EFFECT OF PROLONGED EXPOSURE TO HYPERBARIC CONDITIONS ON MYOCARDIAL ELECTRICAL ACTIVITY AT REST AND DURING WORK

G. N. Evstropova

UDC 612.172.4;612.176]-06;612.274

Myocardial electrical activity was studied in divers at rest and during physical exertion of varied intensity at normal pressure and during exposure for 1 week to a pressure of 5 atm $N_2 + O_2$. At rest and during work of equal power, under hyperbaric conditions the heart rate was slower than at 1 atm, although its increase during work was greater than at 1 atm. During work under increased pressure there was a more marked increase in amplitude of the P wave, possibly due to increased resistance in the pulmonary circulation under hyperbaric conditions; the amplitude of the T wave was reduced and the S-T interval depressed. Some divers showed signs of impairment of metabolic processes in the myocardium and disturbances of its automatic activity and conductivity.

KEY WORDS: *hyperbaric conditions; electrocardiography; physical exertion.*

The data on the effect of exposure of man for periods of several days to increased pressure on the state of his cardiovascular system are fragmentary and contradictory [1, 6, 8, 9, 11-13].

In this investigation the effect of prolonged exposure to hyperbaric conditions on electrical activity of the heart was studied.

EXPERIMENTAL METHOD

Changes in myocardial electrical activity at rest and during work were studied in subjects kept for 1 week under a pressure of 5 atm. The partial pressure of oxygen in the pressure chamber was 350-380 mm Hg, of nitrogen 3392-3424 mm Hg, of CO_2 6-8 mm Hg, and of water vapor 20-21 mm Hg; the temperature was 25-26°C. Six professional divers aged 28-32 years took part in the experiments. Work on a bicycle ergometer consisted of a series of successive 5-min stages (300, 450, 600, 750, and 900 kg·m/min) separated by 3-min rest intervals, continuous work for 10-12 min at 900 kg·m/min, and work at the level of maximal oxygen consumption. The ECG was recorded at rest using standard, amplified, and Wilson's leads, before work, during work, and in the recovery period using Nebb's leads.

EXPERIMENTAL RESULTS AND DISCUSSION

During prolonged exposure to a pressure of 5 atm the resting heart rate (HR) of the divers was slower, and the duration of the R-R and Q-T intervals longer, than under a normal pressure (Table 1). On certain days during the stay under hyperbaric conditions the systolic index (SI) of four divers was higher than its expected value for that particular HR by 3-16%. In diver B, during the first day of the stay under increased pressure, transient extrasystoles of the bigeminy type were observed at night; the extrasystoles originated from the middle part of the atrioventricular node (Fig. 1). Changes in the amplitude of the P and T waves at rest under hyperbaric conditions varied in direction in different subjects. After the second day of the stay under increased pressure the amplitude of the P wave of four divers increased by 15-70% and of the other two it decreased by 34-45%. Meanwhile, the ampli-

Laboratory of Underwater Biomedicine, Research Institute of Water Transport Hygiene, Ministry of Health of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR V. N. Chernigovskii.) Translated from Byulleten Éksperimental'noi Biologii i Meditsiny, Vol. 84, No. 9, pp. 259-262, September, 1977. Original article submitted April 15, 1977.

