HEAT EMISSION AND BODY TEMPERATURE OF ALBINO RATS EXPOSED TO HYPERBARIC OXYGEN

V. V. Matsynin

UDC 612.273.1

In model experiments in which bodies simulating an animal were heated under steady-state conditions the effect of hyperbaric oxygen (1.2-4 atm) on the level of heat flow (HF) from the bodies and their temperature was studied. Under hyperbaric conditions an increased level of HF was recorded, followed by a decrease as the exposure continued. At the same time the temperature of these bodies fell, evidence of increased heat loss. Periods of compression and decompression were accompanied by a marked rise and fall of HF respectively. In experiments on albino rats fluctuations in the HF level during compression and decompression were smaller, the HF level during exposure to a constant high pressure remained virtually constant, and the rectal and subcutaneous temperature did not differ statistically significantly from their initial level. It is suggested that this effect may be the result of increased heat production.

KEY WORDS: hyperbaric oxygen; heat flow; body temperature.

The study of energy metabolism under hyperbaric oxygen (HBO) conditions is a promising method of elucidating the mechanism of its toxic action. There is information in the literature on the uncoupling effect of hyperoxia on energy formation processes in the mitochondria [3, 8] and also on its hypothermic effect [1, 2, 6, 7], a reduction in the total oxygen consumption has been observed, and actual heat formation exceeds the value calculated from the gas exchange [5, 10, 15]. In order to study this problem methods of recording the heat flow (HF) and thermometry were used.

EXPERIMENTAL METHOD

Female albino rats weighing 160-200 g, belonging to a strain from the A. A. Bogomolets Institute of Physiology, Academy of Sciences of the Ukrainian SSR, were used. The dynamics of the changes in HF was recorded by means of an HF sensor of the DTP-05 type [4] directly on the tape of a type EPP-09 potentiometer. The animals were fixed to wooden frames in the supine position and the DTP-05 sensor was located above the region of the xiphoid process, where the HF level was maximal. The detector from a TEMP-60 electrothermometer was located subcutaneously in the same region. In other series of experiments the detector was placed in the rectum. Conditions of HBO were produced in an airtight chamber with a volume of 0.07 m^3. The rate of compression and decompression in the experiments of the various series was 1 atm/min. Oxygen was used under a pressure of 1.2-1.4 and 4 atm for the experiments and the duration of exposure was 60 min, so that the equivalent conditional toxic doses of HBO were 0.1 and 2 units, respectively [9]. The HF system was calibrated by means of a 25-W electric lamp. With a voltage of 20 V a level of HF equal to that in the experiments with the animals, numerically equal to 2.3 W, was obtained. According to data in the literature [14], heat production of the albino rat in a resting state, measured by direct calorimetry, is 8.38 ± 0.23 kcal/kg/h, or about 2 W calculated for an animal weighing 200 g. The heat level recorded in these experiments was thus a little overestimated, but was commensurate with the actual value.

Department of Hypoxic States, A. A. Bogomolets Institute of Physiology, Academy of Sciences of the Ukrainian SSR, Kiev. (Presented by Academician of the Academy of Medical Sciences of the USSR, N. N. Sirotinin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 86, No. 10, pp. 410-414, October, 1978. Original article submitted November 15, 1977.

 0007-4888/78/8610-1294$07.50

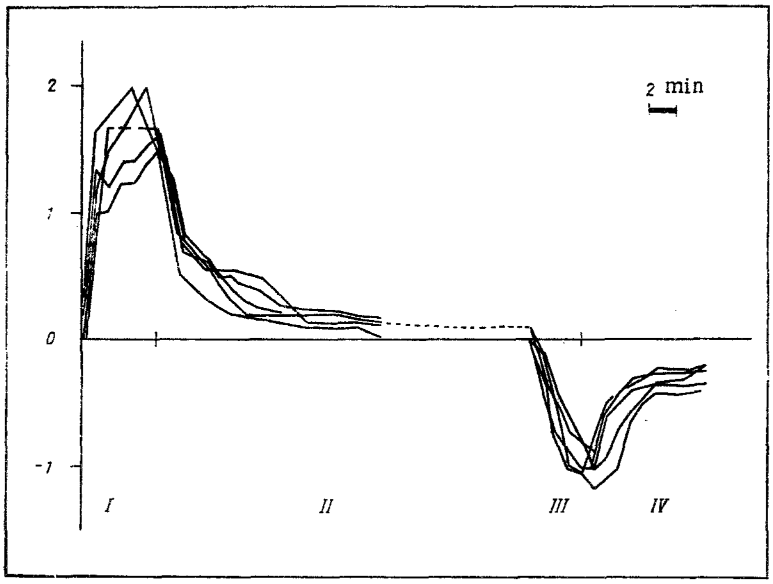

Fig. 1. Changes in HF level in experiments without a constant source of heat. Oxygen pressure 4 atm. Here and in Figs. 2 and 3: I, II, III, IV) periods of experiment: compression, plateau, decompression, and postcompression period. Abscissa, time (in min); ordinate, HF level (in W).

