Enclosure VIII

LUNG DIFFUSING CAPACITY FOR CARBON MONOXIDE AND ALVEOLAR-ARTERIAL TENSION DIFFERENCES FOR OXYGEN AND CARBON DIOXIDE IN COALMINERS STILL AT WORK [1]

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[1] Research supported by the High Authority of the European Community for Coal and Steel, by the Fonds National de la Recherche Scientifique and by the Fonds de la Recherche Scientifique Médicale, Brussels, Belgium.

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Previous work on pulmonary function in coalminer's pneumoconiosis has been carried out chiefly on workers who were complaining or asking for examination. The occurrence of bronchitis, tuberculosis, loss of physical training and changes in pulmonary function due to ageing tend to overestimate the importance of pneumoconiosis.

For these reasons, one of us (2) investigated the effects of different stages of pneumoconiosis on 301 volunteers, between 23 and 43 years of age, working underground in the coal-field of Campine (Belgium).

At rest, from category 2 p of simple pneumoconiosis onwards, there was a significant increase ($p < 0.05$) in mean alveolar-arterial O_2 gradient, which averaged 24.2 ± 7.7 mm Hg against 15.4 ± 7.1 mm Hg for surface workers. This O_2 gradient increased only slightly as pneumoconiosis worsened and there was a poor correlation with the X-ray picture. This correlation was found to be better during the 20 minute exercise.

A recent research was undertaken more recently in order to confirm and complete the first study.

Material and Methods.

A group of 73 subjects was studied : 30 normal males and 43 coalminers ranging in age respectively from 23 to 43 and from 31 to 43. All the coalminers were volunteers and had been normally active the day before the experiment.

The chest X-rays of the coalminers, classified according to the in-

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roentgenal classification of Geneva (1953), were divided in 3 groups :

- Group I (13 subjects) : r_1, m_1;
- Group II (17 subjects) : r_2, m_2, Ro_2, Am_2;
- Group III (11 subjects) : r_3, m_3, Am_3.

Lung diffusing capacity for CO, capillary blood volume and diffusing capacity of the alveolar capillary membrane were measured at rest and during exercise by the single breath method of Forster and al. (6). An automatic apparatus designed in our laboratory was used for the measurement of lung diffusing capacity (3).

An indwelling catheter was inserted in the brachial artery. A thermocouple was introduced $\pm$ 15 cm deep in the rectum of most of the subjects.

Forty ml of blood were taken in order to calibrate the P_{O_2} electrodes. The subject was then asked to rest for 45 minutes in the sitting position. This position was adopted for all the measurements.

Collections of expired air and arterial blood were made in the following sequence :

- at rest, breathing room air, after the breathing during 15 minutes of a low O_2 mixture (11-12 %) and then, in a randomized order, after the breathing during 15 minutes of a high O_2 mixture (50-60 %) and of pure oxygen (100 %);
- during exercise (10 minutes, 120-150 W on a cycloergometer), while breathing pure oxygen (100 %), room air and a low O_2 mixture (12-13 %).

Blood samples were taken into oiled syringes which were directly immersed in iced water. The P_{a,O_2} was measured by a modified Clark electrode.

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$D_{L,CO}$ = 23.3 (H) − 0.3 (A) − 21.0 (s = 4.0)

where H = height in meters and A = age in years.

[redacted] demonstrates a slight reduction of mean $D_{L,CO}$ in group I (91 % of normal value) and a more obvious lowering in groups II and III (82 % and 83 %). When considering individual values it is interesting to notice that the $D_{L,CO}$ of 7 coalminers is significantly lowered as compared to the theoretical value (2 in the first, 3 in the second and 2 in the third group). The mean value of their $(A-a)D_{O_2}$ difference while breathing a low O_2 mixture, at rest and during exercise, was found to be higher than the mean value for the same difference in the group of coalminers considered as a whole [redacted].

4. [redacted] while breathing pure oxygen (hyperoxia).

$(A-a)D_{O_2}$, while breathing pure O_2, at rest and during exercise, is augmented in coalminers [redacted].

5. $(A-A)PCO_2$ while breathing room air (normoxia)

$(a-A)PCO_2$, while breathing room air, at rest, is only little, not significantly, augmented in coalminers [redacted].

