COMPARATIVE ANALYSIS OF THE EFFECT OF OVERLOADING AND HYPOXIA ON THE OXYGEN TENSION IN THE BRAIN TISSUES

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Several authors [1-3, 11] have established that overloading causes sharp changes in the functional state of the central nervous system, which most investigators associate with manifestations of acute hypoxia resulting from disturbances of the cerebral circulation [10, 17, 20, 25].

This point of view clashes not only with experimental findings relating to the special features of the course of cerebral hypoxia [7, 9, 15, 24, 25] and to the ability to maintain the constancy of the cerebral circulation in the presence of marked hemodynamic disturbances [2, 8, 23], but also with the results of direct investigations of the cerebral circulation during the period of action of overloads [13, 14, 19-22]. This problem could be clarified by the determination of the oxygen concentration in the brain tissues by the method of polarography [12, 16], but few such investigations have been made. Experiments on anesthetized cats have shown that during moderate overloading (unfortunately the author cited gives no details) in the direction from head to pelvis, the value of pO_2 in the superficial layers of the brain may fall significantly [18]. Somewhat different results were obtained by other workers [4-6]. In chronic experiments on dogs it was found that a fall in the value of pO_2 in the brain tissues takes place only when the overloading exceeds 4 g. With lower values of overloading the pO_2 in the brain tissues may actually increase slightly. As a result of the investigations undertaken by the authors cited above it was concluded that oxygen lack is "one of the principal factors in the pathogenesis of the disturbances caused by accelerations."

The object of the present investigation was to clarify the problem of the relative role of hypoxia in the mechanism of the disturbances of the activity of the central nervous system during overloading and also to study the influence of repeated overloading on the value of pO_2 in the brain tissues.

EXPERIMENTAL METHOD

Chronic experiments were performed on cats and rabbits. The oxygen tension in the brain tissues was determined polarographically [12, 16] with a potential difference of 0.65 V. The cathode consisted of stationary platinum electrodes 0.14 mm in diameter, which were implanted by means of a stereotaxic apparatus in different parts of the brain 5-7 days before the experiment began. The anode was a silver chloride electrode 4 cm^2 in area, clipped to the medial surface of the concha auriculae. The diffusion currents were recorded by a type VD-1 micrograph (Kirr, Holland).

Acceleration was produced by a centrifuge of radius 2 m. In experiments on cats the influence of overloads ranging from 2 to 23 g (in the direction head–pelvis) and from 2 to 10 (pelvis–head) was investigated. In the experiments on rabbits the magnitude of the overloads varied from 2 to 12 g and from 2 to 5 g respectively. The length of exposure was 1.0-1.5 min. To eliminate local overloads the animals were placed in special containers, shaped to fit their body. The inside walls of the container were covered with a layer of foam rubber.

The degree of hypoxia was estimated from altitude tests – the animals were "elevated" in a pressure chamber to an "altitude" of 6000 and 10,000 m (cats) or 5000 and 8000 m (rabbits).

The "ascent" and "descent" took place at a mean velocity of 50 m/sec. The mean length of the animals' stay at "altitudes" of 5 and 6 km was 1.5-3.0 min, and at altitudes of 8 and 10 km not more than 1 min. To elim-

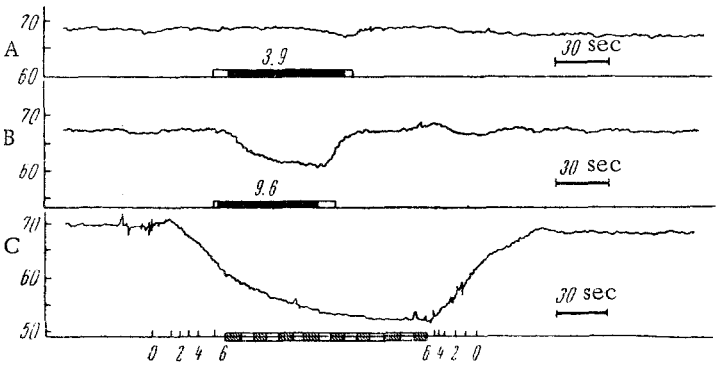

Fig. 1. Effect of the magnitude of overloading on the pO_2 level in a cat's brain tissue: A) change in pO_2 in the region of the anterior colliculi during overloading of 3.9 g in the direction head–pelvis; B) during overloading of 9.6 g; C) during "ascent" to an "altitude" of 6000 m. Here and in Figs. 2 and 3, along the axis of ordinates – pO_2 in relative units; along the axis of abscissas – time of exposure. The thickened line denotes the "plateau" period of overloading, and the number above it shows its magnitude. In the experiments with an "ascent" to an "altitude" the "altitude" in kilometers is plotted along the axis of abscissas.

inate any effect of one factor on the other, in some experiments the animals made their "ascent" before exposure to overloading, and in others after.

To judge how the animals tolerated overloading, recordings were made of their respiration, ECG, and in some experiments to the EEG. Altogether 37 experiments were carried out on four cats and 11 rabbits. In each experiment the animals were exposed to the action of 3-10 overloads.

