RESPIRATORY RESPONSE TO CO_2 BY CONTROLLED ALVEOLAR HYPERCAPNIA

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A method of assessing the respiratory response to a hypercapnic stimulus after an increase in alveolar pCO_2 in accordance with an assigned program is suggested. The results are independent of the metabolic level, resistance to respiration, and other factors. Unlike the widely used rebreathing method, this new method enables the ventilatory sensitivity to CO_2 to be compared at rest, during muscular work, when the resistance to respiration is changed, and so on. It can also be used for both clinical and experimental investigations.

KEY WORDS: regulation of respiration; response to hypercapnia; muscular activity; resistance to respiration.

To assess the functional state of the system controlling respiration determination of the response of the pulmonary ventilation to measured hypercapnia ("ventilatory sensitivity") is widely used in practice. The rebreathing method is most frequently adopted. Its advantages are its speed and high informativeness: an adequate number of points for plotting the curve reflecting dependence of the increase in pulmonary ventilation on the increase in pCO_2 in the alveolar air ($\Delta\dot{V}/\Delta p_A CO_2$) can be obtained at once. Admittedly, differences in the initial level of ventilation, and also the effect of these differences on the course of equalization of the CO_2 concentration in the lungs–bag system can distort the initial part of the curve appreciably. This disadvantage is overcome in Read's modification, which is based on the principle of creation of an "open loop" [1, 2]: Before the test the system is filled with a mixture in which the CO_2 partial pressure is close to pCO_2 of mixed venous blood, as a result of which during rebreathing the increase in $p_A CO_2$ takes place uniformly and independently of ventilation: it is due entirely to metabolic production of CO_2. At the same time, this feature is a disadvantage of the method: With an increase in the gas exchange in the body, especially during muscular work, accumulation of CO_2 in the rebreathing system can take place so fast that the curve of the response can no longer be compared with that obtained at rest. Furthermore, as the present writer's investigations have shown, with an increase in resistance in the air passages equalization of the CO_2 concentration in the lungs–bag system is delayed, whereas if the resistance is reduced (by breathing a mixture of helium and oxygen) it is accelerated, and this also can affect the results of the test.

The method developed by the writers is designed to produce progressive alveolar hypercapnia in the subject tested within the same range as during rebreathing by Read's method, the increase in $p_A CO_2$ is produced in accordance with a strictly assigned program and is independent of the conditions under which the test is carried out. For this purpose a gradually increasing flow of CO_2, the rate of which is regulated in order to produce an assigned increase in $p_A CO_2$ in the course of a definite time interval, is added to the flow of inspired (in an open system) air or oxygen or other gas mixture.

As shown in Fig. 1, the experimental subject or animal breathes through a mask, mouthpiece, or tracheal cannula (1) through a pneumotachographic tube (2). Of course any other method of recording pulmonary ventilation may also be used. The CO_2 concentration in the expired gas, including in its alveolar portion, is recorded continuously on a capnograph (3), and the results are displayed on an oscilloscope (4). Monitoring the rise in $p_A CO_2$ the operator (5) uses the rotameter (6) to regulate the supply of CO_2 from the cylinder (7) into the breating tube so that this increase corresponds exactly to the program indicated by a special line on the

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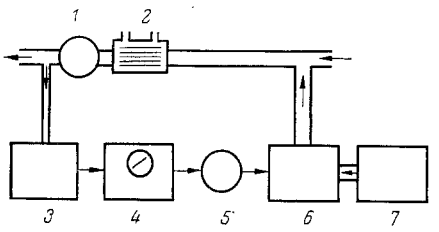

Fig. 1. Block-diagram of apparatus for controlling p_ACO_2 in accordance with assigned program. Explanation in text.

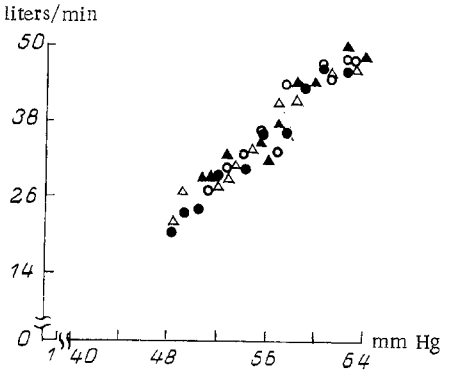

Fig. 2. Dependence of pulmonary ventilation in man on p_ACO_2 in tests by rebreathing method (two tests, indicated by empty and filled circles respectively) and by the control alveolar hypercapnia method (also two tests, indicated by empty and filled triangles). Abscissa, partial pressure of CO_2 in alveolar gas (in mm Hg); ordinate, volume of pulmonary ventilation (in liters/min).

oscilloscope screen, with which the beam showing the momentary value of p_ACO_2 must coincide. Horizontal displacement of the beam is so designed that it passes from beginning to end of this line in a time equal to the duration of the test.

The program envisages a steady increase with time in the value of p_ACO_2 from its initial level of 50 mm Hg, at which it is set beforehand, to 63 mm Hg in 2.5 min. Within this range, the dependence of ventilation on the hypercapnic stimulus is sufficiently linear. The lower limit of this range also lies definitely above pCO_2 of mixed venous blood of a person performing submaximal muscular work, otherwise the method would be unsuitable during intensive physical exertion.

The comparative investigations carried out showed complete agreement between results obtained at rest by Read's rebreathing method and by the method of controlled alveolar hypercapnia. The differences between the corresponding curves of ventilation as a function of p_ACO_2 (Fig. 2) were not statistically significant.

The method described above gave satisfactorily reproducible results. It was used by the writers to assess human respiratory responses to hypercapnia during exposure to various muscular loads, to changes in the resistance to the gas flow in the air passages, and so on. In principle it can be used to investigate ventilatory sensitivity not only of man, but also of animals, to CO_2.

LITERATURE CITED

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