THE EFFECT OF OXYGEN LACK AND PROLONGED RADIAL ACCELERATION ON ANIMALS

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Problems in aviation medicine cannot be successfully solved without comprehensive studies of the effects on animals and man of the principal factors encountered in flight, especially oxygen lack and radial acceleration.

The investigations of I. M. Sechenov [9], I. P. Pavlov [6], V. V. Pashutin [7] and others have shown that in the course of evolutional development and adaptation to the external environment, defensive mechanisms have been formed to prevent injury to the organism.

Experimental research has shown that in the presence of considerable oxygen lack, and also when radial acceleration reaches extremely high values, notwithstanding the existence of compensatory mechanisms, profound disturbances of the various systems of the body may arise, affecting especially the activity of the higher divisions of the brain [2, 3, 4, 8, 10, 12, and others]. However, much remains to be done in connection with the study of the appearance and development of compensatory and adaptive reactions to the influence of anoxia and acceleration on the body.

We undertook the investigation of conditioned reactions of respiration and cardiac activity in conditions of oxygen lack in animals at a height of 2000-10 000 m, and we also studied the character of the changes in the roentgenological picture of the thoracic organs in relation to the different values of the acceleration produced by spinning in a centrifuge.

EXPERIMENTAL METHOD

Experiments were carried out on 20 dogs. For the pressure chamber experiments conditioned motor, respiratory, and cardiovascular reflexes were developed and consolidated as a preliminary step by V. P. Protopopov's method. The conditioned stimuli were a bell, a light of variable intensity, and pure tones produced by a sound generator: 1000 and 400 vibrations per second. The unconditional stimulus was an electric current. The interval between the stimuli was 4 minutes. The experiments were performed in the pressure chamber in conditions corresponding to ground level and altitudes of 2000 to 10 000 meters; their duration was not less than 50 minutes.

The respiratory movements, the electrocardiogram, and the markers of the conditioned and unconditioned stimuli and the time (in seconds) were recorded simultaneously on a multichannel ink-recording oscillograph.

The effect of radial acceleration on the organism was studied on a centrifuge with a radius of 3.66 meters, fitted with an x-ray apparatus. The effects of centrifugal forces equal to 2-9 g, acting in the direction from head to foot, were studied.

EXPERIMENTAL RESULTS

In the pressure chamber investigations we studied both the conditioned and the unconditioned reflex reactions of respiration and cardiac activity to anoxia.

In these investigations the changes in respiration at heights of 2000-10 000 meters were expressed in some dogs as an increase in the amplitude, and in others as an increase in the frequency of the respiratory movements, i.e., the function of respiration was modified in a manner depending on the individual peculiarities of the dogs. The rate of the heart was increased in all the dogs in a rarefied atmosphere (Table 1).

The strengthening of respiration and of the cardiac activity during oxygen deprivation may be the result of a reflex not only from the chemoreceptors of the carotid sinus and cardio-aortic regions, but also from receptors in other parts of the cardiovascular system and tissues [11].

When a conditioned reflex was developed in ground level conditions, as a rule the reactions of the heart and respiration appeared much sooner than the motor defensive reaction, and conversely, when extinction took place, the motor defensive reaction was the first to disappear. The conditioned reflex changes in respiration and cardiac activity was closely related with the initial functional state of the respiratory and vasomotor centers. For instance, if the conditioned stimulus was applied against the background of a slow respiration rate, as a rule the change took the form of an increased frequency of respiratory movements, and vice versa. As an illustration we show a curve recorded in one of the experiments at a height of 2000 meters (Fig. 1).

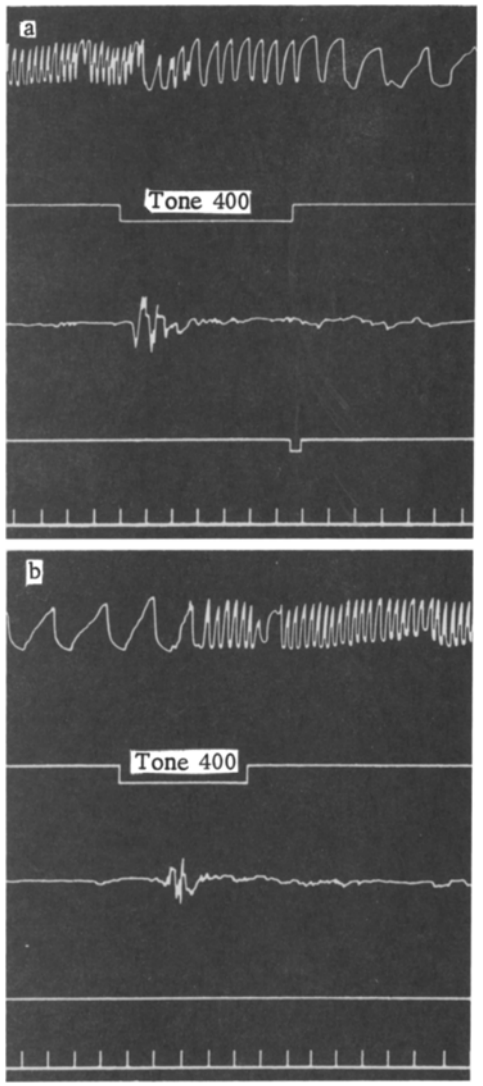

Fig. 1. Change in the character of respiration during the action of a conditioned stimulus. a) Slowing of respiration; b) increased rate of respiration.