RESULTS

During overloading of the cats and rabbits no essential differences were observed in the picture of the changes in the pO_2 level in their brain tissues. At the same time, it was found that the changes in pO_2 in the rabbits developed at slightly lower degrees of overloading than in the cats. No significant differences were found in the changes in the pO_2 level in the brain tissues of the cats and rabbits during their "ascent."

Since the pO_2 level in the brain tissues showed different changes depending on the magnitude, direction, and repetition of the overloading, the experimental results were assessed for each factor separately.

During overloading in the direction head–pelvis ranging from 1.5 to 3.5 g, the pO_2 level in the brain tissues usually rose slightly at the actual moment of exposure to its action or remained at the initial level (Fig. 1).

With more severe overloading – from 5 to 7 g (cats) and from 4.5 to 5.5 g (rabbits), at the beginning of exposure the pO_2 level in the brain tissues also rose slightly at first, but then – after 15-30 sec – it fell either to its initial value or below it, although remaining within physiologically normal limits.

Overloads ranging from 8 to 12 g (cats) and from 6 to 9 g (rabbits) led to an appreciable fall in pO_2 in the brain tissues in both the cortex and the subcortical structures. The fall was greater the longer the duration of exposure to overloading. However, no strict relationship could be established between the magnitude of the overload and the pO_2 level in the brain tissues.

The altitude tests showed that during exposure to overloading the pO_2 level in the animal's brain tissue remained higher than during its "ascent" to 5000 m. A more marked fall in pO_2 (corresponding to an "ascent" to 8000-10,000 m) was observed only when the cats were exposed to overloads ranging from 16 to 23 g, and the rabbits – from 14 to 18 g (see table). During exposure to these overloads, the animals developed marked disturbances of their cardiac activity and external respiration.

Comparative Assessment of Changes in pO_2 in Brain Tissues during Exposure to Overloading and in Conditions of Acute Oxygen Insufficiency*

Factor	No. of animals	No. of determinations	M	σ	P	P (by comparison with "ascent" to an "altitude" of)		
			by comparison with initial state (in %)			5000 m	8000 m	10,000 m
Overloading in direction head–pelvis:								
1.5-5.5 g	11	26	95 ± 1.6	8.1	< 0.01	< 0.01		
6.0-10 g	11	14	79 ± 4.7	13.4	< 0.01	= 0.8	< 0.01	
14-18 g	8	8	56 ± 2.8	7.9	< 0.01	< 0.01	0.8	< 0.01
Overloading in direction pelvis–head 3-5 g	7	9	53 ± 1.4	5.2	0.01	< 0.01	0.9	< 0.1
During "ascent" to an "altitude" of (in m):								
5000	11	17	78 ± 0.3	5.8	< 0.01			
8000	11	12	57 ± 2.1	7.3	< 0.01			
10,000	8	8	45 ± 1.0	3.0	< 0.01			

* The pO_2 level in the initial state is taken as 100.

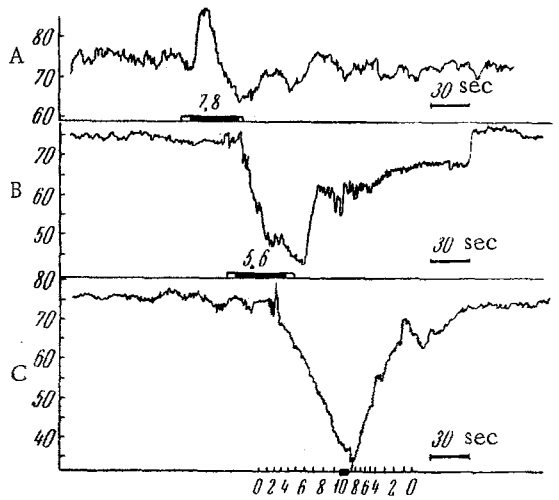

Fig. 2. Effect of direction of overloading on changes in pO_2 in a rabbit's brain tissues: A) changes in pO_2 in the region of the reticular formation of the tegmentum during overloading of 7.8 g in the direction head–pelvis; B) during overloading of 5.6 g in the direction pelvis–head; C) during "ascent" to an "altitude" of 10,000 m.

Changes of a quite different character of the pO_2 level in the brain tissues were observed during overloading in the direction pelvis–head (see Fig. 2 and the table). Even comparatively small overloads caused a sharp fall in the pO_2. In contrast to overloading in the direction head–pelvis, during overloading in the direction from pelvis to head the curve of the changes in pO_2 fell almost vertically. Comparison with the results of the altitude tests showed that the pO_2 level in the brain tissue fell under these circumstances to the level corresponding to the elevation to an altitude of 8000-10,000 m. Essential differences in the changes in pO_2 during overloading in the direction pelvis–head were also observed in the immediate after-period. Whereas during overloading in the direction head–pelvis (mean values) the restoration of the pO_2 in the brain tissues began immediately after the exposure had ended and it followed a uniform course, in the case of overloading in the direction pelvis–head restoration took place differently.

