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Ontogenetic variability of information condition of the renal tubular system of white rats

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Abstract

We investigated the developmental changes of the information parameters of the renal tubular system which displays the level of adaptive resources. It was found a cyclic variation of the studied parameters. Ontogenetic periods which are 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 fewer quantity of structural elements serving as a potential reserve.

INTRODUCTION

The study of developmental changes in mammals and 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 regenerative capabilities of living systems in different hierarchical levels [3;10]. Several authors do not exclude the existence of a direct link of the system information change with the development of pathological processes in the various 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 and age energy-information changes. Considering that entropy of tissue systems is steadily increasing with age, we have to assume that the changes of that criterion are 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 [4,6,12,8,9,5,11,7].

In this regard 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 renal tubular system of mammals, we have used organs of 5000 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 and several treatments for dehydration in alcohol by the usual method organs were pouring in paraffin. Sections having 5μm thickness were cut and stained with hematoxylin and eosin and histopathological analysis was carried.

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_{max}), informational morphological entropy (H), informational morphological organization (S), the relative morphological entropy (h) and redundancy (R) [1;2]. In this case, the baseline characteristics which were used to calculate these parameters can vary widely (the linear dimensions of the structures, their number, etc.). In this research nuclei volume in cells of an epithelium of kidney tubules was defined. Morphometric parameters of nuclei were measured by image analyzer "Videotest". Then was carried out a breakdown of the aggregate into classes, and then was conducted a study of the entropy of the renal tubular system.

Informational morphological capacity H_{max}, which means maximum structural diversity, is calculated on this formula [2]:

$$H_{max} = \log_2 n,$$

where n - number of classes.

Next, we made 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 [2].

The calculation was performed using the formula:

$$H=-\Sigma P_i \log_2 P_i,$$

where ΣP_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 [1,2,3,4].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, displays the state of the system adaptability to date. For determination of this parameter this formula was used [2]:

$S=H_{max}-H$.

It is necessary to consider that when H = Hmax, 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 [2]:

$h= H/H_{max}$.

High levels of relative morphological entropy are an evidence of the disorder of system and significantly reducing of its structural integrity [2].

The coefficient of the relative organization of the system (redundancy factor) R is given by [2]:

$R=(S/H_{max})\times100\%=(1-h)/100)\%$.

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 renal tubular system of rats during ontogeny is characterized by H_{max} value equal to 2.807±0.003 bit.

In the study of the dynamics of information parameters in tubular system during postnatal ontogenesis, we found that the values of the tested parameters have certain periodic oscillations. For kidneys of newborn rats (Fig.1) revealed that the rate of H is 1.81±0.01 bits, S is 0.997±0.004 bits, h is 0.6448±0,007 bits, and the value of R is 35.52±0.07%.

In the next days of the study reveals a gradual reducing of the values of parameters H, h, and increasing of S and R, continuing up to the 4th day of postnatal ontogenesis. In this period the value of H is decreased to 1.77±0.02 bits, h decreases to 0.6329±0,006 bits. At the same time the value of S is increased to 1.03±0.017 bits, R - up to 36.71±0.63% (Fig. 2,3,4).

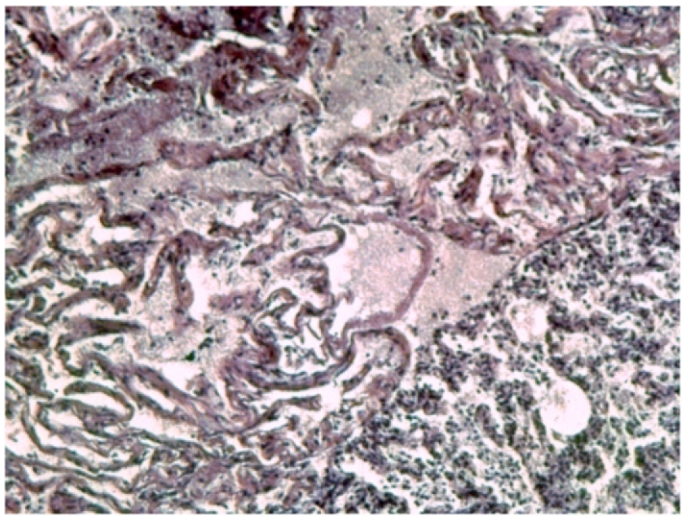

Fig. 1. Newborn rat renal tubular system. HE × 200

Further it was observed the increase of H and h, but the reduction of S and R continued to 18 days of postnatal ontogenesis. At this time, H was 1.88±0.01 bits, S 0.93±0.01 bits, h-0.6681±0.004 bits, R - 33.19±0.38%.

