DIURNAL VARIATION IN PULMONARY DIFFUSING CAPACITY AND EXPIRATORY VOLUMES

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Summary : The pulmonary diffusing capacity for Carbonmonoxide (DLco) was measured in 20 normal volunteers of either sex at 9 a.m., 12 noon and 5 p.m. Forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were also determined after each DLco measurement. There was a fall in the mean noon value of the diffusing capacity of the lungs which was statistitically significant. The value at 5 p.m. was almost same as the noon value. The forced expiratory volume in one second and the forced vital capacity followed a similar trend. The DLco, FEV_1 and FVC appear to exhibit a diurnal rhythm.

Key words : diurnal rhythm, pulmonary diffusing capacity, forced expiratory volume in one second, forced vital capacity

INTRODUCTION

When oxygen is taken up from the alveoli of the lungs it has to penetrate the barrier of the tissue elements and fluids separating it from the molecules of haemoglobin in the red cells. This process is one of simple physical diffusion.

In the past several techniques have been described to estimate the diffusing capacity of the lungs (DLco). Presently single breath holding techniques as described by Krogh (10) and modified by Forster *et al.* (6) is popular. In this technique carbon monoxide is used as a test gas. Several factors affect DLco (15). Besides these factors, there are also spontaneous variations in the pulmonary diffusing capacity.

Sequential studies on the diffusing capacity of the lungs were carried out in the past by Munt *et al.* (13) in an exposure chamber, where the DLco showed an average decrease of 5% in 12 normal subjects over four hours. Cinkotai and Thomson (2) also studied effects of diurnal rhythms on DLco. In their observations, DLco progressively fell at the rate of 1.2% per hour between 9.30 a.m. to 5 p.m.

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The present work reports the nature and extent of variations in DLco and forced expiratoly volume between 9 a.m. to 5 p.m. Also a correlation of FEV_1 and FVC has been attempted with the pulmonary diffusing capacity.

MATERIALS AND METHODS

Twenty normal subjects of both sexes took part in this study. They were all either doctors or staff working in the respiratory laboratory; they had no significant history of pulmonary or cardiac diseases. They were all familiar with DLco measurements. Their ages ranged from 20 to 60 years, their surface area varied from 1.37 to 2.14 square meters. Each subject was asked to sit for 5 minutes near the machine before the measurements commenced. Smokers abstained from smoking two hours before each measurement. Two readings were taken and the best out of the two was noted.

Resparameter (P.K. Morgan Ltd.,) Mark-IV was used for DLco measurements. A standard sitting posture was employed.

The subject inhaled a breath of test gas mixture which contains 20% oxygen, 12% Helium, 0.2% Carbon monoxide in Nitrogen. The breath was held for 8-10 seconds by the subject and then he was asked to expire out. All of this expiration except the first litre was collected and analysed as the alveolar gas. Diffusing capacity of the lungs was calculated by using the nomogram designed by Fletcher (5). The possibility of error in carbon monoxide gas analyser was virtually excluded by frequent calibration.

Following DLco measurements FEV_1 and FVC were recorded with a recording spirometer. The best of the two readings was noted.

RESULTS

The mean diffusing capacity of the lungs at 9 a.m. was found to be 30.01 *ml/min/mmHg* which fell to 28.47 *ml/min/mmHg* at noon and 28.55 *ml/min/mmHg* at 5 p.m. (Fig. 1, Table-I). This fall at noon was statistically significant ($P < 0.01$.).

The mean alveolar volume was 5532 *ml* at 9 a.m., 5507 *ml* at noon and 5504 *ml* at 5 p.m. (Table-I).

Mean FEV_1 was found to be 3652 *ml* at 9 a.m. 3547 *ml* at noon and 3572 *ml* at 5 p.m. The percentage of fall was found to be 2.8 of the resting value at noon and remained almost at the same level at 5 p.m. Mean FVC recorded was 4401 *ml* at 9 a.m., 4289 *ml* at noon and 4362 *ml* at 5 p.m. The percentage of fall was 2.6 and 0.9 of the resting value at noon and 5 p.m. respectively. The values were corrected to B.T.P.S. (Table-II, Fig. 2).