Depending on the severity of the factor operating, two variants of the restoration of the initial pO_2 level were observed: in some cases it took place extremely slowly and was stepwise in character, while in others it took place only after a phase of a considerable increase in the oxygen tension. Throughout this period the external respiration and the activity of the cardiovascular system (as shown by the ECG) remained essentially unchanged. The same animal, whose central nervous system was in a strongly inhibited state after exposure to overloading, began to react immediately after the end of the phase of increased pO_2 to stimulation (pinprick, a puff of air, etc.). Hence, restoration of the animal's activity took place simultaneously with a fall in the pO_2 level in the brain tissue. The first variant of restoration was observed in the case of exposure to small overloads, the second in the case of the largest overloads which could be tolerated or after exposure to repeated overloading.

Experiments with the repeated exposure to overloading showed that the pO_2 level in the brain tissues did not remain unchanged in these circumstances, even if the magnitude of the overloads was constant. The changes in pO_2

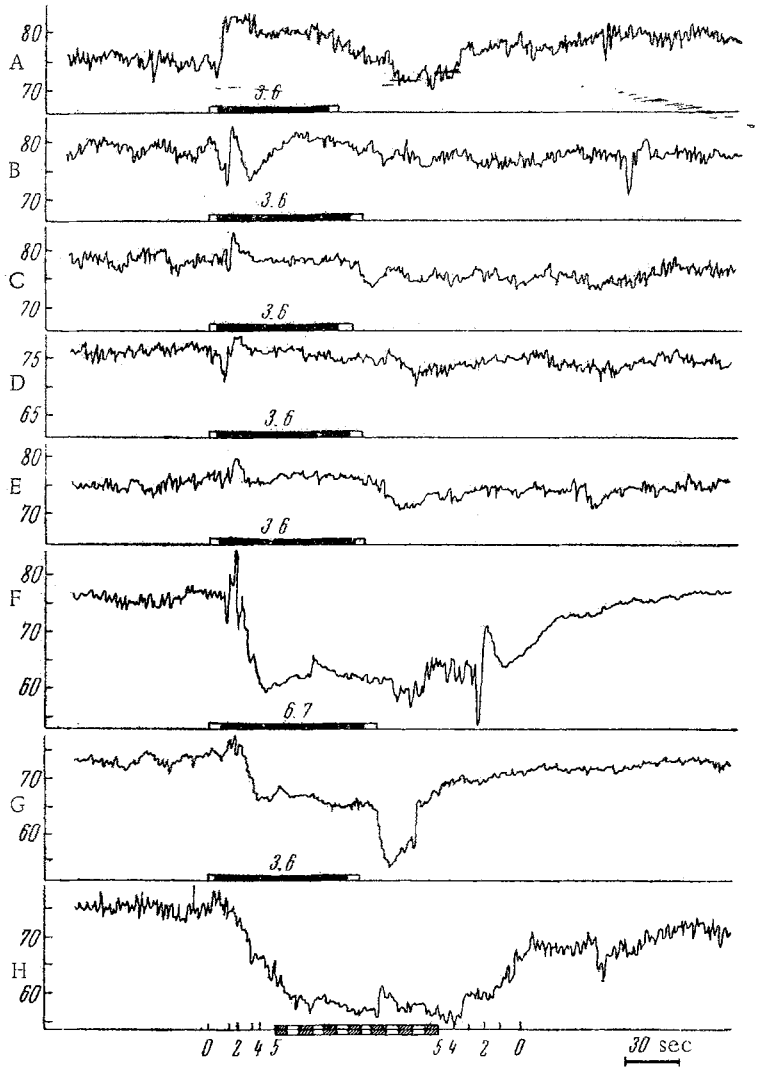

Fig. 3. Effect of repeated exposure to overloading on pO_2 in the rabbit's brain tissue: A-E, G) changes in pO_2 in the region of the geniculate bodies during overloads of 3.6 g in the direction head–pelvis; F) overloads of 6.7 g; H) during "ascent" to an "altitude" of 5000 m.

were especially sharp when the overloads approached the limit of toleration. The results of one experiment in which an animal was exposed for 45 min to seven overloads are shown in Fig. 3. All these overloads except the sixth were of 3.6 g. As Fig. 3 shows, the level of pO_2 in the brain tissues changed with each successive exposure in a manner slightly different from the time before. The most marked changes in pO_2 were observed after the sixth overload, which gave rise to a distinctive breakdown of the compensation mechanisms. As a result of this, during the seventh overload (also 3.6 g) the pO_2 level in the brain tissues fell almost to the same level as during exposure to the sixth. However, it is clear from a comparison with the results of the altitude test that in this case also the pO_2 level in the brain tissues remained at a higher level than during the "ascent" to an "altitude" of 5000 m.

SUMMARY

A chronic experiment on cats and rabbits was used to investigate by the method of polarography the influence of gravitational stress and hypoxic hypoxia on the pO_2 value in various parts of the brain. Differences were found in the character of pO_2 changes depending on the value, direction, and recurrence of overload influences.

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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 the first issue of this year.
