EFFECT OF PROLONGED EXPOSURE TO A HYPEROXIC ENVIRONMENT ON THE GAS EXCHANGE OF ALBINO MICE

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Conflicting data may be found in the Soviet and Western literature on the effect of increased oxygen concentration on the living organism. Most authors [2, 4, 7, 9] consider that gaseous mixtures rich in oxygen (50-60%) cause a moderate increase in the gas exchange indices. Meanwhile, some authors [3] have found a low level of gas exchange in persons breathing air enriched with oxygen to this degree. During exposure to mixtures with a higher oxygen concentration (8-100%) a distinct depression of the gas exchange is observed in man and animals [3, 13]. Meanwhile, an increase in the oxygen consumption has been described in these conditions [11]. Many of the investigations cited above has been carried out with the use of relatively short exposures. Few investigations have been made of the influence of prolonged exposure to an environment enriched with oxygen on the gas exchange of the organism.

The object of this investigation was to study the dynamics of the gas exchange of animals during prolonged exposure to an environment with an increased oxygen concentration

EXPERIMENTAL METHOD

Experiments were carried out on 76 male albino mice of line CC 57W, aged three months, which were placed in groups of 10 at a time in two hermetically sealed chambers. The experimental group was placed in one chamber filled with the hyperoxic mixture, and the control group of mice was placed in the other chamber filled with air. The chambers were connected with a closed system for regeneration of the air, in which the carbon dioxide excreted by the animals was absorbed by a chemical alkaline absorbent, the water vapor by silica–gel and a condensation device, and the other metabolic products of the organism by activated charcoal. The chambers were ventilated by means of a blower. Oxygen was supplied automatically through a gas meter to replace that used by the animals. The total oxygen consumption was measured daily over a period of 17 h (from 4 p. m. to 9 a. m.). The carbon dioxide excreted by the animals was estimated by titration of the chemical alkaline absorbent throughout the period of the experiment. The temperature in the chamber was kept at 20-23°. Twice daily, at 9 a.m. and 4 p.m., control estimations were made of the composition of the gas in the chambers by means of a Haldane apparatus. The gas exchange was determined in the following conditions, denoting the length of continuous stay of the animals in environments with different oxygen concentrations: with 40% oxygen 27 days (series I), with 60% oxygen 39 days (series II), with 80% oxygen 42 days (series III), and with 90% oxygen 10 days (series IV).

EXPERIMENTAL RESULTS

In the animals kept in an environment containing 40% oxygen mixed with nitrogen, the oxygen consumption rose during the first three days on the average by 20% over its initial level, and the level of oxygen consumption of control animals kept in an environment of air. Subsequently, the oxygen consumption of the mice of this group fell to the initial values, and their gas exchange was almost identical with that of the control mice. Replacement of the hyperoxic environment with air after the 27th day of the experiment, had no effect on the level of the oxygen consumption (Fig. 1).

A different picture was seen when the mice were kept in a mixture of nitrogen and 60% oxygen for 39 days. From the first day of the experiment the oxygen consumption of these animals began to increase and it reached its maximal level by the 25th-26th day of exposure (80% of the initial level). Later, the level of the gas exchange gradually fell. By the 34th day of the experiment and thereafter it was the same for the experimental and control animals. After replacement of the hyperoxic environment by air, the gas exchange of the experimental animals showed no difference from that of the controls (Fig. 2).

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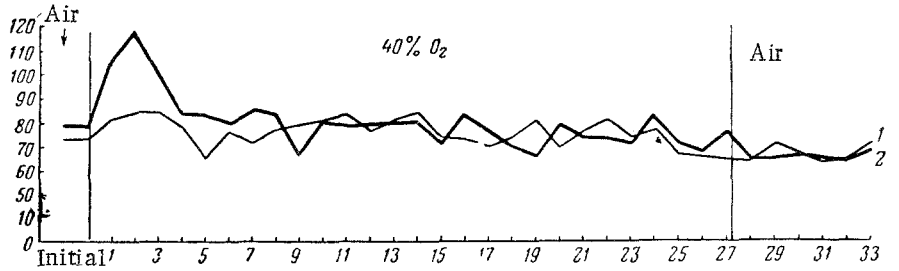

Fig. 1. Dynamics of oxygen consumption in a hyperoxic medium with a 40% concentration of oxygen. Here and in Figs. 2-4: 1) control; 2) experimental group of mice. Along the axis of ordinates—oxygen consumption (in ml/mouse/h), along the axis of abscissas — days.

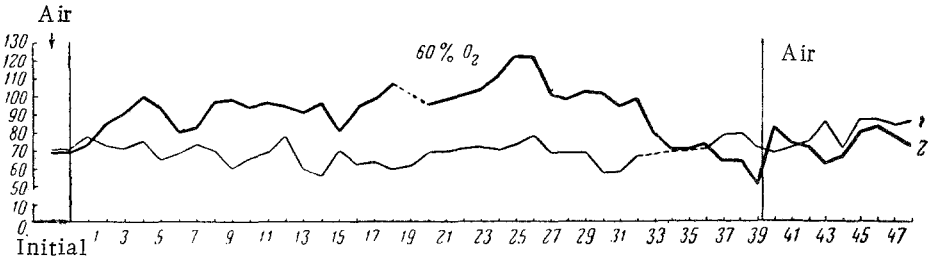

Fig. 2. Dynamics of oxygen consumption in a hyperoxic environment containing 60% oxygen. Here and in Fig. 3, the broken line denotes an interruption in the recording of the oxygen consumption.

