Research Article

Ontogenetic variability of information condition of a thymus of white rats

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Abstract: We investigated the developmental changes in the information parameters of the thymus to define the level of adaptive resources of this organ. It was revealed that studied parameters undergo cyclic changes in ontogenesis. Ontogenetic periods characterized by low values of information morphological organization are critical, because at this time organs are characterized by a low level of regenerative-adaptability and less number of structural elements constituting a potential reserve.

Keywords: thymus, ontogeny, entropy, adaptation

INTRODUCTION

The study of developmental changes in mammals, the mechanisms of their implementation at different levels from the molecular to the system, remain one of the most urgent problems of modern biology. Changes in pre- and postnatal development are increasingly seen as a phenomenon caused by the dynamics of adaptation and regeneration capabilities of living systems in different hierarchical levels [2,14]. Several authors do not exclude the existence of a direct link of the system information change with the development of pathological processes in the different periods of ontogeny. It is shown that the frequency of various pathologies manifestation, and the tension of physiological processes, including the immunobiological reactivity, are subject to certain developmental cycles. There are several reports on the interrelation of aging to age energy-information changes. Consideration that entropy of tissue systems is steadily increasing with age, we have to assume the changes of that criterion, displaying the state of adaptation and regenerative abilities of the organism and tissue homeostasis, during periods of ontogenesis, marking the manifestation of a disease process [6,12,9,10,16,11,13,8].

Ontogenetic changes of the information parameters displaying a level of adaptation resources of a liver and renal tubular system were described in earlier conducted researches [2].

It seems also currently important to investigate and describe changes of functioning of immunocompetent organs in ontogenesis, which are not described at present [7,5].

In this connection it is relevant to examine an ontogenetic variation of regenerative-adaptive abilities of mammalian tissue.

MATERIALS AND METHODS

To study the developmental variability of information condition of the thymus of mammals we have used organs of 9500 white Wistar rats. The organs were taken to study since birth. The maximum age of the animals used in the study - 3 years and 8 months.

All of the studied organs were collected after euthanasia of animals under anesthesia. After fixation of the material with 10% neutral buffered formalin for a portion of the wiring done by the usual method followed by pouring in paraffin. In conducting research bodies, paraffin-embedded, were prepared by serial sections of 5-6 microns.

Hematoxylin-eosin staining was performed by the standard technique. Stained sections were embedded in balsam.

Based on the concept of information in a tissue system as the displaying of the diversity of functions and morphology of the process such indicators were proposed and validated for assessing the information of
organs and tissues - informational morphological capacity \(H_{\text{max}}\), informational morphological entropy \(H\), informational morphological organization \(S\), the relative entropy of the morphological \(h\) and redundancy \(R\). [1]. In this case, the baseline characteristics which used to calculate these parameters can vary widely (the linear dimensions of the structures, their number, etc.). In our study was defined the volume of the nuclei of thymus cells. The cells of red pulp of the thymus underwent karyometry. Morphometric parameters of nuclei were measured by image analyzer "Videotest". Then carried out a breakdown of the aggregate into classes, and then conducted a study of the entropy of the system of the renal tubular system.

Informational morphological capacity \(H_{\text{max}}\), which means maximum structural diversity, is calculated on this formula [1,3,4]:

\[H_{\text{max}} = \log_2 n,\]

where \(n\) - number of classes.

Next, the calculation of the real structural diversity \(H\). Real structural diversity is the parameter that clearly illustrates the degree of determinism of the morphofunctional system in time and space [1,3,4].

The calculation was performed using the formula:

\[H = -\sum P_i \log_2 P_i,\]

where \(\sum P_i\) - sum of probabilities of stay of the measured parameter of cells in one of existing classes; \(\log_2 P_i\) - logarithm of the probability of staying in one of the possible classes. In this case, the value of \(P_i\) is defined as the classical probability [1,3,4]. Knowing the maximum and actual structural diversity, we can calculate the organization of the system \(S\), which means the difference between the maximum possible and the real structural diversity (implemented structural diversity). This parameter, in our opinion, display the state of the system adaptability to date. To determine the value of this parameter is used the formula [1,3,4]:

\[S = H_{\text{max}} - H.\]

It is necessary to consider that when \(H = H_{\text{max}}\), the system is deterministic, but such relation to the vast majority of permissible is possible only in theory.

Then we determined the coefficient of relative entropy of the system, or (the coefficient of compression of information) \(h\) as [1,3,4]:

\[h = \frac{H}{H_{\text{max}}}.\]

High levels of relative morphological entropy is an evidence of the disorder of system and significantly reducing of its structural integrity [1,3,4].

The coefficient of the relative organization of the system (redundancy factor) \(R\) is given by [1,3,4]:

\[R = \frac{S}{H_{\text{max}}} \times 100\% = \left(1 - h\right) / 100\% .\]

The statistical difference determined using repeated measures analysis of variance or paired Student t-tests. A p value of < 0.05 was considered statistically significant.

All procedures were carried out in compliance with the EC Directive 86/609/EEC and with the Russian law regulating experiments on animals.