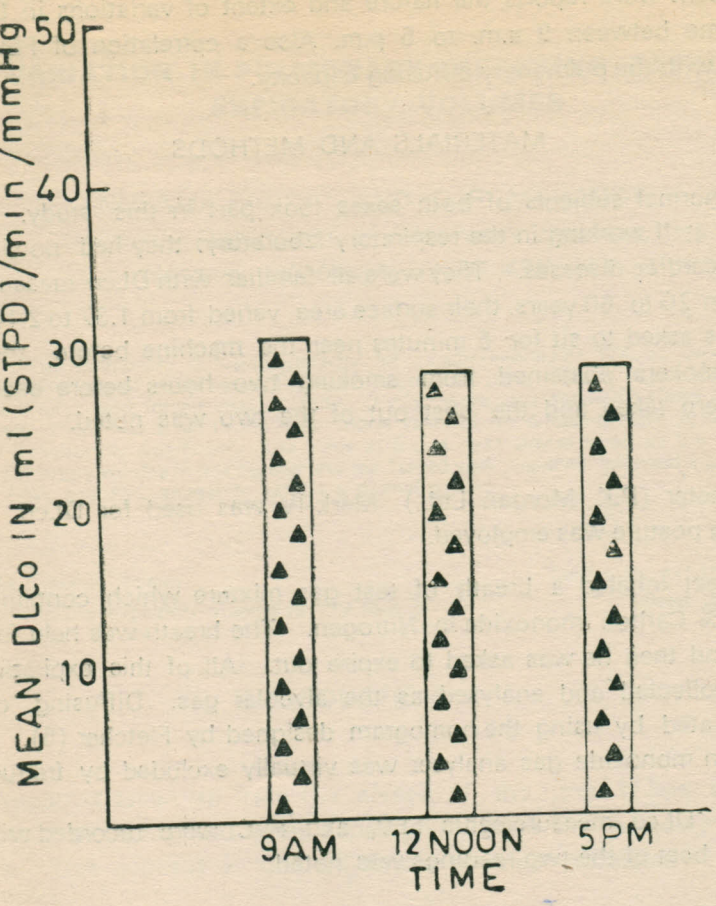

Fig. 1 : Mean diffusing capacity of the lungs.

DISCUSSION

Many technical factors may lead to the change in DLco. Therefore, in this study, adequate precaution had been taken to eliminate such errors. The subjects were very much familiar with such measurements; therefore emotional tension was not a major problem. Standard sitting position was used in all cases. DLco in sitting position is less than in supine and more than in standing position (15). All subjects were made to sit for five minutes before each test. The carbon monoxide analyser and helium analyser were frequently calibrated. Smokers gave up smoking 2 hours before each test. Any increase in blood carbon monoxide back pressure due to smoking during DLco determination may cause a progressive decrease in carbon monoxide diffusing capacity. Cinkotai and Thomson (2) have shown that even in most series the average pre-experimental

fractional concentration of Co in pulmonary capillaries in smokers was 0.0004% at atmospheric oxygen concentration, and there was an average increase of 0.00008% for each DLco estimation. The magnitude of this effect is too small to explain the observed changes in DLco. Also it has been shown from their experiments that the half life of elimination of carbon monoxide from the body is about two hours.