This relationship between the change in the autonomic components of the conditioned reaction and the initial functional level of respiration and cardiac activity was apparent only at moderate altitudes (1000-5000 meters). At altitudes of 6000-9000 meters the changes in respiration and cardiac activity were unconditioned in character and were aimed at adapting the organism to existence in the unfavorable conditions of the atmospheric environment. At heights of 9000 meters or more, profound changes in vitally important functions began to develop, in the form of periodic respiration, arrhythmia of the pulse, and so on.

In second series of experiments we studied the effect of prolonged radial acceleration on the organism. Numerous investigations by Soviet and other workers have shown that considerable changes take place in the functional state of the central nervous system as a result of disturbance of the cerebral circulation and of the displacement of organs and tissues [4, 8, 10, 13, 14].

In our research we used a roentgenological method to obtain a closer insight into the character of the blood flow in the pulmonary vessels and the chambers of the heart during the action of radial acceleration of different magnitudes.

The changes which we found during acceleration were as follows: a decrease in the size of the heart, and in tne intensity of its shadow, and a change in the pattern of the lung markings. These changes were dependent on both the physical characteristics of the acceleration (magnitude and duration) and the functional state of the organism.

Examination of the roentgenograms taken at the moment of action of acceleration on anesthetized animals shows that essential changes appeared in the radiological picture of the thoracic organs during acceleration of the order of 2-4 g, whereas in unanesthetized animals similar changes were observed only during exposure to greater acceleration (6 g and over). The roentgenograms obtained in an unanesthetized dog during the action of acceleration of 2 and 6 g are shown in Fig. 2.

The results of linear and planimetric measurements of the heart shadow made on these roentgenograms are given in Table 2.

It will be seen from Table 2 that the decrease in the transverse diameter and also in the area of the heart shadow in the anesthetized animals was more marked during exposure to small accelerations (2-4 g). A higher magnitude of acceleration (6-8 g) caused a less marked change in the dimensions of the heart shadow. In the unanesthetized animals the changes in the area of the heart shadow were proportional to the magnitude of the acceleration.

