Information Characteristics of Cardiomyocytes Exposed to Contrasting Temperatures

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UDC 616.127.018.1-02:612.012.43]-07

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny,* Vol. 117, № 5, pp. 543-544, May, 1994
Original article submitted January 4, 1994

Information analysis of the intracellular reorganization occurring in the cardiomyocytes of Wistar rats is performed after total hypothermia and total hyperthermia. It is demonstrated that the structural and relative entropies decrease and the redundancy coefficient increases after total hypothermia, indicating a reduction in the structural diversity of cardiac myocytes and the formation of a new stable morphofunctional state of these cells. There are no significant changes in the information characteristics of cardiomyocytes after a single total hyperthermia.

Key Words: *cardiomyocytes; total hypothermia; total hyperthermia; information analysis*

Application of information analysis to morphological studies offers an integral evaluation of the state of morphological systems, permits identification of the direction of their changes under the influence of unfavorable conditions, and gives an idea of the redundant (hidden) reserves of structures which are believed to broaden the adaptive-compensatory abilities of morphological systems and increase the reliability of their function [1,3]. Analysis of information parameters also allows one to compa-re the dynamics of changes in the same morphological systems under the influence of various extreme factors and to predict the direction of these changes.

Previously we performed a stereological investigation of the intracellular reorganization of rat cardiomyocytes after total hypothermia and total hyperthermia [4-6], which allowed us to establish some patterns in the spatial reorganization of cardiomyocytes and to characterize the qualitative changes in the major ultrastructures. The objective of this study was to evaluate the direction and intensity of intracellular regeneratory processes under these conditions using information analysis.

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MATERIALS AND METHODS

Information analysis of intracellular reorganization in Wistar rat cardiomyocytes was performed after exposure of the animals to contrast temperatures: moderate total hypothermia (3-4°C during a 6- and 8-week periods), intensive total hypothermia (-7°C during 8- and 16-day periods) [4,5], and on days 3 and 7 after total hyperthermia (43°C, 45 min) [6]. The information characteristics (entropy, relative entropy, and redundancy coefficient) at different temperatures were calculated for the cardiomyocyte (cell system) and its major structural components (subsystems): myofibrils, mitochondria, agranular sarcoplasmic reticulum, T tubules, and sarcoplasmic matrix, using the data of stereological analysis of intracellular reorganization of cardiomyocytes (volume density) under the same experimental conditions. The information parameters were calculated from conventional formulas [1,3,7]. The data were statistically analyzed using Student's t test.

RESULTS

Analysis of information parameters of rat cardiomyocytes after exposure to extreme temperatures revealed a significant decrease in entropy and relative entropy after total hypothermia (Tables 1 and

0007-4888/94/0005-0545$12.50

TABLE 1. Information Parameters of Rat Cardiomyocytes after Moderate Total Hypothermia ($M \pm m$)

Parameter	Control	Period of hypothermia	
		6 weeks	8 weeks
Entropy, db. units	1.600±0.006	1.549±0.037	1.498±0.014*
Relative entropy	0.690±0.003	0.667±0.016	0.645±0.006*
Redundancy coefficient, %	31.1±0.25	33.3±1.61	35.5±0.62*

Note. Asterisk indicates $p<0.05$.

2). The decrease was greater after intensive total hypothermia (22% by the end of the experiment compared with 6% after moderate hypothermia). It should also be mentioned that entropy and relative entropy had already significantly decreased by day 8 of the study (Table 2). Since entropy is a measure of the amount of structural disorder in a system [1,3], its reduction under these experimental conditions indicates an increase in the amount of order in the structural organization of cardiomyocytes or a decrease in their structural diversity.

Comparison of these data with the results of stereological analysis of the intracellular reorganization of cardiomyocytes after total hypothermia [4,5] indicates that the decrease in structural diversity results predominantly from a relative increase in myofibril mass, as evidenced by an increase in their volume density. There was a parallel decrease in the "saturation" of a unit of the myofibril volume by the main sarcoplasmic organelles. The same decrease in this parameter occurred in both experimental models (32% after moderate hypothermia and 28% after intensive hypothermia); however entropy and relative entropy decreased to a greater degree after intensive hypothermia, which reflected the changes in volume density of practically all major structures of the cardiomyocyte.