EXPERIMENTAL RESULTS

The first step was to study the role of physical factors arising under the influence of the changed gas pressure in the closed system. For this purpose three series of model experiments were carried out first, and experiments on animals later.

The scheme of the experiment without a constant source of heat was to record the initial (zero) HF at normal atmospheric pressure and in the absence of any additional external source of heat, during elevation of the pressure in the chamber (period of compression) up to an assigned level, during the plateau period, decompression, and in the postcompression period. Curves showing changes in the HF level in the course of the experiment are given in Fig. 1: a sharp rise in the compression period, a fall and stabilization close to the initial level in the plateau period, a sharp fall in the decompression period, and a rise toward the initial level in the postcompression period.

Experiments also were carried out with an artificial source of heat. In series I the source of heat was a vessel containing water at a temperature of about 30°C. The original record of one experiment of this series is shown in Fig. 2. Because of cooling of the vessel, the curve reflecting the initial HF level had a definite slope in these experiments. Compression was accompanied by an increase in HF. In the plateau period the rate of cooling of the vessel increased (the gradient of the curve was greater), whereas decompression was accompanied by a sharp fall of HF and a subsequent rise in the postcompression period.

In series II the source of heat was a 100 Ω resistor of the PE-75 type. By a suitable choice of voltage its temperature was raised to 30-35°C (which was constantly controlled by means of the detector of an electrothermometer placed in the resistor) and a definite level of HF was attained. The voltage applied to the resistor was maintained at the same level by means of a voltmeter and rheostat included in the circuit. The most characteristic feature of this series of experiments was a progressive decrease in HF from 1.61 ± 0.16 W at the 4th minute of the plateau to 0.95 ± 0.11 W at the 20th minute and a decrease in the temperature of the resistor by 3-4°C, and also a greater and longer decrease in the two values during decompression.

In the same part of the investigations repeated measurements were made of the gas temperature in the chamber. It was found to rise sharply (by 3-4°C) in the period of compression, to fall during the plateau period, and to fall considerably (by 2-3°C below the initial level) in the period of decompression.

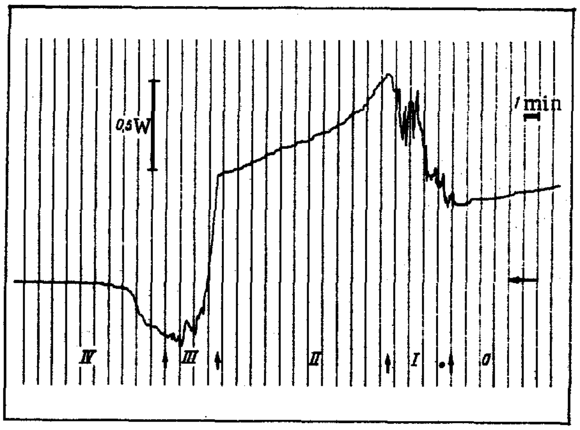

Fig. 2. Changes in HF level in model experiment with vessel filled with water at 30°C. Oxygen pressure 4 atm. 0) Initial level. Here and in Fig. 3 arrows near Roman numerals mark boundaries between periods of experiments.