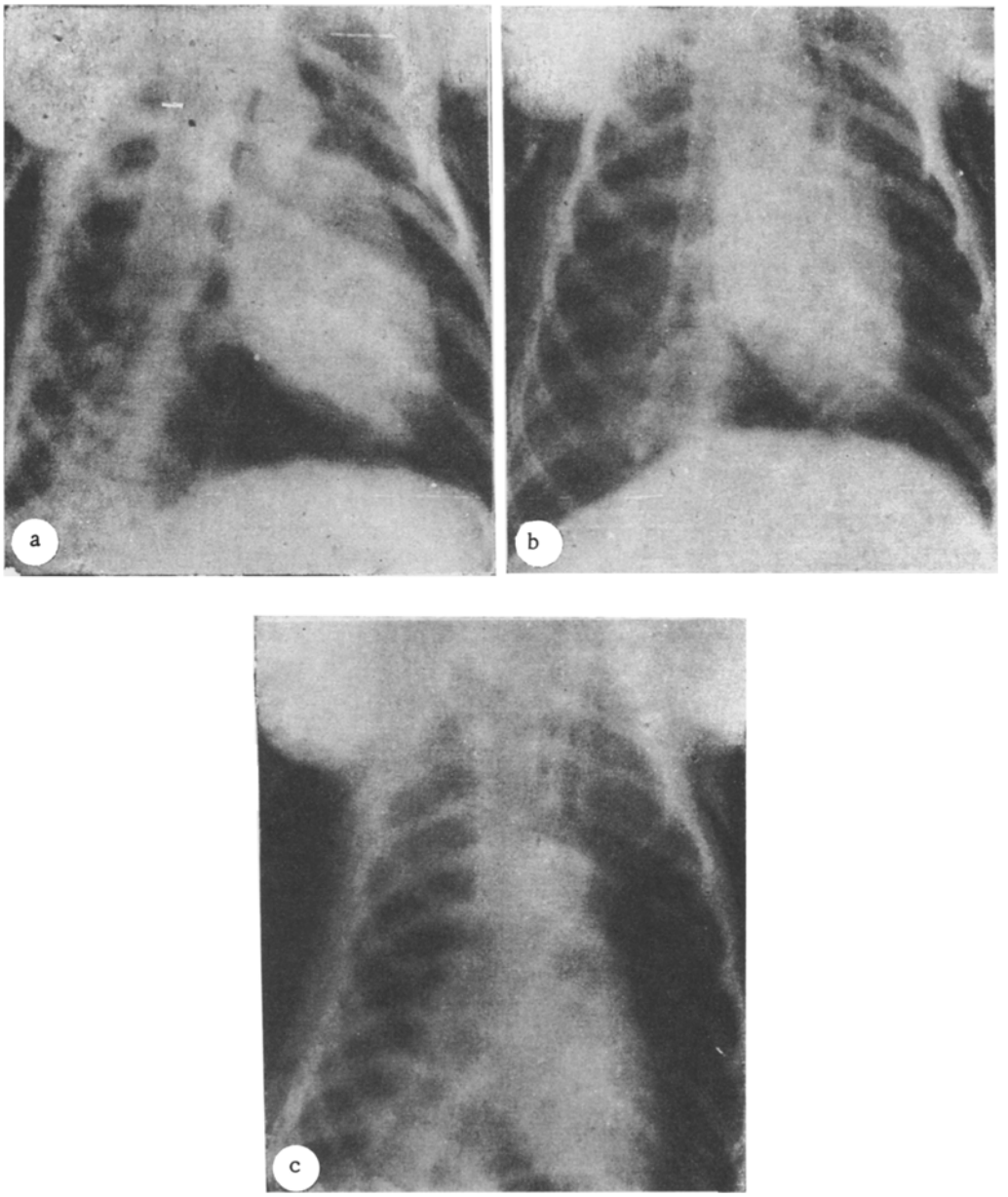

Fig. 2. Roentgenogram of the thoracic organs of the unanesthetized dog Bobik in its initial state (a) and after exposure for 20 seconds to an acceleration of 2 g (b) and 6 g (c).

During the action of acceleration the normal blood supply of the vitally important organs and, in particular, the central nervous system, is impaired, which leads to a reduction of the working capacity of the organism. Furthermore, the afferent impulses arising as a result of displacement and deformation of the tissues and organs also have a definite effect on the functional state of the central nervous system. When the acceleration is small, the afferent impulses have a positive effect, for they bring into play the compensatory, adaptive reactions of the body. During long exposure to great acceleration, such profound functional disturbances develop in the circulatory system that the afferent impulses arising in the displaced and deformed organs and tissues may have an adverse effect on the functional state of the central nervous system.

TABLE 1. Heart Rate at Ground Level and in a Rarefied Atmosphere

Dog	Ground level	Rarefied atmosphere equivalent to an altitude of (in meters):				
		2,000	4,000	6,000	7,000	10,000
Pirat	80	90-100	110-115	120-150	130-170	220-260
Kashtan	100	110-130	140-170	180-220	220-250	260-300
Zhuchka	95	130-150	160-180	180-200	200-220	250-270
Markiza	110	140	150	160-170	165-180	–
Bobik	90	135	160	160-180	170-200	–
Tsvetok	80	95-105	100-120	115-145	130-160	210-255

TABLE 2. Results of Measurement of the Heart Shadow

Magnitude of acceleration (in g)	Unanesthetized dog Bobik			Unanesthetized dog Bobik		
	Diameter (in cm)	Length (in cm)	Area (in cm^2)	Diameter (in cm)	Length (in cm)	Area (in cm^2)
0	5.3	7.0	32	6.3	7.2	35
2	4.5	7.3	25	6.2	7.5	34
4	4.0	7.5	23	6.0	7.2	32
6	4.0	6.8	21	5.8	7.0	29
8	3.9	7.2	22	5.8	5.9	24

From the analysis of our experimental findings we may conclude that during the action of moderate oxygen deprivation and small magnitudes of acceleration (up to 4 g) the compensatory, adaptive mechanisms can counteract the adverse influence of these factors, whereas in acute anoxia (altitudes of 7000 meters or higher) and during great acceleration (5 g or more) the working of the compensatory mechanisms is disturbed and considerable impairment of the various functional systems of the body develops.

SUMMARY

In conditions of oxygen defiency in raising the animals to the altitude of 2,000-10,000 m a study was made of the conditioned reflex reactions of respiration and cardiac activity; an inquiry was also made into the character of the changes occurring in the roentgenological picture of the chest organs in relation to various acceleration values created in rotation on a centrifuge. As established, in conditions of oxygen deficiency at the altitude of 6,000-9,000 m the vegetative components of the conditioned reflexes are depressed almost completely and are replaced by the unconditioned ones, manifested in a marked intensification of the respiratory function and of the cardiac activity. At the altitudes of over 9,000 m there occur marked disturbances of these functions, manifested in periodic respiration and cardiac arrhythmia.

With the action of the centripetal forces on the organism in the direction head tail a reduction of the size and of the intensity of the cardiac shadow takes place, as well as a shift in the position and deformation of internal organs. The character and the extent of the changes in the roentgenological picture of internal organs depends both on the value and the duration of the acting acceleration, and on the initial functional state of the central nervous system.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
