EFFECT OF ELECTRICAL STIMULATION OF THE HYPOTHALAMUS AND CEREBRAL CORTEX ON TEMPERATURE HOMEOSTASIS OF RABBITS EXPOSED TO HYPEROXIA

I. I. Antonov

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The role of the anterior and posterior portions of the hypothalamus and its interconnection with the cerebral cortex in rabbits in the changes in temperature homeostatis occurring during exposure to a raised oxygen pressure was investigated by recording the temperature of the principal heat-producing and heat-transmitting organs and tissues. Excitation of nervous structures was produced by electrical stimulation in various stages of exposure to oxygen.

Prolonged inhalation of gas mixtures with high oxygen concentrations at normal and raised oxygen pressures has been shown to lead to the development of progressive hypothermia [1-3].

The object of the present investigation was to examine the role of the cerebral cortex and hypothalamus in the changes in temperature homeostasis occurring in animals exposed to a hyperoxic atmosphere.

EXPERIMENTAL METHOD

The experiments were carried out in a portable recompression chamber with an oxygen concentration of 96±1% at normal atmospheric pressure (760±20 mm Hg) for 4-5 days or in oxygen at a pressure raised to 2660 mm Hg. Electrodes were first implanted into the anterior and posterior parts of the hypothalamus and into the region of the sigmoid gyrus of the cortex, and stimulating pulses (0.5-2 V, 50/sec) were passed through them at various stages of exposure to oxygen. Immediately before each experiment, thermoelectric probes were inserted into the animals' liver, skeletal muscles, and subcutaneous cellular tissue, and thermocouples into the rectum; thermocouples also were glued to the skin on the ear and over the spine. Measurements were made with a mirror galvanometer. During the experiments, changes in respiration, in the lumen of the auricular vessels, and in the general behavior of the animals were observed visually. Altogether 98 rabbits were tested.

EXPERIMENTAL RESULTS

The pretoxic stage of exposure of the rabbits to oxygen was characterized by slowing of respiration, constriction of the auricular vessels, general motor activity, a raised temperature in the rectum, liver, and skeletal muscles, and a lowered temperature on the skin of the ears and spine. Stimulation of the anterior hypothalamus at this time increased the respiration rate, sometimes to the extent of causing tachypnea, dilated the vessels of the ear and, as can be seen in Tables 1 and 2, lowered the temperature in the liver, rectum, and thigh muscles, but raised the skin temperature of the ears and over the spine. In addition, marked inhibition of motor activity was observed. When the stimulation stopped, the animals' previous condition was restored. Stimulation of the posterior hypothalamus, on the other hand, caused a more marked increase in temperature of the rectum, liver, and skeletal muscles and a decrease in the skin temperature of the ears and dorsum.

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TABLE 1. Effect of Electrical Stimulation of Hypothalamus and Cerebral Cortex on Dynamics of Changes in Temperature (in deg.) of Certain Organs and Tissues of Rabbits Breathing Oxygen under Normal Barometric Pressure and at Neutral External Environmental Temperature

