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Morphological And Morphometric Characteristics Of Rat Thymus During Experimental Intestinal Cicatricial Process

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Abstract

The intestinal cicatricial process is accompanied by the development of systemic morphofunctional changes affecting the central organs of immunogenesis; however, the features of age-related timus restructuring in this pathology have not been sufficiently studied. The aim of the study is to study the morphological and morphometric features of the thymus of white purebred rats of various ages during the experimental intestinal cicatricial process. Materials and methods. The study was conducted on white purebred rats aged 4, 7, and 10 months. The intestinal cicatricial process was experimentally modeled, after which histological and morphometric studies of the thymus were conducted. The histological specimens were stained with hematoxylin and eozine. The architectonics of the thymus lobes, the state of the cortical and medullary substance, cell density, vascular bed features, and the organ's main morphometric indicators were evaluated. The obtained results were subjected to statistical processing. Results. It was established that in the control group of 4-month-old animals, the thymus is characterized by a well-defined cortical substance with a high density of lymphoid cells, which corresponds to the period of active functional formation of the immune system. During the experimental intestinal cicatricial process in all age groups, structural disorders of the thymus were identified, manifesting as

a decrease in cortical substance thickness, a decrease in thymocyte density, a relative increase in medullary substance, vascular disorders, and signs of involuntary changes. The severity of morphological and morphometric changes increased with age, indicating a decrease in the compensatory capabilities of the thymus. Conclusion. The experimental intestinal cicatricial process causes a pronounced age-dependent structural restructuring of the thymus, accompanied by changes in its morphometric parameters and signs of decreased functional activity. The obtained data expand the understanding of the mechanisms of damage to the central organs of immunogenesis in chronic intestinal pathology and can serve as a basis for developing immunocorrective therapy methods.

Keywords: Thymus, intestinal cicatricial process, rats, morphology, morphometry, age characteristics, immunogenesis, experiment.

Introduction

Intestinal cicatricial processes are one of the most significant consequences of chronic inflammatory diseases and surgical interventions, leading to persistent morphofunctional disorders of the intestinal wall, the development of fibrosis, impaired motor activity, and changes in the barrier function of the organ. In recent years, special attention has been paid to studying the systemic consequences of chronic intestinal pathology, as a long-lasting inflammatory process is accompanied by a disruption of immune homeostasis and the involvement of central organs of immunogenesis [1, 2, 3].

The thymus is the primary organ of T-cell immunity, where proliferation, differentiation, and selection of T-lymphocytes occur [4, 5]. The morphofunctional state of the thymus reflects the level of the body's immunological reactivity and changes under the influence of various pathological factors [6]. It is known that chronic inflammation is accompanied by the development of accidental involvement of the thymus, the disruption of its lobule architecture, a decrease in cortical substance volume, a decrease in thymocyte density, and changes in the functional activity of epithelioreticulocytes [7, 8]. However, the characteristics of the morphological restructuring of the thymus during the intestinal cicatricial process have not been sufficiently studied [9].

In recent years, most research has been dedicated to the mechanisms of intestinal fibrosis development, the role of cytokines, growth factors, and connective tissue remodeling. At the same time, changes in the central organs of the immune system, particularly the thymus, during experimental intestinal cicatricial process remain poorly studied [7, 10, 11]. There is insufficient data on the age-related characteristics of morphological and morphometric changes in the thymus, as well as the relationship between intestinal fibrosis processes and the functional state of the immune system [12, 13].

Studying the age-related characteristics of morphological and morphometric changes in the thymus during experimental intestinal cicatricial process is of great importance for understanding the mechanisms of the immunopathogenesis of this pathology [14]. A comprehensive assessment of the structural organization of the thymus in white purebred rats of various ages allows for determining the nature of adaptive-compensatory changes in the central organ of immunogenesis, identifying features of its age-related reactivity, and expanding understanding of the relationship between chronic intestinal pathology and the immune system [15, 16].

In this regard, the purpose of this study was to study the morphological and morphometric features of the thymus of 4-, 7-, and 10-month-old white purebred rats during the experimental intestinal cicatricial process. The obtained results can serve as an experimental basis for further studying the mechanisms of immune disorders in intestinal fibrosis and developing pathogenetically grounded methods for their correction.

Purpose of the Research

To study the morphological and morphometric changes in the rat thymus during the experimental intestinal cicatricial process.