Inhalation of hyperoxic mixtures (40-60% oxygen) was thus accompanied by a transient increase in the oxygen consumption. In the first case, an increase in the oxygen consumption was observed for a short time (3 days) while in the second case it lasted longer (26 days). The higher level of oxygen consumption in the mice of the experimental group in both series of experiments was accompanied by an increase in the excretion of carbon dioxide by the animals. No difference between the weight of the control and experimental animals was observed as a result of the experiment.

The results of these experiments showing an increase in the gas exchange of mice kept in hypertoxic environments are in agreement with those of the author's earlier experiments in which mice were kept for 5 days in an environment containing 60% of oxygen [4].

The increased gas exchange in mice kept in a hyperoxic environment may be the result of changes in the level of the oxidative metabolic processes in the body associated with the modified gaseous composition of the atmosphere [8]. On the other hand, the hyperoxic environment increases the excitability of the respiratory center and increases the volume of the pulmonary ventilation [10], and this may also be a cause of the increase in the oxygen consumption. The subsequent restoration of the normal level of gas exchange may evidently be interpreted as a manifestation of the adaptation of the organism to the increased oxygen concentration (40-60%) in the air.

Conversely, in the animals kept in an environment with an 80% concentration of oxygen, from the first days a persistent fall in the level of the oxygen consumption was observed, to 27% of its initial value. The level of the gas exchange fell particularly sharply on the 8th-9th day of the experiment. Later the level of the oxygen consumption became stabilized (44% below the initial level). The weight of the animals was decreased by 20% after the experiment. When the hyperoxic environment was replaced by air, the gas exchange of the mice showed a tendency to return to normal. However, during the 8 days after the end of the experiment, the oxygen consumption failed to return to its initial value (Fig. 3), although the weight of the mice was restored to its initial level.

In the experiment in which the mice inhaled a mixture containing 90% of oxygen, as in the preceding experiment, after the first day of exposure the oxygen consumption began to fall, and by the 4th day it had fallen to 60% below the initial level. On the 7th day of the experiment, some of the mice began to die. Replacement of the hypertoxic environment by air was accompanied by death of most of the animals. At necropsy, edema of the lungs

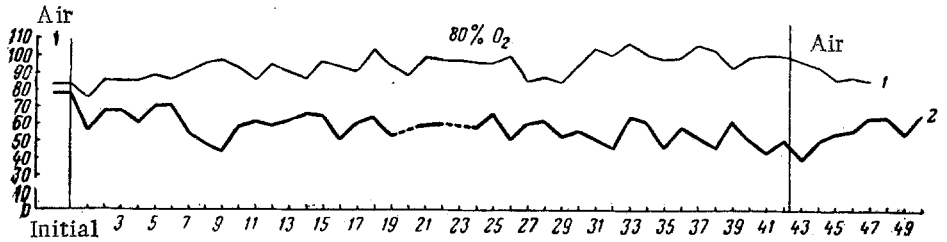

Fig. 3. Dynamics of the oxygen consumption in a hyperoxic environment containing 80% of oxygen.

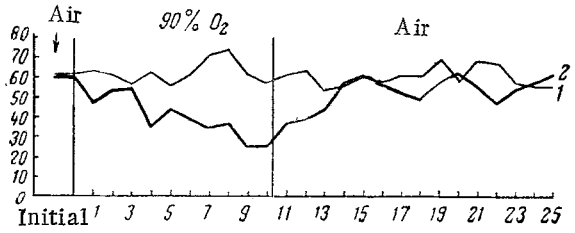

Fig. 4. Dynamics of the oxygen consumption in a hyperoxic environment containing 90% of oxygen.

was found. In the three surviving mice after the change to inhalation of air, a gradual increase of the oxygen consumption began, reaching its initial level on the 4th day (Fig. 4). Such a comparatively rapid restoration of the level of the gas exchange was probably due to the higher resistance of the surviving mice to the toxic action of oxygen.

In these experiments, therefore, the prolonged stay (42 days) in an environment containing 80% of oxygen did not cause their death, although the animals became apathetic and adynamic, and their appetite diminished. There are reports in the literature that rats kept for long periods in a gaseous environment with the same concentration of oxygen developed pathological changes in the lungs [1, 6].

An environment containing 90% of oxygen proved frankly toxic for the mice. The animals began to die on the 7th day of exposure. According to reports in the literature, mice die at the same times when inhaling pure oxygen [12].

The significant depression of the level of gas exchange in the mice in these experiments in environments containing 80% and 90% of oxygen was evidently connected primarily with the general depression of metabolism as a result of the excess of oxygen [5]. At the same time, other factors associated with the influence of oxygen on the cardiovascular system (vasoconstriction, slowing of the blood flow, slowing of the heart rate), or with disturbance of the function of the lungs (inflamatory phenomena, edema, atelectasis, a decrease in the volume of pulmonary ventilation, etc. [1, 6, 13]), may also play a part.

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