The redundancy coefficient increased in both regimes of total hypothermia (Tables 1 and 2), indicating the formation of a new stable structural-functional system and its high reliability in a new environment. It may be assumed that one of the species adaptive programs is being realized at the cellular level [2] is characterized by minimized functioning of cell systems, as evidenced by the decrease in structural diversity. Presumably, merely the elimination of the influence of an unfavorable factor is insufficient for a return to the initial morphofunctional state. Induction of morphogenetic processes appropriate for a certain period of ontogenesis is necessary.

There were no pronounced changes in the information parameters of cardiomyocytes after total hyperthermia (Table 3), indicating the absence of changes in the structural diversity of cardiomyocytes.

Thus, comparison of information characteristics of cardiomyocytes after the influence of different temperatures on the animal organism revealed a decrease in structural entropy and an increase in the redundancy coefficient after total hypothermia (in contrast to total hyperthermia), which indicates the formation of a new morphofunctional state of cardiomyocytes, characterized by a reduction of structural diversity and a decline in the intensity of intracellular processes.

TABLE 2. Information Parameters of Rat Cardiomyocytes after Intensive Total Hypothermia ($M \pm m$)

Parameter	Control	Period of hypothermia	
		6 weeks	8 weeks
Entropy, db. units	1.696±0.030	1.372±0.023*	1.324±0.002*
Relative entropy	0.730±0.013	0.591±0.010*	0.570±0.001*
Redundancy coefficient, %	27.0±1.3	40.9±1.0*	43.0±0.1*

Note. Asterisk indicates $p<0.01$.

TABLE 3. Information Parameters of Rat Cardiomyocytes after a Single Total Hyperthermia ($M \pm m$)

Parameter	Control	Period of hypothermia	
		6 weeks	8 weeks
Entropy, db. units	1.512±0.047	1.507±0.066	1.496±0.011
Relative entropy	6.651±0.020	0.649±0.028	0.644±0.005
Redundancy coefficient, %	34.9±2.0	35.1±2.8	35.6±0.5

This study was financially supported by the Russian Foundation for Basic Research, project code 93-04-7353.

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Inhibition of Generalized Wound Infection in Immunized Rats

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UDC 617-001.4-022-092.9]-092:612.017.1]-07

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 117, № 5, pp. 545-546, May, 1994
Original article submitted October 11, 1993

The occurrence of the pyocyanic bacillus in the blood and spleen is compared after intramuscular administration to intact and immunized animals. It is demonstrated that blood clearance is performed by transferring the causative agent to splenic phagocytes. It is suggested that antibodies agglutinize the microorganisms in the primary focus of infection and prevent their entry into the blood.

Key Words: *antibodies; agglutination; bacteremia; sepsis*

Previously it was found that immunization facilitates blood clearance from systemically administered bacteria [5,7]. This was attributed to the opsonizing effect of antibodies on microorganisms and the accelerated uptake of them by liver and spleen macrophages. The potective activity of the antibodies was explained in a similar manner in subsequent papers, for example, upon infection caused by the pyocyanic bacillus (*Pseudomonas aeruginosa*) [6,8]. In real life, as opposed to experiment, the agents causing wound infection usually do not enter the blood directly, but first make contact with tissues and may modulate the probability and duration of bacteremia not only by opsonization but also by agglutination of bacteria. It is more difficult for bacterial aggregates formed as a result of agglutination to cross the tissue-blood barrier [1-3]. In other words, if bacteria have entered the tissue, blood sterility can be maintained by antibodies through opsonization and probably by agglutination. It is not an easy task to differentiate the effects of agglutination and opsonization on bacteremia. We attempted to solve this problem bearing in mind that opsonization facilitates the removal of bacteria from the blood and as-

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0007-4888/94/0005-0547$12.50