**RESULTS**

We found that the thymus of rats during ontogeny is characterized by \(H_{\text{max}}\) value equal to 2.58 ± 0.004 bit.

At the study of the dynamics of informational parameters in thymus during postnatal ontogenesis, we found that the values of the tested parameters have certain periodic oscillations.

For thymus of newborn rats (Fig.1) was revealed that the value of \(H\) is 1.14 ± 0.02 bits, \(S\) was equal to 1.44 ± 0.02 bits, \(h\) was 0.4421 ± 0.007 bits, and the value of \(R\) contained 55.79 ± 0.81%.

In the first day of ontogenesis we observed a gradual reduction in the values of parameters \(H, h, R\), and increase quantities of \(S\) and \(R\), continuing up to the 4th day of postnatal ontogenesis. In this period the value of \(H\) decreased to 1.11 ± 0.02 bits, \(h\) decreases to 0.4282 ± 0.005 bits. At the same time the value of \(S\) increased to 1.48 ± 0.02 bits, \(R\) - up to 57.18 ± 1.25% (Fig.1,2,3).

Next, we observed the increase of \(H\) and \(h\), but the reduction of \(S\) and \(R\) continued to 11th day of postnatal ontogenesis. At this time, \(H\) was equal to 1.38 ± 0.05 bits, \(S\) – 1.20 ± 0.05 bits, \(h\)-0.5340±0.01 bits, \(R\) – 46.52±1.10%. Then, up to 29th day, we observed a decrease of \(H\) to 1.32 ± 0.03 bit. At this time, \(S\) was 1.22±0.03 bit, \(h\) was 0.5142±0.01 bit, value of \(R\) increased to 48.58±0.90%.

By 52 days of development \(H\) increased to 1.47±0.03 bit, \(S\) was equal to 1.10±0.03 bit, \(h\) was equal to 0.5720±0.01 bit, \(R\) – 42.79±1.2%. By 93 days \(h\) again decreased to 1.36±0.02 bits, \(S\) increased to 1.22±0.02 bits, \(R\) increased to 0.5262±0.008 bits, \(R\) was equal to 33.36 ± 0.90%.

At 146th day of postnatal development thymus was characterized by \(H\) equal to 1.72±0.02 bit, \(S\) – 0.86±0.02 bit, \(h\) – 0.6664±0.008 bit. At the same time \(R\) was 33.36±1.2%. By 240 days \(H\) level reduced to 1.62±0.02 bits, \(S\) increased to 0.96±0.02 bits, \(h\) reduced to 0.6272±0.008 bits, \(R\) increased to 37.21±1.36%.

On 361st day of ontogeny \(H\) increased to 1.94±0.02 bit, \(S\) reduced to 0.64±0.02 bits, \(h\) increased to 0.7527±0.004 bit, \(R\) was equal to 24.73±0.8%.
day 577 of postnatal ontogenesis rat thymus was characterized by H equal to 1.83±0.02 bit, S was equal to 0.75±0.02 bit, h – 0.6527±0.006 bits and R was equal to 28.98±1.20%.

On the 854 day of ontogenesis H had a rise to 2.20±0.02 bits, h increased to 0.8527±0.009 bits. Accordingly, S compared to the previous described period reduced to 0.380±0.02 bit, R - to 14.73±0.99%.

By 1300 days of ontogenesis, H reduced to 1.91±0.01 bit, h – up to 0.7423 ± 0.006 bits. At the same time, S increased to 0.67 ± 0.01 bits, R - to 25.97 ± 2.10%.

**Fig. 1**: Dynamics of parameters $H_{\text{max}}$ and H in rat thymus at prenatal ontogenesis

(Here in after ordinates in brackets are the day of ontogenesis taking into account the prenatal).

**Fig. 3**: Dynamics of parameters S and h in the rat thymus at postnatal ontogenesis.
DISCUSSION AND CONCLUSIONS

Conducted research clearly shows that all the examined parameters, characterizing the information state of the thymus of rats, undergo natural cyclic changes during both the prenatal and postnatal ontogenesis.

We highlight alternating rise and fall of energy-information parameters. Period of ontogenesis, which will have another critical point (point of change of parameter vector, the upper or lower extreme point) is defined by the equation:

$$T_n = T_{n-1} + 1.29 \times T_{n-1},$$

Where,

- $T_n$ - a critical period of ontogenesis (including the prenatal ontogenesis);
- $T_{n-1}$ - previous extreme point with the same sign (in days including the prenatal ontogenesis); 1.29 - a constant factor.

In ontogenesis we revealed the following periods for which change of energy-information parameters is characteristic: infantilism period, juvenile period, the period of youth, adulthood, old age and the period of maximum age. Such distribution of extreme points of energy-information state shows a gradual increase of entropy at the ontogenesis and increase of width of the period at a relatively constant amplitude of the magnitude of energy-information parameters.

Ontogenetic periods, for which low values of informational morphological organization are peculiar, are critical, because at this time tissues and organs are characterized by a low level of regenerative and adaptive opportunities and low quantity of structural elements constituting a potential reserve.

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