Stage	Place of measuring temperature	Intact animals		Stimulation of anterior hypothalamus		Stimulation of posterior hypothalamus		Stimulation of cerebral cortex	
		$M \pm m$	P	$M \pm m$	P	$M \pm m$	P	$M \pm m$	P
Ordinary atmosphere	Liver	38,32±0,14	<0,005	36,25±0,10	<0,001	39,02±0,15	<0,005	38,87±0,12	<0,005
	Rectum	37,66±0,33	<0,005	35,78±0,24	<0,005	38,15±0,35	<0,005	38,04±0,25	<0,005
	Thigh muscles	37,20±0,42	<0,02	35,13±0,53	<0,01	38,03±0,51	<0,01	37,93±0,39	<0,005
	Subcutaneous cellular tissue	36,14±0,26	<0,005	35,02±0,39	<0,005	36,23±0,25	<0,005	36,57±0,28	<0,005
	Skin over spine	34,56±0,29	<0,005	35,00±0,21	<0,001	32,71±0,56	<0,001	34,49±0,33	<0,005
	Skin of ear	33,47±0,36	<0,001	35,15±0,27	<0,005	31,19±0,44	<0,005	33,51±0,41	<0,005
Pretoxic	Liver	38,85±0,12	<0,001	38,02±0,15	<0,005	39,17±0,05	<0,001	39,12±0,15	<0,005
	Rectum	38,25±0,17	<0,005	37,71±0,22	<0,005	38,92±0,10	<0,005	38,59±0,12	<0,001
	Thigh muscles	37,90±0,35	<0,005	36,44±0,31	<0,005	38,26±0,29	<0,005	38,22±0,34	<0,005
	Subcutaneous cellular tissue	36,51±0,39	<0,005	36,05±0,37	<0,005	37,07±0,41	<0,005	37,58±0,35	<0,005
	Skin over spine	34,52±0,41	<0,01	36,01±0,35	<0,005	32,41±0,37	<0,01	34,61±0,45	<0,01
	Skin of ear	33,87±0,45	<0,01	36,23±0,41	<0,005	29,73±0,39	<0,005	32,92±0,47	<0,005
Subtoxic	Liver	38,05±0,08	<0,005	37,87±0,15	<0,005	38,63±0,16	<0,005	38,47±0,11	<0,001
	Rectum	37,14±0,21	<0,005	37,05±0,19	<0,005	37,97±0,15	<0,005	37,51±0,15	<0,005
	Thigh muscles	36,95±0,39	<0,01	36,29±0,41	<0,005	37,12±0,33	<0,01	37,25±0,37	<0,005
	Subcutaneous cellular tissue	36,10±0,27	<0,005	35,97±0,35	<0,005	36,76±0,29	<0,005	37,01±0,33	<0,005
	Skin over spine	34,21±0,31	<0,005	34,51±0,45	<0,005	30,02±0,46	<0,005	34,43±0,41	<0,005
	Skin of ear	32,55±0,43	<0,005	33,03±0,41	<0,005	28,21±0,39	<0,005	32,89±0,45	<0,01
Toxic (pulmonary)	Liver	38,02±0,12	<0,001	37,91±0,18	<0,005	38,75±0,07	<0,001	38,25±0,05	<0,001
	Rectum	38,45±0,19	<0,005	37,83±0,22	<0,005	38,71±0,11	<0,001	38,43±0,10	<0,001
	Thigh muscles	37,59±0,27	<0,005	37,11±0,31	<0,005	38,15±0,29	<0,005	37,71±0,31	<0,005
	Subcutaneous cellular tissue	37,06±0,24	<0,005	36,89±0,29	<0,005	37,47±0,33	<0,005	37,19±0,25	<0,005
	Skin over spine	36,35±0,39	<0,005	36,51±0,44	<0,005	33,11±0,42	<0,005	36,41±0,43	<0,005
	Skin of ear	36,47±0,37	<0,005	36,59±0,49	<0,005	29,35±0,39	<0,001	36,43±0,41	<0,005

TABLE 2. Effect of Electrical Stimulation of Hypothalamus and Cerebral Cortex on Dynamics of Changes in Temperature (in deg.) of Certain Organs and Tissues of Rabbits Breathing Oxygen under Raised Pressure and at Neutral External Environmental Temperatures

Stage	Place of measuring temperature	Intact animals		Stimulation of anterior hypothalamus		Stimulation of posterior hypothalamus		Stimulation of cerebral cortex	
		$M \pm m$	P	$M \pm m$	P	$M \pm m$	P	$M \pm m$	P
Ordinary atmosphere	Liver	38,32±0,14	<0,005	36,25±0,10	<0,001	39,02±0,15	<0,005	38,87±0,12	<0,005
	Rectum	37,66±0,33	<0,005	35,78±0,24	<0,005	38,15±0,35	<0,005	38,04±0,25	<0,005
	Thigh muscles	37,20±0,42	<0,02	35,13±0,53	<0,01	38,03±0,51	<0,01	37,93±0,39	<0,005
	Subcutaneous cellular tissue	36,14±0,26	<0,005	35,02±0,39	<0,005	36,23±0,25	<0,005	36,57±0,28	<0,005
	Skin over spine	34,56±0,29	<0,005	35,00±0,21	<0,001	32,71±0,56	<0,001	34,49±0,33	<0,005
	Skin of ear	33,47±0,36	<0,001	35,15±0,27	<0,005	31,19±0,44	<0,005	33,51±0,41	<0,005
Pretoxic	Liver	39,27±0,19	<0,005	37,52±0,12	<0,005	39,31±0,14	<0,001	39,33±0,15	<0,005
	Rectum	38,18±0,38	<0,002	36,73±0,25	<0,005	38,25±0,27	<0,001	38,21±0,10	<0,005
	Thigh muscles	37,75±0,35	<0,005	36,67±0,29	<0,005	38,03±0,29	<0,005	37,82±0,23	<0,005
	Subcutaneous cellular tissue	35,53±0,37	<0,001	35,55±0,41	<0,005	36,11±0,41	<0,005	35,60±0,31	<0,005
	Skin over spine	31,36±0,50	<0,005	34,31±0,43	<0,005	31,15±0,57	<0,005	31,31±0,47	<0,005
	Skin of ear	26,12±0,49	<0,005	33,45±0,37	<0,005	25,78±0,43	<0,005	26,25±0,53	<0,005
Subtoxic	Liver	36,41±0,21	<0,005	36,39±0,33	<0,001	36,92±0,09	<0,005	36,65±0,12	<0,001
	Rectum	36,03±0,15	<0,005	36,11±0,19	<0,001	36,75±0,15	<0,005	36,12±0,19	<0,005
	Thigh muscles	38,23±0,44	<0,005	37,82±0,35	<0,005	38,91±0,27	<0,005	38,45±0,47	<0,005
	Subcutaneous cellular tissue	37,11±0,51	<0,005	36,95±0,63	<0,001	36,29±0,55	<0,005	37,08±0,59	<0,005
	Skin over spine	33,31±0,47	<0,005	33,47±0,51	<0,005	27,82±0,31	<0,005	33,35±0,42	<0,005
	Skin of ear	34,12±0,39	<0,005	34,25±0,42	<0,005	25,23±0,19	<0,005	34,10±0,43	<0,005
Toxic (pulmonary)	Liver	36,29±0,16	<0,001	36,01±0,08	<0,005	36,81±0,06	<0,001	36,21±0,20	<0,001
	Rectum	36,25±0,12	<0,005	35,75±0,23	<0,005	37,02±0,19	<0,001	36,43±0,29	<0,001
	Thigh muscles	38,41±0,37	<0,01	37,35±0,21	<0,005	38,98±0,25	<0,005	38,17±0,41	<0,005
	Subcutaneous cellular tissue	36,96±0,53	<0,005	36,57±0,49	<0,005	36,72±0,52	<0,005	36,63±0,47	<0,005
	Skin over spine	34,14±0,59	<0,01	34,25±0,47	<0,005	33,51±0,83	<0,01	33,82±0,59	<0,01
	Skin of ear	34,23±0,51	<0,01	34,71±0,53	<0,005	31,92±0,47	<0,01	34,12±0,45	<0,01