Discussion

The preliminary results of the second research program confirm the widening of the $(A-a)D_{O_2}$ difference previously found in coalminer's pneumoconiosis, while breathing room air, at rest and chiefly during exercise (2).

According to the classical analysis of Rahn and Fenn (3), $(A-a)D_{O_2}$ difference while breathing room air may be due to 2 factors : venous ad-

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[illegible], uneven distribution of ventilation to perfusion and failure in diffusion equilibration between alveolar air and blood.

On the contrary, the $(A-a)DO_2$ difference while breathing a low O_2 mixture would depend more completely upon diffusion limitation and $(A-a)DO_2$ while breathing pure O_2 upon venous admixture, i.e. the fraction of pulmonary blood flow that is totally non-ventilated. This virtual shunt, as utilized by Ayres and al. (1) arises from uneven distribution of ventilation to certain parts of the pulmonary capillary perfusate that, were it completely non-ventilated, would create the observed oxygen difference.

$(A-a)DO_2$ difference is probably due, not to any degree of shunting or diffusion limitation, but to distribution abnormalities. Alveoli that are relatively overventilated or have no perfusion at all will thus dilute the alveolar gas coming from normally ventilated and perfused alveoli.

$D_{L,CO}$ measured by the single-breath method seems to be poorly influenced by irregular distribution of ventilation to perfusion.

Rahnow (2) considered ventilation-perfusion abnormalities as the main reason for the increase of the $(A-a)DO_2$ difference observed at rest and during exercise in categories 2 and 3 of simple pneumoconiosis. He pointed out that the pathogenic mechanism was probably more complex in massive fibrosis where, in addition to the above-mentioned abnormalities, a restriction in O_2 diffusing capacity could be expected in some instances peculiar from a decrease in the pulmonary vascular bed. Additional venous admixture was found slightly increased in coalminers' pneumoconiosis, but its role in arterial desaturation seemed of secondary importance.

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The second research program concerns almost exclusively simple pneumoconiosis, since no cases with diffuse at stages B and C were investigated.

$(A-a)DO_2$ difference is found to be widened while breathing room air, at rest and during exercise. Theoretically, $(A-a)DO_2$ difference in these conditions could be influenced by some degree of diffusion limitation. However, it is generally believed that at rest and while breathing room air diffusion impairment plays only a minor role, even when $(A-a)DO_2$ difference is augmented while breathing a low O_2 mixture. On the other hand, the augmentation of the $(A-a)DO_2$ difference while breathing pure O_2 supports an increase of the venous admixture. A part of the augmentation of the observed $(A-a)DO_2$ difference while breathing room air can therefore be attributed to some degree of venous admixture.

Nevertheless, the most important part of the widening of the $(A-a)DO_2$ difference while breathing room air can be attributed to uneven distribution of ventilation to perfusion and more precisely to alveoli that are well perfused but poorly ventilated.

The decrease of the $D_{L,CO}$ and the increase of the $(A-a)PO_2$ difference while breathing a low O_2 mixture, at rest and during exercise, observed in the coalminers would tend to demonstrate that some degree of diffusion limitation exists in certain cases of simple pneumoconiosis.

On the contrary, the number of alveoli that are ventilated but not perfused seem to be augmented only slightly in coalminers' pneumoconiosis,

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as shown by the discrete elevation of the $(a-A)DO_2$ difference.

Summary

A first research project was performed on 101 coalminers still at work, between 35 and 45 years of age. This investigation, made on subjects in the supine position, showed a widening of the $(A-a)DO_2$ difference which was statistically significant at most from stage 2 p onwards and appeared even more significant during exercise.

A more recent and more elaborate study on 20 normal volunteers and 43 coalminers still at work, investigated in the sitting position, confirmed the increase of the $(A-a)DO_2$ difference while breathing room air, at rest and during exercise, from the early stages of simple pneumoconiosis onwards.

Furthermore, some degree of diffusion limitation seems to exist in certain cases of coalminers' pneumoconiosis, as shown by the decrease in $D_{L,CO}$ and the widening in the $(A-a)DO_2$ difference while breathing a low O_2 mixture.

Finally, the augmentation of the $(A-a)DO_2$ difference while breathing pure O_2 would suggest a slight increase of the venous admixture.

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