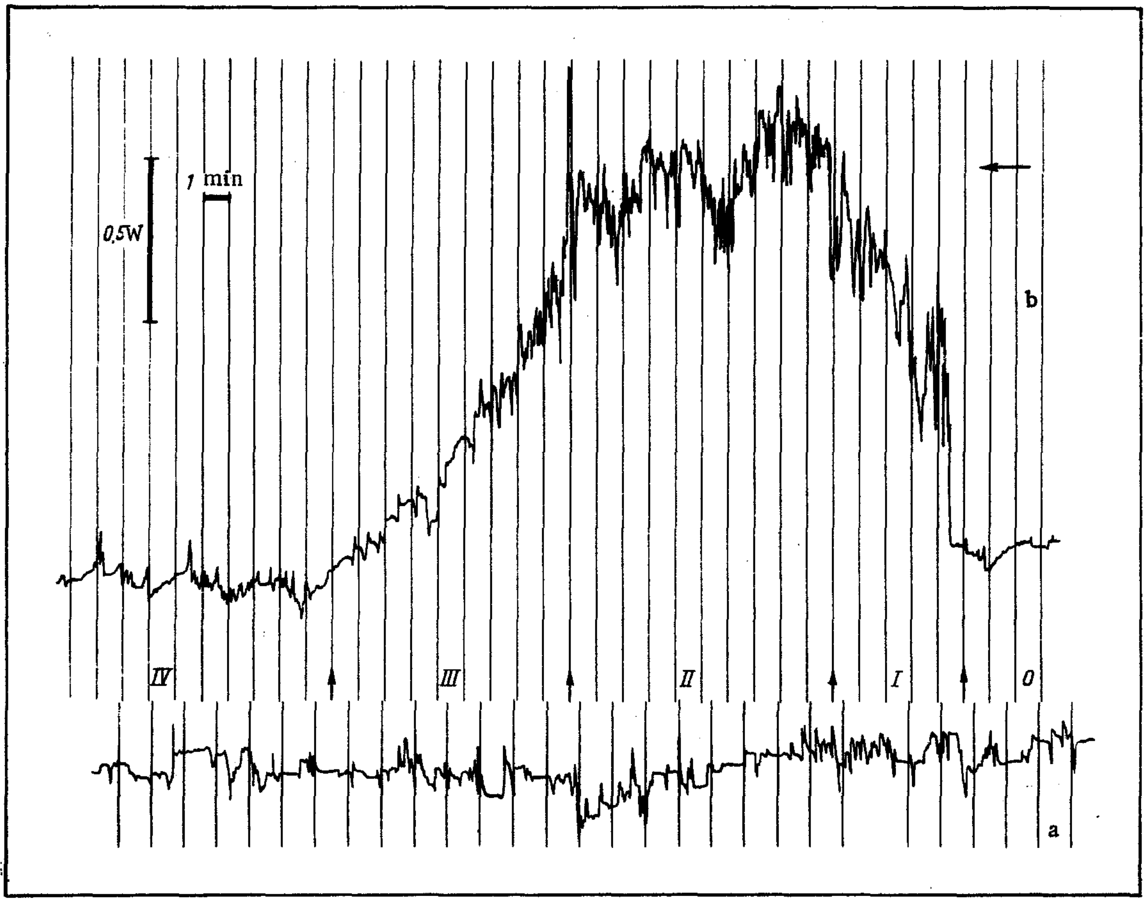

Fig. 3. Experiment on albino rat: a) sample of record of initial HF for a period of 30 min; b) dynamics of changes in HF in experiments with exposure to hyperoxia of 4 atm.

The process of compression and decompression of the gas in the chamber was accompanied by emission and absorption of heat, respectively; under steady-state hyperbaric conditions the heat loss of the warmed body increased. This effect could be due to changes in the thermal conductivity and heat capacity of the gas under pressure. According to data in the literature [11-13], the hyperbaric pressures of oxygen in these experiments were too low to

TABLE 1. Changes in HF (in W) in Experiments with Albino Rats (M ± m)

Conditions of HBO, atm	Compression		Plateau						Decompression		Postcompression period			
	2 min	4 min	0	5	10	20	40	60	2 min	4 min	2	4	6	10
			min								min			
1,2—1,4	0,08 ± 0,03	—	0,11 ± 0,06	0,07 ± 0,03	0,08 ± 0,02	0,09 ± 0,02	0,11 ± 0,04	0,12 ± 0,06	—	—	0,11 ± 0,07	0,08 ± 0,02	0,11 ± 0,03	0,08 ± 0,03
4,0	0,67 ± 0,08	0,89 ± 0,09	1,18 ± 0,09	0,87 ± 0,07	0,71 ± 0,07	0,70 ± 0,08	0,72 ± 0,09	0,68 ± 0,08	0,06 ± 0,10	0,05 ± 0,07	0,02 ± 0,06	0,05 ± 0,04	0,02 ± 0,05	0,04 ± 0,03

cause any appreciable change in the thermal conductivity of the gas. The heat capacity of a gas rises in proportion to the rise of pressure. For instance, for oxygen under a pressure of 1 atm and at 20°C the specific heat is 0.015 cal/mole•deg, whereas at 4 atm it is 0.060 cal/mole•deg (calculated by the use of an Edmister–Ruby correlation [11]).