The direction of changes of the studied information parameters changes after the 27th day up to 36th day of postnatal ontogenesis, when there is a new change. By this time, compared to the previous described period, H rises to 1.80±0.020 bits, h increases to 0.669±0.010 bits. S is reduced to 0.90±0.020 bits, R is 35.87±0.89%.

On 68th day of postnatal ontogenesis rat renal tubular system is characterized by H equal 2.18±0.008 bits, S equal to 0.64±0.008 bits, h 0.7705±0.003 bit and R, which amounted to 22.95±0.89%.By the 110 days of postnatal ontogenesis H decreased to 2.09±0.020 bits, h - to 0.7463 ±0.003 bits. The value of S at this time declined to 0.7192 ± 0.02 bits, R - up to 25.37±0.63%.At 183 days after birth H is 2.31 ± 0.013 bits, S 0.50 ± 0.013 bits, h 0.8239 ± 0.004 bits, R 17.61±0.4%.

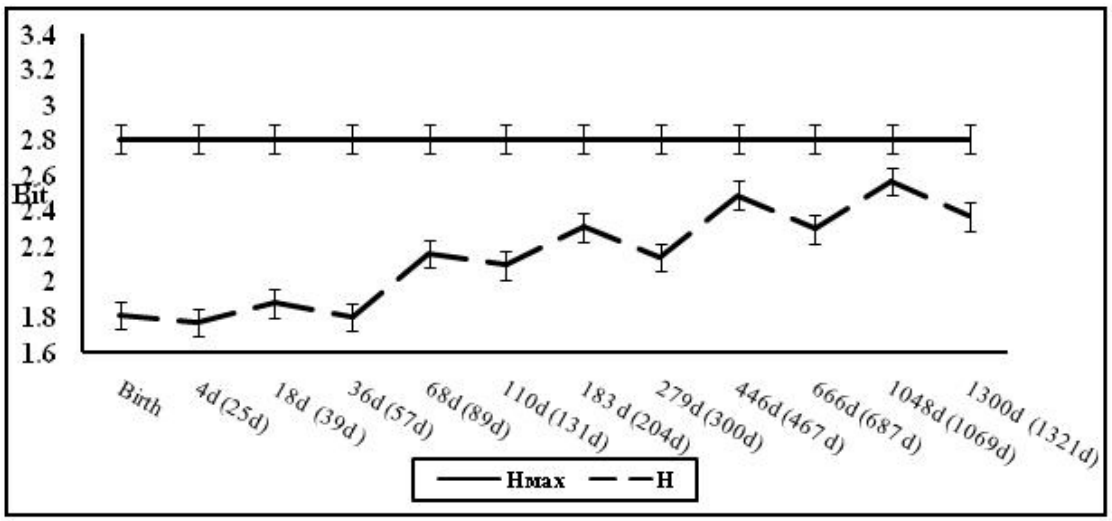

Fig.2. Dynamics of indicators Hmax and H in rat renal tubular system in prenatal ontogeny (Hereinafter ordinates in brackets are the day of ontogenesis taking into account the prenatal).

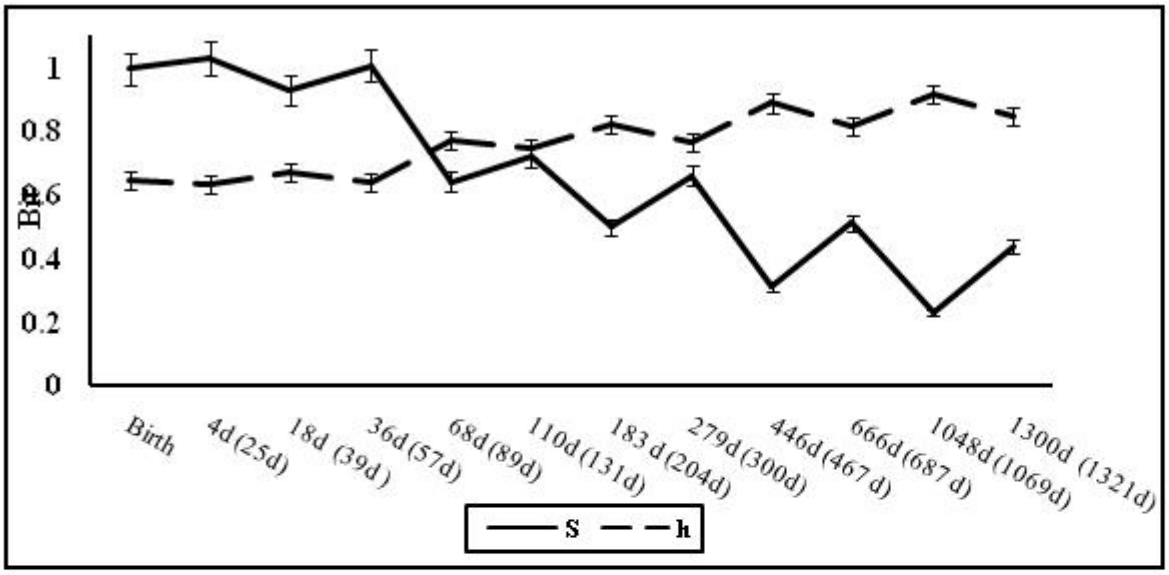

Fig. 3. Dynamics of parameters S and h in the rat renal tubular system in postnatal ontogenesis.