Materials and Methods

Experimental research was conducted on white purebred rats aged 4, 7, and 10 months, which were divided into two groups: control and experimental. The control group animals were kept in standard vivarium conditions, while the experimental group rats were reproduced with a model of the intestinal cicatricial process. After the experiment was completed, the animals were removed from the experiment, and a thymus sample was taken for further morphological and morphometric research.

Histological preparations were prepared according to the generally accepted methodology and stained with hematoxylin and eozin. Microscopic examination assessed the features of thymus architectonics, the state of cortical and medullary matter, the severity of cellular infiltration, vascular changes, and signs of involuntary processes. Morphometric analysis included determining the main quantitative indicators of the structural components of the thymus.

Results and Discussion

As a result of chronic inflammatory, fibrous, and cicatricial processes in the intestines, constant antigen stimulation occurs in the body, long-term exposure to inflammatory mediators, and functional strain on the immune system organs.

Certain changes were identified in the total area of the thymus, the volume of lobes, the relative area of the cortical layer, and the density of lymphoid cells. The decrease in the number of lymphocytes in the cortical layer was evaluated as one of the primary signs of the functional restructuring occurring in the thymus.

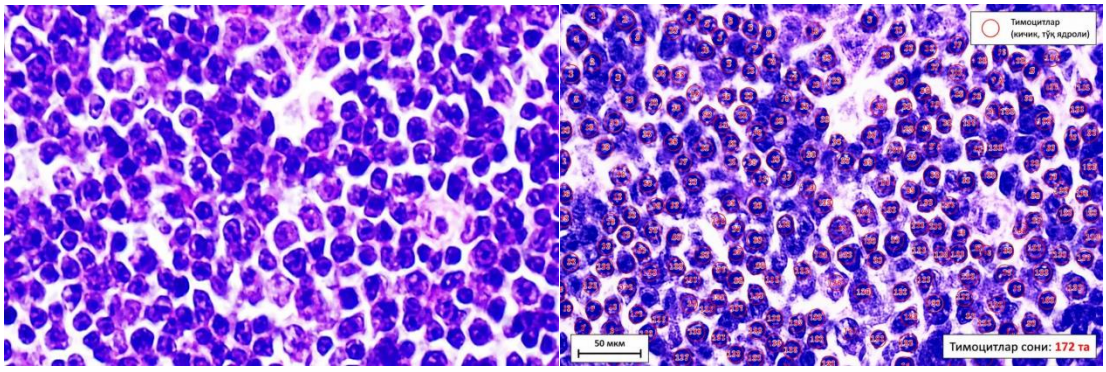
Changes in the cortical part of the thymus may primarily be associated with the emergence of factors influencing the processes of lymphocyte development and selection.

Differences in shape and size are also observed in the thymus corpuscles, which is explained by adaptation processes to the functional impact of the thymus. It is noted that these changes are related to the general inflammatory process in the body and the functional state of the immune system organs. An important feature of the morphological changes observed in 4-month-old rats is that they were manifested not by complete thymus involution or deep degenerative disorders, but by functional adaptation processes.

A decrease in the density of lymphocytes in the cortical layer, an expansion of the intercellular spaces, and a decrease in the accumulation of lymphoid elements in certain areas were identified. Such changes indicate the emergence of certain disturbances in the microenvironment of the thymus involved in the maturation of T-lymphocytes.

The body of 4-month-old rats is in an active stage of postnatal development, during which the thymus plays a key role in the formation and improvement of the immune system. At this age, the processes of intensive maturation of T-lymphocytes in the thymus, their differentiation into functionally active subpopulations, and their orientation toward peripheral immune organs proceed intensively. As a result of assessing the cellular density of the thymus lobes, a decrease in the number of lymphoid cells was identified in the experimental rat. In particular, changes in the number of small lymphocytes located in the cortex were evaluated as a factor affecting the primary immunogenic functions of the thymus. These data provide a basis for a more in-depth analysis of changes in the cortical and medullary layers, changes in cellular composition, and the impact of the pathological process on the functional state of the thymus in subsequent stages. When assessing the functional state of the thymus structure, it is important to study the ratio of the cortical and medullary layers of its main morphological zones, their volume indicators, and cellular composition. This is because these parts of the thymus perform various functions and participate in the processes of T-lymphocyte formation, selection, and transformation into mature immunocompetent cells.

In 4-month-old laboratory rats, the cortical part of the thymus is physiologically characterized by high functional activity. Lymphoid cells, especially small lymphocytes at various stages of development, are abundant in this area and constitute the bulk of the thymus lobule. The high cell density of the cortical layer indicates the intensive proliferation and differentiation of T-lymphocytes during this age period (pic. 1).