In the absence of disturbing factors the level of HF from the animal became stabilized within a few minutes and remained so throughout the period of observation (Fig. 3a), with only slight fluctuations due to the animal's movements. With an increase in pressure in the chamber the value of HF rose sharply to reach a maximum by the beginning of the plateau period. This was followed by stabilization of HF at above the initial level, corresponding to the value of the pressure. In the decompression period HF fell to its initial level or below, and later returned to the initial level in the postcompression period (Fig. 3b). The changes described above were clearly manifested in experiments involving exposure to oxygen under a pressure of 3 atm. In the experiments in which the hyperoxia did not exceed 0.2-0.4 atm, on the other hand, deviations of HF usually did not go beyond 0.2 W. The results of these series of experiments are given in Table 1. Despite the outward similarity between the periodic changes in the experiments in which an artificial source of heat was used and those on animals, significant differences were revealed in those periods of the experiment when the maximal cooling effect of the hyperbaric oxygen could be expected: the plateau and decompression periods. In the first of these periods the animals were able to maintain a practically stable HF level, but in the second the fall in HF was much less marked than in the model experiments. The rectal temperature of the albino rats remained close to its initial value and the subcutaneous temperature fell by not more than 1.5°C (by 0.4-0.6°C on average for the group). Meanwhile the temperature of the resistor under similar conditions fell by 3-5°C.

In two small series of experiments the effect of pure oxygen and a mixture of 5% oxygen with 95% nitrogen under a pressure of 4 atm on the dynamics of HF in albino rats was compared. Analysis of the results gave parallel lines at higher values of HF in the experiments with oxygen.

It can be concluded from these experimental results that under hyperbaric conditions the animal's heat loss rises. The absence of any significant changes in rectal and subcutaneous temperature under these circumstances suggests that the cause might be increased heat production in the body during exposure to hyperbaric oxygen.

LITERATURE CITED

1. V. I. Arsen'eva, in: Abstracts of Proceedings of an All-Union Conference on Heat Exchange and Temperature Regulation [in Russian], Leningrad (1967), pp. 4-6.
2. V. A. Berezovskii, The Oxygen Tension in the Tissues of Animals and Man [in Russian], Kiev (1975).
3. A. M. Gerasimov, P. M. Gramenitskii, and L. F. Panchenko, in: Hyperbaric Oxygenation. Clinical Application and Safety Precautions [in Russian], Moscow (1975), pp. 251-252.
4. O. A. Gerashchenko, Fundamentals of Calorimetry [in Russian], Kiev (1971).
5. E. S. Gramenitskaya, in: Abstracts of Proceedings of an All-Union Conference on Heat Exchange and Temperature Regulation [in Russian], Leningrad (1967), pp. 19-20.
6. P. M. Gramenitskii and V. I. Arsen'eva, in: The Effect of an Increased Oxygen Pressure on the Organism [in Russian], Rostov-on-Don (1969), pp. 25-26.
7. S. M. Dionesov, V. D. Kravchinskii, and S. I. Prikladovitskii, Fiziol. Zh. SSSR, 17, 1004 (1934).
8. V. V. Matsynin, Fiziol. Zh. (Ukr.), No. 4, 523 (1970).
9. V. V. Matsynin, Fiziol. Zh. (Ukr.), No. 6, 848 (1975).
10. V. V. Matsynin, in: Abstracts of Proceedings of the Second All-Union Congress of Pathophysiologists [in Russian], Vol. 1, Tashkent (1976), p. 441.
11. R. C. Reid and T. K. Sherwood, The Properties of Gases and Liquids: Their Estimation and Correlation, McGraw-Hill, New York (1966).
12. Encyclopedic Dictionary of Physics [in Russian], Vol. 5, Moscow (1965), pp. 150-151.
13. N. V. Tsederberg, The Thermal Conductivity of Gases and Liquids [in Russian], Moscow–Leningrad (1963).
14. L. K. Cherednichenko, Physiological Calorimetry [in Russian], Moscow–Leningrad (1965).
15. P. Bert, On the Effect of a Raised Barometric Pressure on Animal and Plant Organisms [in Russian], Petrograd (1916).