

PATHOLOGICAL PHYSIOLOGY AND GENERAL PATHOLOGY

THE EFFECT ON MONKEYS OF A PROLONGED STAY IN AN ENVIRONMENT WITH AN INCREASED OXYGEN CONCENTRATION

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Experiments conducted by various authors [8,14,24] on animals and man have not yielded a consistent answer to the question of the influence of increased concentrations of oxygen on the nervous system.

The study of the prolonged action of a hyperoxic atmosphere on monkeys may provide much additional information concerning some aspects of the influence of this environment on the functions of the human organism. Such information may help to solve the problem, at present uncertain, of the maximal allowable periods during which man may inhale hyperoxic gaseous mixtures.

In the present investigation, the dynamics of certain physiological indices was studied in monkeys kept for 10 days in a gaseous environment containing 60% of oxygen.

EXPERIMENTAL METHOD

Experiments were conducted on two young, sexually mature macaque (body weight, 3.6 kg) and capuchin (body weight 1.9 kg) monkeys. For more than three months before the experiments began, the animals were fixed to a special frame. The work of American investigators [21,22] and of the authors [10] has shown that monkeys are readily adapted to a prolonged stay in conditions of restricted motor activity.

During the experiment, the monkey, fixed to the frame, was placed in an airtight chamber 400 liters in volume, fitted with a window for observation and luminescent illumination, switched on daily from 7 a.m. until 7 p.m.; the rest of the time the animals were kept in relative darkness. The chamber was connected by pipes to a closed system of regeneration of the gaseous environment, so that the given oxygen concentration in the chamber was maintained; the concentration of carbon dioxide was 0.2-0.4%, the relative humidity 70-80%, and the temperature 25-26°.

After a period of adaptation to the experimental conditions, each experimental monkey was investigated for 10 days in an atmosphere of the usual composition. A hyperoxic environment (60% of oxygen, 40% of nitrogen) was then created in the chamber and the animals were kept in it for the next 10 days. Investigations then continued in an atmosphere of the normal composition. The observations on the macaque monkey continued for 5 days after the return to ordinary air, and those of the capuchin monkey for 5 days. During the period of the experiment, the length of time spent by the monkeys awake and asleep in each 24-h period was recorded. Every h the volume of oxygen consumed and the respiration rate were recorded. Every 5 days, the rectal temperature of the animals was measured by means of an electrical thermometer, and blood was obtained for analysis by puncturing the tail.

Two indices were used to characterize the higher nervous activity of the monkeys: the rate of extinction of the orienting reflex and the probability assessment of events (discrimination between levers by the frequency of reinforcement of pressures on them). The orienting reflex was investigated by the method of L. G. Voronin and G. I. Shirkova [4] and it was tested every 2-3 days in the experimental animals. The probability assessment of events was studied in the monkeys by means of a method in which pressures on two identical levers were reinforced

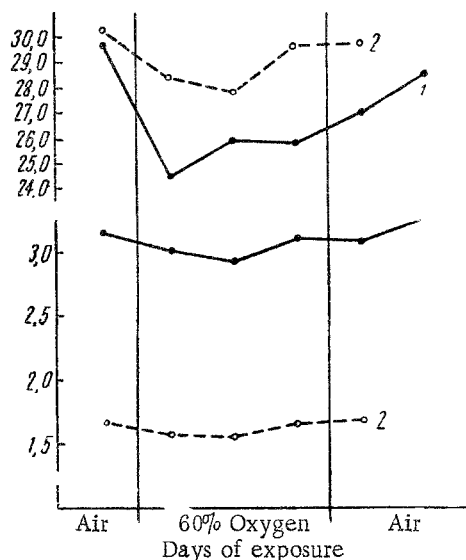


Fig. 1. Effect of hyperoxic environment on the respiration rate (A) and oxygen consumption (B) of the macaque (1) and capuchin (2) monkeys. Along the axis of abscissas — periods of observation and exposure (in days); along the axis of ordinates — respiration rate per min (A) and oxygen consumption in liters/min (B). Each point on the curve represents the mean value during a 3-day period of observation.

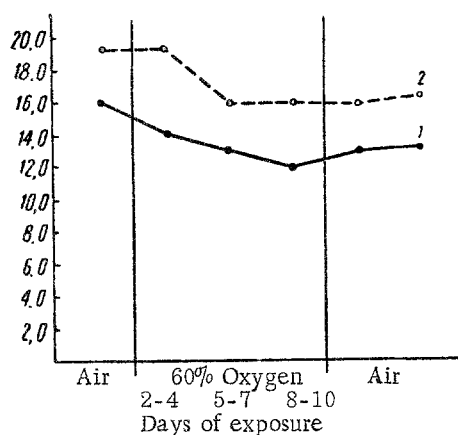


Fig. 2. Effect of a hyperoxic environment on duration of the daily period of waiting (in h) in the macaque (1) and capuchin (2) monkeys. Rest of legend as in Fig. 1.

objects (pieces of rubber tube) which were offered to the animal at intervals of 30 seconds, was observed. The monkey took the tube, sniffed at it, bit it, and played with it. This reaction was shown many times so long as the monkey continued to take the tube. If, for a period of 10 sec, the animal did not take the tube offered to it, the reaction died away and the test was reapplied at the stipulated time. The orienting reflex was considered to be extinguished if the monkey did not take the offered object 5 times in succession. The rate of extinction of the orienting reaction

at different frequencies and in the following order: three pressures on the left lever and one on the right [9]. The investigations were carried out once in 5 days. The number of pressures applied to each lever during the experiment (100 pressures) was recorded.