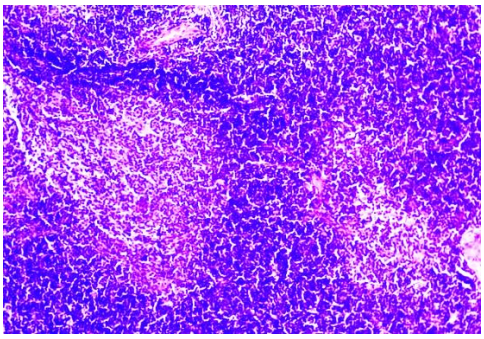
Picture 1. Study of the morphometric parameters of the thymus of 4-month-old laboratory rats against the background of experimental intestinal scarring. Hematoxylin-Eosin. Ok10 X Ob 40.

In the thymus of 7-month-old rats included in the control group, the overall architecture of the organ was preserved. From the outside, the thymus is surrounded by a connective tissue capsule, and it has been observed that the barriers emerging from it separate the organ's parenchyma into separate segments.

Specifically, it was established that the distribution of lymphoid cells is relatively stabilized, the role of stromal elements increases, and functional balance is formed in the internal structure of the organ.

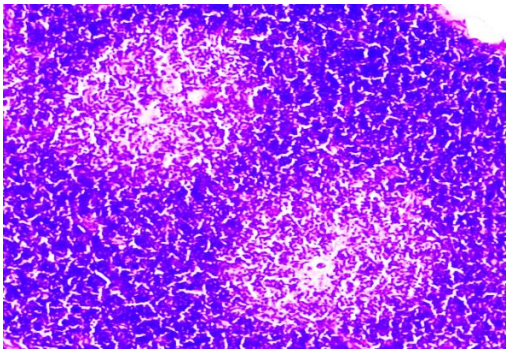
The long-term inflammatory state formed in the body as a result of the pathological process and the strain on the immune system led to the emergence of functional adaptive reactions in the thymus tissue.

The identified changes in the thymus of 7-month-old rats were characterized not by deep destructive processes, but mainly by adaptive and compensatory properties. The general architecture of the organ was preserved, and the functioning of its main functional parts continued (pic. 2).



Picture 2. Study of the morphometric parameters of the thymus of 7-month-old laboratory rats against the background of experimental intestinal scarring. Hematoxylin-Eosin.Ok10 X Ob10.

In the thymus of rats included in the 10-month control group, the overall architecture of the organ was preserved. From the outside, the thymus is surrounded by a capsule, from which connective tissue barriers separate the organ's parenchyma into individual segments. One of the main morphological changes in the thymus of 10-month-old rats was the reduction of the lymphoid parenchyma. At the same time, since these changes occur in combination with age-related involvement processes, it is incorrect to evaluate them solely as the result of pathological effects. In this area, a decrease in lymphocyte density, changes in intercellular relationships, and a reduction in the volume of lymphoid tissue were identified. These changes in the cortical part may be one of the factors influencing the processes of T-lymphocyte formation and selection in the thymus. An increase in the relative significance of epithelial reticular cells in the medullary part and differences in the position of thymus corpuscles indicated a functional readaptation of the organ. As a result of a general assessment of cellular composition, a redistribution process in the lymphoid cell population was identified in the thymus of a 10-month-old experimental rat. A decrease in the number of small lymphocytes, changes in the ratio of medium to large cells, and an increase in the activity of stromal cells confirm changes in the functional state of the thymus (pic. 3).



Picture 3. Study of morphometric parameters of the thymus of 10-month-old laboratory rats against the background of experimental intestinal scarring. Hematoxylin-Eosin. Ok10 X Ob 10.

As a result of comparing the changes occurring under the conditions of experimental intestinal scarring with the indicators of 4- and 7-month-old rats, age-related differences became more pronounced.

Significant differences in morphometric parameters were identified in the thymus of 4-month-old rats in the experimental group compared to animals of the same age in the control group. The ratio of the cortex to the medulla was 55.8±1.7%, which was lower than the control group figure of 62.4±1.8%. This indicates that the chronic inflammatory state resulting from intestinal scarring caused early involvement of the lymphoid tissue of the thymus.

The thymocyte count was 152.4±5.8 tissue units, which is lower than the control group's figure of 185.6±6.4×106/g. This condition is explained by the death of lymphoid cells in the thymus under the influence of a pathological process, the slowing of their formation process, and an increase in the load on the immune system. Lymphocyte density also decreased, amounting to 2141±76.8 units/mm2 (compared to 2481±85.6 units/mm2 in the control).

