HUMAN ECOLOGY

Metabolic Interrelations between Rat Brain Lipids during Geomagnetic Perturbations

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Lipid components in various brain structures undergo different changes during geomagnetic perturbations. These changes involve synthetase, hydrolase, and transferase biotransformations of lipids. These changes reflect differences in metabolic activities in the left and right cerebral hemispheres and the development of biochemical cerebral asymmetry under the effect of natural stress factors. Changes in lipid metabolism probably reduce adaptive capacities of the organism.

Key Words: *lipids; brain; geomagnetic activity*

Studies of the biological effects of geomagnetic field demonstrated sensitivity of different living organisms to this natural abiotic risk factor [10]. Neurodynamic processes directly or indirectly switching the chronobiological systems to pathological or stress regimens are most sensitive to solar electromagnetic radiation. Studies of the mechanisms underlying biological effects of geomagnetic field should focus on neurobiochemical processes of adaptation to geomagnetic perturbations. However, this problem received little attention.

Previous studies showed that adaptation to pathological states and diseases is accompanied by changes in the content of lipid components [7,9]. Total lipids and individual phospholipids of the brain are involved in transduction of physiological signals in various cells, memory processes, structural organization of biological membranes, and realization of genetic information [1,7, 13]. Here we studied changes in the content of these compounds during enhanced geomagnetic activity (GMA).

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MATERIALS AND METHODS

Experiments were performed on 140 male Wistar rats weighing 180±30 g and kept under standard conditions. The samples were collected during magnetic storms of various intensities in 1998-1999. The materials taken under conditions of normal GMA were used for comparative studies. The maximum amplitudes of geomagnetic field strength (D-, H-, and Z-components) were obtained from the Institute of Earth's Magnetism, Ionosphere, and Radiowave Propagation (Troitsk). Rat brain was removed 25-30 sec after decapitation under raush narcosis. All manipulations with the brain were performed at a temperature of melting ice. We studied the cortex, white matter, and neostriatum of the left (LH) and right hemispheres (RH). The weight of samples did not exceed 30 mg. Lipids were extracted by the method of Blie and Drier with modifications [9]. Total lipids and phospholipids were fractionated by thin-layer chromatography on silica gel. The quantitative analysis of individual lipid fractions was performed by the method of degradation with sulfuric acid. The content of phospholipids was estimated by the amount of lipid phosphorus [3,6]. Lipid contents were expressed in percents of the total lipid fraction. The results were analyzed by Student's t test. The differences were significant at $p<0.05$.

RESULTS

The content of total lipids in various brain structures underwent different changes during geomagnetic perturbations (Table 1). The content of phospholipids in the gray matter increased by 8.5% in RH, but decreased by 5.4% in LH (compared to the control). The increase in phospholipid content in the gray matter of RH was primarily associated with changes in the concentration of phosphatidylinositol, but not phosphatidylcholine (Table 2). The relative content of phosphatidylinositol increased probably due to synthetase and transferase reactions in the phosphatidylcholine-phosphatidylinositol system. A 1.4-fold increase in the content of free fatty acids (FFA) in the gray matter during geomagnetic disturbances was probably related to hydrolysis of triglycerides and cholesterol esters catalyzed by endogenous lipases: the content of these substance decreased by 37.1 and 34.1%, respectively. The content of phospholipids in the gray matter of LH decreased by 5.4% during geomagnetic disturbances. These changes were accompanied by FFA accumulation (Table 1), which indicated activation of endogenous phospholipases A1 and A2. Previous studies demonstrated activation of phospholipases in the nervous tissue during stress [12]. The relative content of phospholipids decreased, while the concentration of FFA increased in the white matter of RH during geomagnetic disturbances, which indicated activation of phospholipid hydrolysis. However, the relative content of triglycerides increased, which probably resulted not only from synthetase processes, but also from acyltransferase reactions in the phospholipid-diglycerides-triglycerides system realized through FFA and their CoA derivatives [2,14]. The relative contents of FFA and triglycerides increased in the white matter of LH during geomagnetic disturbances, while the concentration of cholesterol esters decreased by 1.2 times (Table 1). A 20.4% decrease in the relative content of cholesterol esters in the white matter of LH was probably associated with their hydrolysis to FFA or acyltransferase transformations into triglycerides. It should be emphasized that during geomagnetic disturbances the content of FFA increased in the white and gray matters of both hemispheres, which modulated the phospholipid state of membranes and the intensity of lipid metabolism. These processes impair transduction of chemical signals in various cells and regulation of intracellular processes [7,8] and, in addition to changes in the lipid composition of membranes, contribute to the negative effects of magnetic storms.