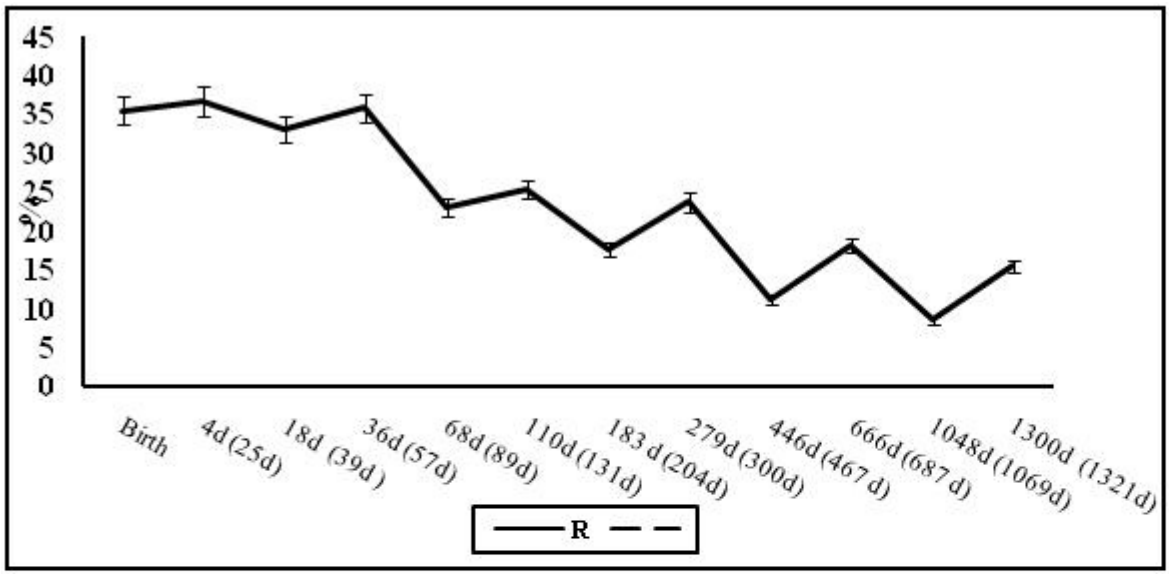

Fig. 4. Dynamics of parameters R in rat renal tubular system in postnatal ontogenesis.

By 279 days of postnatal ontogenesis H decreased again, reaching 2.14±0.02 bits, h 0.7633 ± 0.006 bits. The value of S at this time increased to 0.66±0.017 bits, R - to 23.67 ± 0.63.

On 446th day of postnatal ontogenesis the rat renal tubular system is characterized by H equal to 2.49±0.010 bits, S equal to 0.31±0.010 bits, h - 0.8881±0.004 bits and R, equal to 11.19 ± 0.39%. At 666 day of ontogenesis H decreased to 2.30±0.014 bits, h is decreased to 0.8181±0.005 bits. Accordingly, S compared to the previous described period raised to 0.51±0.014 bits, R increased to 18.19± 0.49%

At 1048 days after birth H is 2.57 ± 0.006 bits, S 0.23±0.007 bits, h 0.9165 ± 0.002 bits, R 8.53±0.24%.In the last studied period, the 1300th day of ontogeny, H is reduced to 2.37 ± 0,02 bits, h - to 0,8450 ± 0,02 bits. At the same time, S is increased to 0.44 ± 0.03 bits, R - up to 15.50 ± 1.35%.

DISCUSSION

As a result of the conducted researches, we revealed that all the examined parameters, characterizing the information state of the renal tubular system of rats in ontogenesis, undergo the natural cyclic changes both in the prenatal and postnatal ontogenesis.

We highlighted 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 determined 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 ontogeny);

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

CONCLUSION

In ontogenesis we identified such periods in which there is a change of energy-information parameters: the period of infantile, juvenile period, the period of youth, adulthood, old age and the period of maximum age. Such a distribution of extreme points of energy-information state shows a gradual increase of entropy in the ontogenesis and extension of the period at relatively constant amplitude of the magnitude of energy-information parameters.

Ontogenetic periods characterized by low values □□of informational morphological organization are critical, because at this time organs are characterized by a low level of regenerative-adaptability and fewer quantities of structural elements serving as a potential reserve.

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