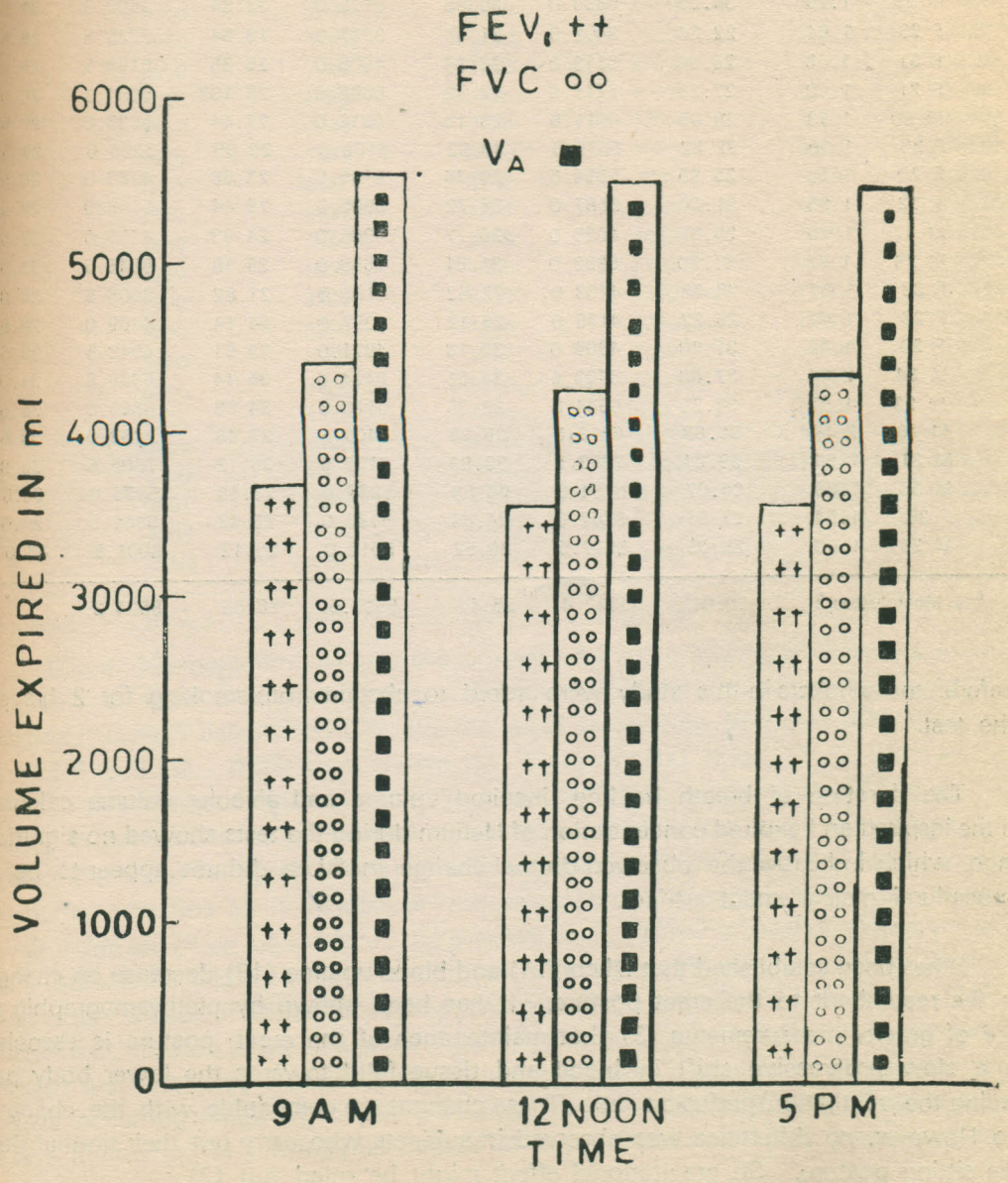

Fig. 2 : Mean alveolar volume, FEV_1 and FVC.

TABLE I : DL_{CO} in *ml* (STPD)/*min*/*mmHg* and V_A (BTPS) in *ml* in 20 healthy normal subjects.

Subjects	Age and sex	Surface area in M^2	9. a.m.		12 noon		5 p.m.		Predicted DL_{CO}
			DL_{CO}	V_A	DL_{CO}	V_A	DL_{CO}	V_A	
CM	M 29	1.79	34.29	6934.0	30.95	6175.0	33.84	6602.0	34.5
LM	F 23	1.64	22.24	3402.0	21.45	3897.0	19.64	3235.5	28.5
CJ	F 31	1.63	25.94	5113.0	26.94	4808.0	25.38	5198.5	28.0
MG	F 21	1.60	27.29	5217.5	22.42	5688.0	25.133	5094.5	28.0
BS	M 60	1.93	29.05	6011.0	28.16	5812.0	27.44	5828.0	26.5
AM	F 22	1.69	32.22	5670.5	30.32	5109.5	29.00	5266.0	29.5
LD	F 23	1.56	25.95	5854.5	26.76	5136.5	23.68	4780.0	28.5
EM	F 32	1.65	31.16	5687.0	32.72	5505.0	29.44	5146.0	29.5
DM	M 47	1.70	26.57	4025.0	25.77	4005.0	24.93	4255.0	27.8
RS	M 24	1.73	31.30	5992.0	31.51	5658.0	35.18	5645.5	33.5
JM	F 33	1.51	23.53	4203.0	22.62	4145.0	21.82	3508.5	25.8
MCF	F 27	1.63	25.22	4195.0	25.12	4097.0	24.14	4469.0	26.5
MM	F 20	1.74	31.90	4806.0	30.13	4871.0	29.91	4948.5	29.5
MS	M 34	2.04	37.80	6409.5	34.51	6424.0	35.14	6825.5	34.0
CS	M 23	1.37	33.25	6344.0	32.35	6020.5	34.68	5865.0	35.5
DH	M 26	2.14	36.88	6813.5	35.99	5409.5	37.66	7632.0	38.5
WM	M 31	1.91	36.24	7353.5	33.99	7108.5	35.12	7705.5	36.8
JB	M 58	1.88	34.07	6194.0	23.58	5983.0	23.15	5935.0	34.5
SM	F 39	1.54	27.51	5287.5	24.84	5136.0	25.42	5961.5	26.0
PG	M 35	1.60	28.05	5217.5	26.52	5018.0	25.12	5001.5	28.0
	Mean value :		30.01	5532.4	28.47	5507.5	28.55	5504.3	

Therefore, the smokers in this study were asked to abstain from smoking for 2 hrs prior to the test.