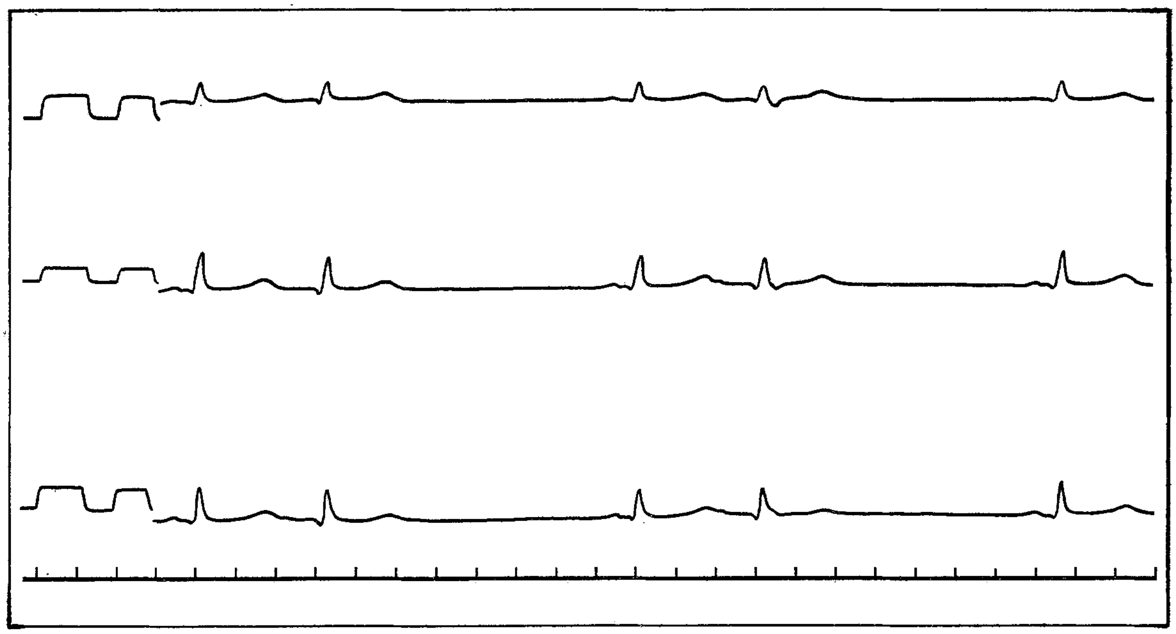

Fig. 1. Extrasystoles in diver B at night of first day of exposure to pressure of 5 atm.

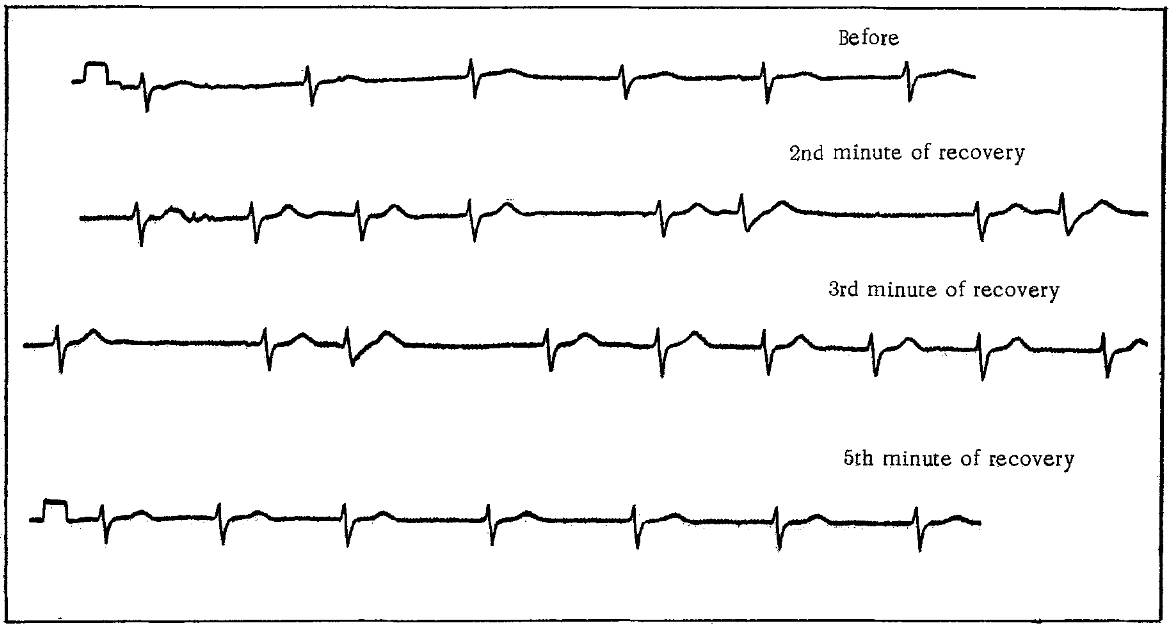

Fig. 2. Disturbances of automatic activity and conductivity of myocardium of diver C after work with an intensity of 900 kg·m/min on sixth day of exposure to a pressure of 5 atm.

tude of the T wave in four divers was reduced by 16-49% and in the other two it increased by 35-36%.