EXPERIMENTAL RESULTS

It is clear from Fig. 1a that the hyperoxic environment led to a decrease in the respiration rate of both monkeys, especially during the first day, and this was considered to be a compensatory reaction of the animal to the excessive oxygen intake [6,15,17]. Slight depression of the gas exchange was also observed at the beginning of the stay in an oxygen-enriched atmosphere (Fig. 1b). Subsequently, the oxygen consumption returned to its original value. These transient changes in gas exchange may be explained by the slowing of the metabolic processes taking place during the inhalation of oxygen [2]. The rectal temperature of the macaque in the period of the after effect was 0.2-0.5° below the initial level; this agrees with reports in the literature [1,18].

During the period of exposure to an environment with an increased concentration of oxygen, the hemoglobin concentration of erythrocyte count of the macaque fell (see table), presumably because of the redistribution of blood and the depression of erythropoiesis, generally regarded as the characteristic reaction to hyperoxia [5,12,13,16,19]. After the animal had been transferred to an atmosphere of normal air, the hemoglobin concentration and color index rose. This may have been due to the emptying of the blood depots in response to a fall in the oxygen concentration in the atmosphere [7,11]. Because of the extreme instability of this index in normal conditions, the blood changes in the capuchin monkey were not investigated.

During the period of stay of the monkeys in the hyperoxic environment, a moderate leukopenia was noted, in general agreement with previous findings in albino mice [3].

Exposure to an environment with a 60% concentration of oxygen caused no significant change in the general condition of the monkeys, although during this period the body weight of the capuchin monkey fell by 6-7%.

In the hyperoxic atmosphere, the daily waiting period of the animals was reduced (Fig. 2), possibly on account of the influence of the high partial pressure of oxygen on interaction between the processes of excitation and inhibition in the central nervous system [14, 24].

In previous investigations [10], it was noted that during exposure to unfavorable conditions, the orienting reaction of the monkeys was depressed. In the present experiments, during investigating of the orienting reflex, the reaction of the animal to uniform inedible

Time of taking blood	Red blood			White blood		
	Erythrocytes (in millions/ mm ³)	Hemo- globin (in g %)	Color index	Leukocytes (in thousands/mm ³)		
				Total	Neutrophils	Lymphocytes
Before experiment	8.0	16.5	0.62	16.9	6.6	9.1
In medium with 60% O ₂ concentration: 5th day	4.1	10.1	0.74	13.4	6.5	6.6
10th day	5.8	13.5	0.70	8.9	3.2	5.4
After transfer to environ- ment of air (5th day)	6.3	17.8	0.85	18.0	6.0	10.9

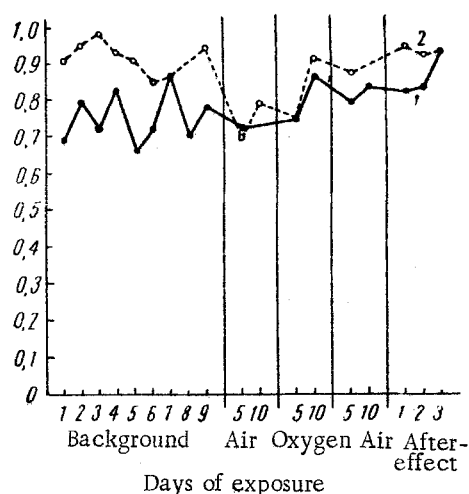


Fig. 3. Effect of hyperoxic environment on system of pressures on levers in monkeys: 1) frequency of pressures on more commonly reinforced lever in the macaque; 2) the same in the capuchin.

before the animals were transferred to the hyperoxic environment was equivalent to 52 ± 11 presentations of the object in the case of the macaque and 59 ± 9 in the case of the capuchin. During exposure to 60% oxygen, the reflex in the monkeys was extinguished after 67 ± 21 and 66 ± 15 presentations of the object, respectively. Hence, a tendency was observed for the rate of extinction of the orienting reflex to be reduced.

Previous observations [9] showed that monkeys readily differentiate between levels by the number of reinforcement of pressures on them (more or less frequently), but they did not learn the order of the pressures. There came a time when the animal almost completely ceased to press on the least frequently reinforced lever. Before the beginning of this experiment, the frequency of pressures on the lever by the monkeys had become constant. During the period of exposure to the hyperoxic atmosphere, the animals retained the system of responses they had previously developed (Fig. 3).

It may be assumed that the changes observed above in the diurnal balance of sleep and waking were not so important as to give rise to disturbances in the reflex activity of the monkeys.

The results obtained thus indicate that the animals remained in a comparatively satisfactory state throughout the experiment. This conclusion is in agreement with information in the literature concern-

ing the relatively high resistance of primates to the action of hyperoxia. For instance, in an environment with 95-99% of oxygen, signs of poisoning appeared in rodents after 15-20 h, in dogs after 36-42 h, but in monkeys not until after 72-96 h of exposure [23]. American investigators have recently reported that no visible functional changes were observed in a chimpanzee kept for 15 h in pure oxygen, apart from slight bradycardia and an increase in the respiration rate [20].

The results of these observations thus showed that exposure of the macaque and capuchin monkeys for 240 h in an environment with a 60% concentration of oxygen gave rise to no pathological changes in the studied functions. Fluctuations in some indices (respiration, the morphological composition of the blood, and so on) that were observed were transient in character. This shows that the monkey is well adapted to life in a moderately hyperoxic environment.

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