Enhanced GMA changed the content of total lipids in the neostriatum of RH and LH. The relative content of phospholipids in RH and LH increased (primarily due to phosphatidylcholine) by 10.2 and 8.2%,

TABLE 1. Metabolism of Total Lipids in Rat Brain under Conditions of Normal Geomagnetic Activity (Control) and during Geomagnetic Disturbances (Experiment, %, $M\pm m$)

Substance	Gray matter		White matter		Neostriatum	
	control	experiment	control	experiment	control	experiment
Phospholipids						
RH	60.24±6.99	65.39±7.06*	62.23±7.02	54.35±6.80*	55.40±6.84	61.06±7.00*
LH	61.53±7.01	58.25±6.94*	61.71±7.01	61.08±7.00	55.78±6.85	60.38±6.98*
Cholesterol						
RH	21.31±5.16	19.42±5.36	19.40±2.04	20.61±6.33	24.81±6.37	22.08±5.86
LH	22.00±5.82	24.13±6.92	22.23±5.89	21.14±5.68	24.46±6.31	21.97±5.84
FFA						
RH	4.53±0.74	6.18±0.85*	6.08±0.83	9.94±0.82*	7.26±0.94	5.06±0.84*
LH	5.99±0.78	9.13±0.75*	4.84±0.80	6.88±0.90*	5.55±0.93	4.85±0.80*
Triglycerides						
RH	5.70±1.44	3.59±1.31*	3.66±1.34	6.17±1.63*	4.48±1.36	2.94±1.19*
LH	4.49±1.36	3.36±1.29	3.15±1.32	4.48±1.36*	7.57±2.79	5.19±2.35*
Cholesterol esters						
RH	8.22±1.29	5.42±0.82	8.63±0.95	8.93±0.97	8.05±0.92	8.86±0.97
LH	5.99±0.87	5.13±0.74	8.07±0.92	6.42±0.86*	6.64±0.93	7.61±0.95

Note. Here and in Table 2: $*p<0.05$ compared to the control.

TABLE 2. Metabolism of Phospholipids in Rat Brain under Conditions of Normal Geomagnetic Activity (Control) and during Geomagnetic Disturbances (Experiment, %, *M*±*m*)

Substance	Gray matter		White matter		Neostriatum	
	control	experiment	control	experiment	control	experiment
Lysophosphatidylinositol						
RH	5.46±0.84	6.22±0.97	4.26±0.69	7.93±0.95*	5.76±0.85	7.81±0.86*
LH	5.23±0.80	10.48±1.80*	5.15±0.79	6.19±0.88	4.72±0.77	4.59±0.75
Lysophosphatidylcholine						
RH	3.66±0.57	8.07±0.98*	4.24±0.68	7.60±0.93*	3.89±0.32	3.38±0.42
LH	3.83±0.31	4.47±0.73*	4.36±0.70	8.90±0.98*	3.98±0.40	4.88±0.80
Sphingomyelin						
RH	30.92±5.74	30.45±5.56	27.99±5.10	30.43±5.55	28.44±5.18	27.08±4.93
LH	29.85±5.45	33.09±6.05*	27.18±4.85	32.97±6.02*	30.26±5.52	30.09±5.49
Phosphatidylcholine						
RH	46.92±8.62	39.48±7.24*	46.12±8.42	36.33±6.33*	42.92±7.85	46.56±8.50*
LH	45.27±8.31	40.75±7.47*	46.47±8.43	34.94±6.39*	46.91±8.41	45.79±8.39
Phosphatidylinositol						
RH	7.69±0.93	11.55±2.04*	10.37±1.63	10.74±1.69	9.97±0.98	7.31±0.82*
LH	11.86±2.08	8.27±0.96*	8.57±0.97	11.40±1.90*	8.16±0.82	8.38±0.87
Cardiolipin						
RH	5.35±0.82	4.23±0.69	7.02±0.92	6.97±0.90	9.02±0.93	7.86±0.86
LH	3.96±0.29	2.94±0.61	8.27±0.95	5.60±0.84*	5.97±0.72	6.27±0.68

respectively. The relative contents of triglycerides and FFA decreased, which was associated with acyltransferase reactions (Table 1).

Changes in the content of individual phospholipids showed that the relative content of sphingomyelin in the gray and white matters increased only of LH (by 10.9 and 21.3%, respectively), which suggested intensification of metabolic processes maintaining membrane stability. Previous studies demonstrated an increase in sphingomyelin concentration in rat brain during immobilization stress [5]. The increase in sphingomyelin content is associated with its formation from phosphatidylcholine [2]. However, it can not be excluded that these substances are synthesized *de novo*. In our experiments, the relative content of sphingomyelin decreased in all brain structures, including the neostriatum. Geomagnetic disturbances probably activate hydrolysis of phosphatidylcholine catalyzed by phospholipases A1 and A2, because the relative contents of FFA and lysophosphatidylcholine increase simultaneously (Table 1). Changes in the content of phosphatidylcholine probably result from transferase transformations in the phosphatidylcholine-sphingomyelin system. Increased GMA is accompanied by a 30.3% decrease in the content of phosphatidylinositol and accumulation of lysophosphatidylcholine in the cortex of LH (Table 2). It should be emphasized that functions of these brain structures include prediction of complex motor and psychic processes [4]. Decreasing the relative content of this phospholipid fraction is accompanied by changes in membrane microviscosity, ion permeability, excitability, and transduction of exogenous signals in cells. The content of phosphatidylinositol decreased also in the neostriatum of RH. However, the relative contents of phosphatidylinositol in the gray matter of RH and white matter of LH during geomagnetic disturbances increased by 50.2 and 33.0%, respectively. These changes probably result from not only biosynthetic processes, but also transferase-catalyzed processes in the phosphatidylcholine-phosphatidylinositol system [2,11].

Thus, lipid components in various brain structures undergo different changes during geomagnetic perturbations, which are related to synthetase, hydrolase, and transferase biotransformations of lipids. These changes reflect various metabolic activities in LH and RH under the effect of natural stressors.

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