At the same time, the thymocyte diameter in the experimental group increased slightly (6.1±0.13 μm), indicating the development of compensatory hypertrophic changes in some preserved cells. The vascular density decreased to 15.2±0.7 units/mm2 (compared to 18.6±0.8 units/mm2 in the control), indicating a decrease in the blood supply to thymus tissue and a decrease in metabolic processes.

In the 4-month experimental group, the number of macrophages was 34.8±1.6 units/mm2, which was higher than the control group's 24.5±1.4 units/mm2. The number of Hassall's corpuscles also amounted to 5.9±0.4 units/mm2, which is higher than the control at 3.8±0.3 units/mm2. This indicates increased destruction of decayed cells, removal of inflammatory products, and regeneration of epithelial structures in the thymus.

A further increase in pathological changes was observed in the 7-month experimental group. The ratio of the cortex to the medulla was reduced to 51.6±1.5%, and the number of thymocytes was 128.6±5.2×106/g of tissue. In 7-month-old animals of the control group, these indicators were 58.7±1.6% and 168.3±5.8×106/g of tissue, respectively.

These changes are associated with constant antigen stimulation in the body as a result of intestinal scarring, an increase in inflammatory mediators, and long-term strain on the immune system. As a result, the number of lymphoid cells in the thymus decreases, and its functional capabilities decrease.

At 7 months of age, the lymphocyte density decreased to 1784.8±65.8 units/mm2, while the number of macrophages increased to 41.5±1.8 units/mm2. The number of Hassall bodies also amounted to 8.1 ± 0.5 units/mm2. This indicates increased phagocytic activity against the background of degradation processes and cell destruction in the thymus.

Morphological changes in the thymus reached their peak in the 10-month experimental group. The ratio of the cortex to the medulla was reduced to 45.7±1.4%, and the number of thymocytes was 101.8±4.7×106/g of tissue. In the 10-month-old animals of the control group, these indicators were 53.2±1.5% and 142.7±5.2×106/g of tissue, respectively.

In the experimental group, the lymphocyte density decreased sharply, reaching 1421±58.6 units/mm2. This indicates a decrease in the immunogenic activity of the thymus and a decrease in the formation of T-lymphocytes. The thymocyte diameter increased to 6.9±0.16 μm, indicating the presence of compensatory changes in some cells.

Vascular density decreased to 11.8±0.5 units/mm2, indicating the development of microcirculatory disorders in the thymus tissue. Simultaneously, the number of macrophages increased to 49.7±2.0 units/mm2, and the number of Hassall bodies to 11.6±0.6 units/mm2. This indicates that age-related and pathological involution processes in the thymus occur simultaneously (Table 1).

Table 1

Morphometric parameters of the thymus of 4, 7, and 10-month-old white outbred rats against the background of experimental intestinal scarring (M±m).

Morphometric indicators	4 months (M±m)	7 months (M±m)	10 months (M±m)
Ratio of cortex to medulla (%)	55,8±1,7	51,6±1,5	45,7±1,4
Number of thymocytes (×106/g of tissue)	152,4±5,8	128,6±5,2	101,8±4,7
Thymocyte diameter (μm)	6,1±0,13	6,5±0,15	6,9±0,16

Density of blood vessels (per 1 mm2 area)	15,2±0,7	13,4±0,6	11,8±0,5
Lymphocyte density (per 1 mm2 area)	2141±76.8	1784.8±65.8	1421±58.6
Number of macrophages (per 1 mm2 area)	34,8±1,6	41,5±1,8	49,7±2,0
Number of Hassall bodies (per 1 mm2 area)	5,9±0,4	8,1±0,5	11,6±0,6

Conclusions

The experimental intestinal scar process is accompanied by pronounced morphological and morphometric changes in the thymus of white asexual rats. The identified disorders are characterized by changes in the organ's architecture, a decrease in the thickness of the cortical substance, a decrease in the density of lymphoid cells, a relative increase in the cerebral substance, and the development of involuntary processes. The degree of structural changes depends on the age of the animals and is most pronounced in rats of older age groups (7 and 10 months), which indicates a decrease in the compensatory and adaptive capabilities of the thymus gland with age. The results obtained expand the understanding of the impact of the intestinal scar process on the central organ of immunogenesis and can serve as an experimental basis for the further study of the mechanisms of immune disorders and the development of pathogenetically grounded methods for their correction.

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