, minute ventilation, breathing frequency, oxygen consumption (VO_2 ml/kg/min), carbon dioxide production (VCO_2 ml/kg/min). Oxygen and carbon dioxide levels were monitored using rapid response analyzers (Beckman OM-11 and Beckman LB-11). Arterial blood gases were measured both at rest and at peak exercise just before the termination of the exercise test using air blood gas analyzer (1L1303). Data analyzed at the breaking point of exercise were maximum heart rate, workload, maximum breathing frequency, maximum minute ventilation, maximum oxygen consumption (VO_2 max ml/kg/min); expired carbon dioxide percent, and dead space/tidal volume $\text{VD}/\text{V}_\text{T}$ ratio.

Arterial samples were drawn from an indwelling radial artery cannula placed at rest. The samples were placed in ice and analyzed immediately. We examined whether an abnormal resting single breath diffusing capacity defined as equal to or less than 80 percent of predicted would predict in individual subjects altered gas exchange during exercise. A decrement in PaO_2 of greater than 5 torr on exercise and/or fall in oxygen saturation of 5 percent or greater was considered significant.

RESULTS

Of the nine subjects, four had simple silicosis and five conglomerate silicosis. Their ages ranged 44 to 72 years. Five out of the nine subjects were smokers. All subjects performed a progressive incremental exercise test, and they achieved a mean workload of four METS. Two out of nine subjects had a normal resting single breath diffusing capacity (greater than 80 percent of predicted) and seven out of nine subjects had abnormal resting single breath diffusing capacity (less than 80 percent of predicted). One of the two subjects with a normal resting single breath diffusing capacity had a decrement in arterial oxygen tension of 11 torr on exercise and seven out of the nine subjects with a resting single breath diffusing capacity less than 80 percent of predicted had decrements in arterial oxygen tension ranging from 5–20 torr on exercise. Three out of nine subjects with conglomerate silicosis had decrements in oxygen saturation of more than 5 percent on exercise. The alveolar-arterial oxygen difference increased on exercise in all seven subjects with abnormal resting single breath diffusing capacity measurements, by a mean value of 15.6 torr. Abnormalities in $\text{VD}/\text{V}_\text{T}$ ratio (defined as greater than 30 percent) were seen in all nine subjects on exercise. One of the nine subjects with a high resting $\text{VD}/\text{V}_\text{T}$ percent ratio of 51.8 had a decrement in $\text{VD}/\text{V}_\text{T}$ percent ratio to 37.8 on exercise.

The VO_2 max in all nine subjects ranged from 5.2 to 25.4 ml/Kg/min with a mean VO_2 max of 17.02 ml/Kg/min. The exercise test was terminated in all subjects by complaints of severe dyspnea.

DISCUSSION

In early cases of silicosis, arterial blood oxygen desaturation is usually not present at rest,⁵ however at high exercise loads a considerable proportion of silicosis patients show some degree of arterial blood desaturation.⁶

Table I
Anthropometric Characteristics of Patients

	AA	AW	CL	LJ	KO	MS	KE	BH	RJ
Sex	M	M	M	M	M	M	M	M	M
Age (yrs)	71	55	67	56	72	70	44	69	52
Height (cm)	169	179	175	170	179	171	175	177	173
Weight (kg)	76	86	69	96	67	74	113	80	70
Smoker (S) Non Smoker (NS)	NS	S	S	NS	S	NS	S	S	NS
					pipe smoker				
Smoker Pack Years	—	30	75	—	5 packs per day x 25 yrs.	—	10	30	—
Type of Occupational Exposure	Grinder Concrete blasting heavy duty	Mechanics	Foundry Steel Mill	Coal Miner	Painter Shipbuilder Grinding wheels	Electrician Shipbuilder Fly on ship	Auto Wash Jet Wash Shipbuilder	Asphalt Road work Construction	Foundry Steel Miner
Exposure Years	25	20	30	9	40	20	22	45	21

	DLCO% PRED	PaO ₂ REST mmHg	PaO ₂ ex (mmHg)	PaO ₂ mmHg
1	56.0	82.0	64.0	18.0
2	72.0	86.0	77.0	9.0
3	44.0	67.0	60.0	7.0
4	80.0	85.0	72.0	13.0
5	100.0	73.0	73.0	0.0
6	56.0	73.0	60.0	13.9
7	90.0	93.0	82.0	11.0
8	75.0	64.0	59.0	5.0
9	55.0	93.0	82.0	11.0