The duration of breath holding, inspired volume and alveolar volume calculated from the inspired and expired concentration of Helium during the tests showed no significant change, which indicates the observed diurnal change in DLco did not appear to be due to procedural measurement artifact.

It has been established that DLco (14) and blood volume (19) decrease on changing from the recumbent to the erect posture. It has been shown by plethysmographic and centre of gravity measurements (3) that maintenance of the erect posture is associated with a slow progressive shift in blood and tissue fulid towards the lower body parts, changing the ventilation/perfusion ratio. These changes are compatible with the change in DLco. However, no difference was observed in subjects who carry out their normal duties in the sitting posture. So gravitational effect might be ruled out (2).

TABLE II : Co-relation of 1-second forced expiratory volume to forced vital capacity at different times of the day.

Subjects	9 *a.m*		12 *noon*		5 *p.m.*	
	FEV_1 *in ml*	*FVC in ml*	FEV_1 *in ml*	*FVC in ml*	FEV_1 *in ml*	*FVC in ml*
CM	5350	5900	5050	5800	5200	6000
LM	1950	3250	1750	2050	2150	2700
CJ	2850	3700	2800	3700	2800	3700
MG	3890	4150	3750	4090	3730	4100
BS	2850	4000	2750	3850	2550	3500
AM	3525	4500	3400	4300	3300	4150
LD	3250	3600	3150	3700	3060	3700
EM	3800	4400	3750	4300	3850	4550
DM	2840	4000	2700	3850	2695	3850
RS	4250	5000	4000	5100	4250	5000
JM	2800	3400	2750	3200	2750	3200
MCF	2700	3250	2750	3350	2900	3500
MM	3550	4100	3500	4050	3400	4050
MS	5100	5600	5150	5700	5000	5600
DH	4900	4770	4850	5700	5000	6850
CS	4500	5150	4250	4950	4500	5000
WM	5300	5900	5100	5800	5050	5750
JB	2851	3850	2850	4000	2700	3850
SM	2650	3500	2650	3300	2650	3400
PG	4150	5000	4000	5000	3900	4800
Mean value	3652.8	4401.0	3547.5	4289.5	3572.0	4362.5

Blood haemoglobin (4) and the urinary adrenaline and nor-adrenaline excretions (8) appear to show a diurnal rhythm. The diurnal rhythm of blood haemoglobin and haematocrit is well established (16, 17) the fall of both being between 9.30 a.m. to 4.30 p.m. is 1.5 to 3.5%. It has been shown by Burrows and Niden (1) in men and dogs, confirmed by Jauasset-Strieder *et al.* (7), by experiments on dogs, that if the pulmonary capillary blood volume is maintained constant by holding the total lung blood volume constant, the DLco falls proportionately with the volume of red blood cells in the capillaries. The diurnal variation in hematocrit or in haemoglobin level might, therefore, account for the reduction in DLco observed in the present study. There is evidence that the level of plasma adrenaline and to a lesser extent, nor-adrenaline (18) rises sharply on awakening. The internal release of both amines falls throughout the day (8). Lewis *et al.* (12) have reported that infusion of nor-adrenaline causes rise in DLco measured in supine position. Although the dose used experimentally by these workers was large in comparison with the naturally occurring range of diurnal variation, the similarity of the two rhythms suggests that the fluctuation in the internal release of these amines may play a part in producing the change in DLco.

The study of FEV_1 and FVC was undertaken to show the magnitude of the change in the airways between the hours of experiment. Lewinsohn and Capel *et al.* (11) have found out that there is relatively large spontaneous variation in the FEV_1 and the FVC occurred between 9 a.m. and 5 p.m. in patients of obstructive airway disease. We found that even in normal healthy subjects there was fall of FEV_1 by 2.8% at noon. The afternoon value of FEV_1 was almost the same as that of the noon value. Similar changes were found in FVC.

It appears that the patency of pulmonary airways decreases in the noon since the airway conductance follows the same trend as the forced expiratory volume. So it is suggestive that decrease in the patency of pulmonary airways may also contribute to the change in the ventilation/perfusion ratio thereby affecting the diffusing capacity of the lungs.

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