In the pretoxic stage, characterized by an increased respiration rate and pulmonary ventilation and by dilatation of the auricular vessels, by a general increase in muscle tone and by the development of general hypothermia, stimulation of the anterior hypothalamus merely lowered the muscle tone, whereas stimulation of the posterior hypothalamus distorted the regular physiological responses characteristic of stage II of exposure to hyperoxia. Marked constriction of the auricular vessles, accompanied by a further decrease in skin temperature of the ears and dorsal region, was observed 3-5 sec after the beginning of stimulation, while on the other hand, the temperature of the rectum, liver, and skeletal muscles was lowered. Instead of being quickened, respiration was slowed. The muscle tone still remained raised.

The toxic stage in animals breathing oxygen under increased pressure was characterized by convulsions, by dilatation of the auricular vessels, a pilomotor response, rapid and deep respiration with brief periods of apnea, and specific temperature changes in the investigated organs and tissues; during the convulsions the temperature of the muscles and rectum was raised, the liver temperature remained low, the brain temperature was sharply reduced, and the skin temperature of the ears and dorsum showed irregular changes. During stimulation of the anterior hypothalamus, muscle tone was reduced, the oxygen convulsions were weaker in intensity, and the temperature in the skeletal muscles was only very slightly raised. The temperature of the rectum and liver was sharply reduced, while the skin temperature of the ears and over the spine was raised. The pilomotor response had disappeared. Stimulation of the posterior hypothalamus, on the other hand, led to an increase in the intensity of the convulsions, reduced the period between convulsions, and caused a sharper increase in the temperature of the thigh muscles, rectum, and liver and a sharper decrease in the skin temperature. Constriction of the auricular vessels and slowing of respiration were observed for a short time.

Stimulation of the cortex in the region of the sigmoid gyri in the pretoxic stage led to a more prolonged elevation of the temperature of the liver and skeletal muscles than in intact animals. In the subtoxic stage of oxygen exposure, stimulation of the cortex, as shown in Tables 1 and 2, inhibited the development of progressive hypothermia. Stopping the stimulation led to a further fall of temperature. Cortical stimulation in stage III (paroxysmal) did not yield definite results. These results suggest a direct influence on the cortex through the hypothalamic centers on the heat balance of the organism during exposure to a hyperoxic atmosphere. This hypothesis is confirmed by experiments in which the rabbits received a preliminary injection of caffeine, causing marked cortical excitation. A more intensive temperature response in the pretoxic stage, accompanied by elevation of the temperature in the principal heat-producing organs, was observed in this group of animals. Ether anesthesia, on the other hand, inhibited the temperature response of the experimental animals.

Predominance of inhibition in the cortex thus weakens the temperature response, while predominance of excitation intensifies it. However, more complex relationships between the cortex and subcortical structures, which have not so far been elucidated, may exist in different stages of exposure to hyperoxia.

LITERATURE CITED

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