	FEV1/ FVC%	TLC% PRED	VO ₂ MAX ml/Kg/min	VD/VT%
1	73.0	61.0	15.9	39.9
2	79.0	62.0	23.0	42.3
3	93.0	44.0	15.1	41.6
4	79.0	90.0	18.5	37.8
5	64.0	125.0	25.4	51.7
6	76.0	64.0	16.1	42.5
7	84.0	75.0	23.4	48.3
8	30.0	108.0	5.2	64.4
9	73.0	52.0	10.6	46.2

In a similar study performed in shipyard workers exposed to asbestos,⁶ a diffusing capacity at rest of below 70 percent of predicted was usually associated with gas exchange abnormalities. However, in some subjects with diffusing capacities above 70 percent of predicted, VD/V_T ratio, abnormal values for arterial oxygen tension and the alveolar-arterial difference in oxygen tension were found.

In our study three of the subjects with resting single breath diffusing capacity above 70 percent but below 80 percent of predicted had decrements in arterial oxygen tension in the range of 5–13 torr. One subject with single breath diffusing capacity of 90 percent of predicted had a decrement in arterial oxygen of 11 torr. Four subjects with single breath diffusing capacities below 70 percent of predicted had decrements in arterial oxygen on exercise in the range of 11 to 20 torr.

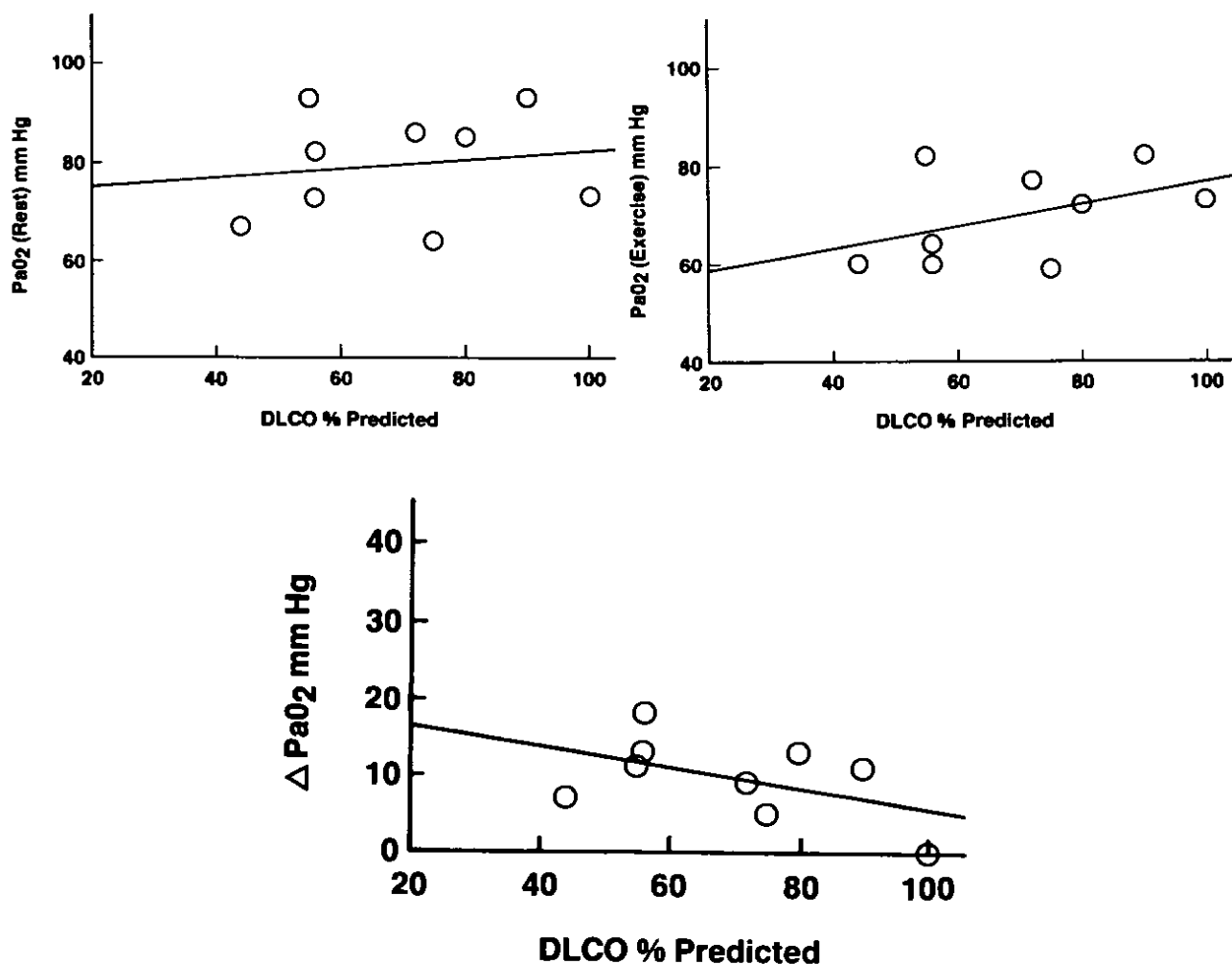
Abnormalities in gas exchange as shown by alveolar-arterial difference in oxygen and dead space/tidal volume ratio were seen in all our subjects during exercise. These abnormalities in gas exchange may be caused by increased perfusion to lung units without proportional increase in ventilation causing hypoxemia thus increasing the alveolar-arterial oxygen difference. Conversely the inability of perfusion to increase appropriately to the well ventilated lung units results in abnormally high dead space/tidal volume ratio and high arterial-