Under hyperbaric conditions the changes in the ECG indices continued to depend on the power of the work done (Table 1). However, during work under an increased pressure HR was slower than during the same work under a pressure of 1 atm. On a given day of the experiment the increase in HR, SI, and the amplitude of the P wave during work under a pressure of 5 atm was greater than during the same work under normal pressure conditions. In two subjects (A and B) on the fifth and sixth days of exposure to hyperbaric conditions, the decrease in the amplitude of the T wave during work with an intensity of 900 kg·m/min and work at the level of the maximal oxygen demand was higher than during the same work under normal pressure

TABLE 1. ECG Indices for Divers at Rest and during work under Pressures of 1 and 5 atm

Indices	Increase in HR during work, %	At rest before work		During work, kg·m/min			
				450		900	
		$M\pm\sigma$	P	$M\pm\sigma$	P	$M\pm\sigma$	P
HR	1	85±7		121±5		184±7	
	5	74±8	<0,01	111±7	<0,01	167±8	<0,01
Increase in HR during work, %	1			39±23		114±20	
	5			68±21	<0,01	134±19	<0,01
SI	1	45±3					
	5	40±2	<0,05				
Increase in SI during work, %	1			9±5		16±4	
	5			14±5	<0,05	27±5	<0,05
Increase in amplitude of P wave during work, %	1			9±4		43±24	
	5			43±20	<0,05	79±25	<0,05

Legend. 1. P) Wilcoxon's criterion for ties pairs of variants. Significance of changes in indices at 5 atm compared with indices at 1 atm was determined. 2. At rest before work under a pressure of 1 atm n = 10, at 5 atm n = 26, during work with an intensity of 450 kg·m/min under a pressure of 1 atm n = 6, and during work with an intensity of 900 kg·m/min under a pressure of 5 atm n = 17.

conditions, whereas in diver B the S-T interval was depressed by 3-4 min. In subject C, at the end of work with an intensity of 900 kg·m/min and during the first few minutes of recovery after work on the sixth day under an increased pressure, disturbances of automatic activity and conductivity were observed (Fig. 2). The recovery of the ECG indices after work under hyperbaric conditions was slower in all the divers than after work under a pressure of 1 atm.

The data on the change in HR agreed with the results of investigations during short exposures to a pressure of 5 atm in an atmosphere of compressed air [2] and prolonged exposure to an atmosphere of He + N_2 + O_2 under a pressure of 6 atm [3, 4], as well as with the results of observations by other workers [1, 8, 9, 11-13], who found a decrease in HR during rest and work under hyperbaric conditions. Bradycardia at rest and a lower HR during work under increased pressure than under normal pressure were evidently connected with the effects of the increased partial pressure of oxygen and, possibly, of other factors of the hyperbaric atmosphere (increased density and increased cooling effect). Meanwhile, the greater increase in HR, SI, and amplitude of the P wave during work under high pressure than under normal pressure conditions, the appearance of more severe impairment of myocardial function during work under these conditions than during work at normal atmospheric pressure, the reduction in the amplitude of the T wave and appearance of depression of the S-T interval, the disturbances of automatic activity and conductivity of the myocardium in some of the subjects, and the delayed recovery of the ECG indices after work all show that the same work under hyperbaric conditions was more severe in its effect than at normal pressure.

Heart rate under hyperbaric conditions thus does not give an adequate idea of the severity of the work done. This conclusion is confirmed by investigations of the gas exchange [5] during work under a pressure of 5 atm in a medium of compressed air: During inhalation of gas mixtures with increased density the provision of energy for work is transferred to a higher level, evidently on account of increased work of the respiratory muscles.

