Some Cytochemical Peculiarities of the Rat Brain Motor System after Space Flight

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Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 119, № 3, pp. 288-290, March, 1995
Original article submitted March 28, 1994

The results of cytochemical cytometry of rat brain suggest that a 9-day exposure of rats to microgravitation conditions lowers the activity of monoaminoxidase in the fibrous structures of layer V of the somatosensory cortex and in the head of *nucleus caudatus*, as well as the activity of acetylcholine esterase in the bodies of neurons forming the head of *n. caudatus*.

Key Words: *somatosensory cortex; head of nucleus caudatus; enzyme activity; rats; space flight*

Biochemical studies of the frontal area of the brain of rats after space flight in the biosatellites Kosmos-782 [3] and "Kosmos-936" [2] have revealed a considerable decrease in the acetylcholine esterase (ACE) activity and the sulfhydryl group content. Subsequent detailed morphological studies of the somatosensory cortex of rats after flight in the biosatellites Kosmos-1667 [1,4], Kosmos-1887 [4], and Kosmos-2044 [4] showed that various compensatory adaptive changes occur in the cortex layers. In order to elucidate the mechanisms underlying the adaptive transformations occurring during weightlessness, we undertook a quantitative cytochemical study in which an attempt was made to measure the activity of ACE, monoaminoxidase (MAO), and glutamate dehydrogenase (GDH) in the somatosensory cortex and the head of the *nucleus caudatus* isolated from the brain of rats after a 9-day flight on board the American biomedical laboratory Spacelab-1.

MATERIALS AND METHODS

The frontal part of the left hemisphere was isolated from rats of experimental (space flight), control experimental (carried out on Earth), postflight adaptation, and control groups. The isolated part of the brain contained the somatosensory area of the cortex and the head of *n. caudatus*. It was placed in an 8% aqueous solution of gelatin and frozen at -150°C by immersing in freon at -12°C cooled with liquid nitrogen. All procedures were performed at the site of the spaceship landing. Some of the material was shipped to the Ames Center of NASA and stored in liquid nitrogen. Other material was shipped to Moscow in Teflon flasks at -70°C and stored in liquid nitrogen. Frontal sections of 20 μ through the somatosensory cortex and the head of *n. caudatus* were cut at -16°C in a cryostat, and the activity of ACE [7], MAO [5], and GDH [8] was revealed by histochemical methods. The intensity of the histochemical reactions was measured in a LYUMAM-I3 cytophotometer at 589 nm for MAO and GDH and at 488 nm for ACE. In the somatosensory cortex, the activity of ACE and MAO was measured in the intercellular fibrous structures of layers III and V, in the head of *n. caudatus* MAO activity was measured in intercellular fibrous structures, while ACE activity was measured predominantly in the bodies of medium-size neurons. In the somatosensory cortex, GDH activity was measured in the bodies of pyramidal cells of layers III and V, in the head of *n. caudatus*, and in the bodies of the medium-size neurons. The results

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0007-4888/95/0003-0279$12.50

TABLE 1. Quantitative Cytochemical Analysis of Enzyme Activity in Layers III and V of the Somatosensory Cortex and in the Head of *n. caudatus* of Rat Brain ($M \pm m$)

Brain structure	Enzyme activity (optical density units $\times 10^3$)			
	control	space flight	postflight adaptation control	postflight adaptation
		MAO		
Somatosensory cortex				
layer III	237±2	249±2	260±2	261±2
layer V	287±2	247±2*	310±1	316±2
N. caudatus	246±2	202±3*	279±3	272±3
		ACE		
Somatosensory cortex				
layer III	231±3	234±4	354±4	366±4
layer V	322±4	303±5	519±7	541±7
N. caudatus	1259±12	907±10*	1135±11	1137±10
		GDH		
Somatosensory cortex				
layer III	277±2	257±6	323±3	316±2
layer V	422±4	404±6	466±4	463±2
N. caudatus	436±3	422±2	527±5	502±6

Note. Asterisk indicates $p<0.05$ compared with the control.

were analyzed using Student-Fisher's test. Histochemical staining and subsequent cytophotometric analysis were performed on sections prepared from the brains of 3 rats after space flight and of 4 rats from the control group of postflight adaptation.

RESULTS

Table 1 shows that after the space flight there were no marked changes in ACE and MAO activity in fibrous structures of layer III of the somatosensory cortex of rat brain. The activity of GDH in neuronal bodies was decreased by an insignificant 7%. In the fibrous structures of layer V, ACE activity tended to decrease, while MAO activity was lowered 14%. The activity of GDH in the bodies of pyramidal cells in layer V remained practically unchanged. After the space flight, MAO activity in fibrous structures of the head of *n. caudatus* was decreased 18%, in the medium-size neurons of this structure the activity of ACE was decreased 28%, while the activity of GDH remained unchanged.

There were no statistically significant changes in ACE, MAO, and GDH activity in the fibrous structures and in the bodies of neurons of the studied layers of the somatosensory cortex of rat brain.

It can be assumed that the decrease in the activity of MAO in fibrous structures of layer V in the brains of rats that had undergone 9 days of weightlessness is indicative of alterations in cerebral monoaminergic structures which modulate the functional state of pyramidal cells in layer V. The activity of ACE in the studied layers did not change appreciably; presumably, 9 days of weightlessness is too short a period for the development of a decrease in ACE activity of the type that has been observed in the frontal area of cortex of rats after a 9-day space flight [3].

The *nucleus caudatus* is known to be confined to the extrapyramidal system and to be involved in the realization of motor activity, producing an inhibitory effect on the cortex. Published data indicate that the density of muscarinic receptors in the striatum of rats is considerably lowered after space flight [6]. Taking into account the decrease in ACE activity in neurons of the head of *n. caudatus* and the decrease in MAO activity in the fibrous structures of *n. caudatus* observed in rats after a 9-day space flight, it may be postulated that the transformation of the relationships between monoaminergic and acetylcholinergic systems in *n. caudatus* can be accompanied by changes in its functional state and, consequently, in the inhibitory effect on brain structures.

However, the alterations in the activity of ACE and MAO and changes in the somatosensory cortex and *n. caudatus* are probably of a functional (apparently adaptive) nature, since nine days after landing the activity of both enzymes was practically the same as in control rats.

Thus, exposure of rats to weightlessness for nine days induces a decrease in MAO activity in layer V of the somatosensory cortex and in the head of *n. caudatus*, which may indicate changes in the modulating influence of cerebral monoaminergic structures on these formations. It can be assumed that the decrease in ACE activity in the head of *n. caudatus*, like the decrease in MAO activity, reflects the transformation of the relationship between the monoaminergic and acetylcholinergic systems, which probably influences the cortex-subcortex associations in the motor system of the brain of rats who have spent nine days in weightlessness. These alterations, however, may be reversible.

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