end tidal difference in carbon dioxide. Our study revealed gas exchange abnormalities similar to those seen in subjects exposed to asbestos.⁶ We also observed high dead space/tidal volume ratios on exercise which could not be predicted by resting single breath diffusing capacity measurements. Thus our results indicate that in seven of nine subjects with silicosis, resting single breath diffusing capacity equal to or less than 80 percent of predicted a decrement in arterial oxygen tension and/or oxygen saturation occurred with exercise.

In summary, in a small number of silicotic subjects, the single breath diffusing capacity measurement at rest appears to predict exercise induced decrements in arterial oxygen tension and/or oxygen saturation. Abnormalities in gas exchange as shown by increased alveolar-arterial oxygen difference and dead space/tidal volume ratios were seen in all subjects during exercise.

REFERENCES

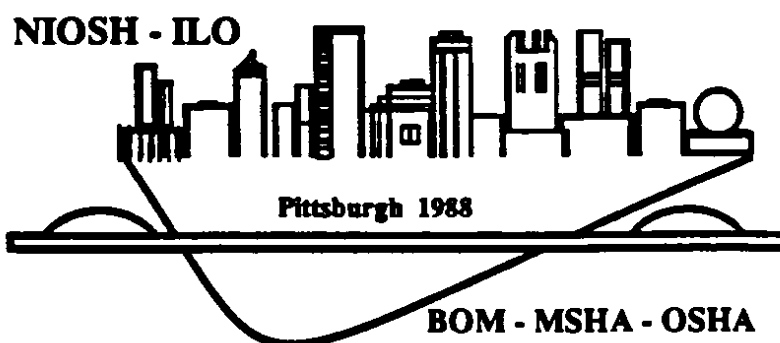
1. Nicaise, R., Vereerstraeten, J., and DeClereq, F.: The diffusion capacity at rest and during exercise in pneumoconiosis. *Select Papers*. 10:70-79, (1967).
2. Cugell, D.W., et al.: Carbon monoxide diffusing capacity during steady exercise. *Am. Rev. Tuberc.*, 74:317, (1956).



3. Kanagami, H., et al.: Studies on the pulmonary diffusing capacity by the carbon monoxide breath holding technique II. Patients with various pulmonary diseases. *Acta Med. Scand.*, 169:595, (1961).
4. Nissardi, G.P., et al.: Lung diffusing capacity on effort in normal and silicotic subjects. *Lav. Umano.*, 17:397-414, (1965).
5. Becklake, M.R., et al.: Lung function in silicosis of the Witwaterstand gold miner. *Am. Rev. Tuberc.*, 62:29, (1950).
6. Owens, G.R., et al.: The diffusing capacity as a predictor of arterial oxygen desaturation during exercise in patients with chronic obstructive pulmonary disease. *New Eng. J. Med.*, Vol. 310, No. 19, pp. 1218-1221, (1984).
7. Sue, D.Y., et al.: Diffusing capacity for carbon monoxide as a predictor of gas exchange during exercise. *New Eng. J. Med.*, Vol. 310, No. 21, pp. 1301-1306, (1987).

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