The increase in amplitude of the P wave at rest and the greater increase in its amplitude during work than at normal pressure, just as changes in the phase structure of the cardiac cycle and rheogram of the lung under hyperbaric conditions [3, 4], are evidently connected with an increase in the resistance in the pulmonary circulation under the influence of factors of the hyperbaric environment (increased density and hyperoxia). Some workers have found [14] that hyperoxia causes vasoconstriction in the lungs and an increase in the pressure in the pulmonary circulation. The increase in work of the respiratory muscles [7, 10] and in the resistance in the pulmonary circulation [3, 4] increased the work of the heart at rest and, more especially, during work. These factors can also be linked with the increase in SI at rest and the great increase in this index during work under hyperbaric conditions.

Disturbances of automatic activity and conductivity of the myocardium observed in some divers during exposure to an increased pressure could reflect an increase in tone of the vagus nerve arising during inhalation of the hyperoxic gas mixture. However, the appearance of these changes simultaneously with marked tachycardia suggests that other mechanisms may be responsible for their development.

LITERATURE CITED

1. G. L. Apanasenko and V. A. Grinevich, in: Ensuring the Safety and Increasing the Efficiency of Underwater Operations [in Russian], Leningrad (1973), pp. 60-61.
2. L. I. Ardashnikova, G. N. Evstropova, and L. A. Chudnovskaya, in: Ensuring the Safety and Increasing the Efficiency of Underwater Operations [in Russian], Leningrad (1973), pp. 63-65.
3. L. I. Ardashnikova, G. I. Kurenkov, B. O. Yakhontov, et al., in: Abstracts of Proceedings of Symposia of the 12th Congress of the I. P. Pavlov All-Union Physiological Society [in Russian], Vol. 2, Leningrad (1975), p. 175.
4. G. N. Evstropova, Abstracts of Proceedings of the Seventh International Symposium on Maritime Medicine [in Russian], Moscow (1976), p. 209.
5. G. I. Kurenkov and B. O. Yakhontov, Fiziol. Zh. SSSR, No. 12, 1813 (1971).
6. U. F. Mazzon, in: The Sealab-2 Underwater Laboratory [Russian translation], Leningrad (1968), pp. 96-106.
7. A. A. Buhlmann, in: Second Symposium on Underwater Physiology, Washington (1963), pp. 98-107.
8. R. W. Hamilton, in: Proceedings of the Third Symposium on Underwater Physiology (ed. by C. J. Lambertsen), Baltimore (1967), pp. 361-374.
9. J. B. MacInnis and G. F. Bond, in: The Physiology and Medicine of Diving and Compressed Air Work (ed. by P. B. Bennett et al.), London (1969), pp. 495-523.
10. R. Marshall, E. H. Lanphier, and A. B. Dubois, J. Appl. Physiol., 9, 5 (1956).
11. J. B. Morrison and J. T. Florio, J. Appl. Physiol., 30, 724 (1971).
12. P. Naiton, L. C. Johnson, and M. Austin, Aerospace Med., 42, 69 (1971).
13. K. E. Schaefer, C. R. Carey, and J. Dougherty, Aerospace Med., 41, 856 (1970).
14. C. D. Wood, G. F. Parkins, A. G. Smith, et al., Aerospace Med., 43, 162 (1972).

CHANGES IN ELECTROGENIC PROPERTIES OF STRIATED MUSCLE FIBERS IN EXPERIMENTAL BOTULISM

V. V. Morrison

UDC 616.981.553-092.9-07:616.74-073.97

Changes in the electrical parameters of fibers of fast and slow muscles were studied during the development of local botulism in rats. In the early stage of poisoning the membrane potential (MP) of fibers of both fast and slow muscles fell. In the late stage of poisoning, marked depolarization of the membrane was accompanied by a change in the input resistance and time constant (RC) of the membrane, rheobase currents, and amplitude of the action potentials evoked by direct intracellular stimulation. Changes in the electrical parameters were more marked in fast muscle fibers.

KEY WORDS: *striated muscle; electrical parameters; botulism.*

Botulinus toxin disturbs neuromuscular transmission by blocking liberation of the mediator from the presynaptic terminals. No significant changes are found under these circum-

A. A. Bogomolets Department of Pathological Physiology, Saratov Medical Institute. (Presented by Academician of the Academy of Medical Sciences of the USSR N. N. Sirotinin.)

Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 84, No. 9, pp. 262-264, September, 1977. Original article submitted December 20, 1976.