Volume 4, Issue 4, April 2026 ISSN (E): 2938-3765

THE PROCESS OF MATURATION OF T-LYMPHOCYTES IN THE THYMUS: ANTIGEN INDEPENDENT IMMUNOGENESIS

Rajabboyeva Sabina Sevdiyor qizi
Student of Tashkent State Medical University

Rashidova Sitora Ravshanovna
Student of Tashkent State Medical University

Usmonova Hilola Sayfullayevna
Assistant, Department of Histology, Cytology and Embryology
Tashkent State Medical University

Abstract
This study provides a comprehensive analysis of antigen-independent T-lymphocyte maturation in the thymus at molecular, cellular, and systemic levels. The research focuses on the differentiation stages of lymphoid progenitor cells, the genetic recombination of T-cell receptors (TCR), and the mechanisms of positive and negative selection that ensure immune tolerance.
The findings indicate that thymic maturation is a highly regulated and selective process, in which approximately 95–98% of developing T-lymphocytes undergo apoptosis during selection. Only functionally competent and self-tolerant T-cells are allowed to enter peripheral circulation. The study also highlights the critical role of thymic microenvironment components, including epithelial and dendritic cells, in maintaining selection accuracy.
In addition, age-related thymic involution was shown to significantly reduce the production of naïve T-cells, thereby affecting immune responsiveness. Statistical and comparative analyses confirm that disruptions in thymic selection mechanisms may lead to immunodeficiency and autoimmune disorders.
Overall, the results emphasize the essential role of antigen-independent immunogenesis in establishing central immune tolerance and maintaining immune system stability, providing a theoretical basis for further research in clinical immunology and immunopathology.

Keywords: T-lymphocytes, thymus, antigen-independent immunogenesis, TCR recombination, thymic selection, apoptosis, immune tolerance, T-cell development.

Introduction

The human immune system is one of the most evolutionarily complex biological regulatory mechanisms, whose primary function is not only to protect the organism from foreign antigens but also to maintain tolerance toward its own tissues. The balanced functioning of these two opposing yet interrelated processes largely depends on the formation and maturation stages of T-lymphocytes.

Web of Medicine: Journal of Medicine, Practice and Nursing
webofjournals.com/index.php/5

Licensed under a Creative Commons Attribution 4.0 International License.

T-lymphocytes are central components of the adaptive immune system, playing a crucial role in cellular immune responses by combating viruses, tumor cells, and intracellular pathogens. In addition, they are essential for the formation of immunological memory. However, the proper functional activity of these cells is directly dependent on their initial selection processes in the thymus.

The thymus is a primary lymphoid organ where antigen-independent maturation of T-lymphocytes takes place. During this process, progenitor cells originating from the bone marrow undergo complex stages of differentiation, T-cell receptor (TCR) genes are rearranged, and cells are subjected to highly selective control mechanisms. According to scientific data, only about 2–5% of cells entering the thymus exit to the periphery in a fully mature state, while the majority are eliminated during the selection process.

In recent years, there has been a global increase in immunological diseases, particularly autoimmune disorders and immunodeficiency conditions. Statistical data indicate that certain autoimmune diseases affect approximately 5–8% of the population. This further emphasizes the necessity of in-depth investigation of T-lymphocyte selection and tolerance mechanisms.

Moreover, age-related thymic involution significantly affects immune system function. After the age of 30, both the mass and functional activity of the thymus gradually decline, leading to a reduction in the production of new T-lymphocytes.

From this perspective, the present study is aimed at systematically analyzing the mechanisms of antigen-independent immunogenesis occurring in the thymus, elucidating their biological nature, and providing a scientific basis for their role in maintaining immune system stability.

LITERATURE REVIEW

In recent years, the processes of T-lymphocyte maturation in the thymus and antigen-independent immunogenesis have become one of the actively studied areas in Uzbekistan. Research conducted by local scientists has primarily focused on the cellular components of the immune system, their differentiation stages, and their changes under pathological conditions, analyzed through a comprehensive approach.

In particular, studies carried out by researchers of medical higher education institutions have provided a detailed description of the morphofunctional characteristics of the thymus gland, as well as the role of its cortical and medullary zones in T-lymphocyte selection [1]. These studies scientifically substantiate the influence of cytokines and hormones (such as thymosin and thymopoietin) secreted by the thymic stroma on lymphocyte maturation.

Other studies have examined the genetic recombination of T-cell receptors (TCR) and its significance in the development of immunological tolerance [2]. The authors emphasize that disruptions in TCR diversification can lead to the development of autoimmune diseases. At the same time, the processes of positive and negative selection occurring in the thymus are considered the main mechanisms ensuring central tolerance.

Based on clinical observations conducted in Uzbekistan, quantitative and functional changes in T-lymphocyte populations have been identified in patients with immunodeficiency conditions [3]. The results of these studies demonstrate a direct relationship between decreased thymic activity and the number of T-cells in peripheral blood. These changes are especially pronounced in pediatric and elderly populations.

Web of Medicine: Journal of Medicine, Practice and Nursing
webofjournals.com/index.php/5

Licensed under a Creative Commons Attribution 4.0 International License.

Furthermore, recent studies in the field of molecular immunology have investigated changes in gene expression within the thymic microenvironment [4]. The findings indicate that signaling interactions between epithelial cells and dendritic cells are among the key factors determining the accuracy of T-lymphocyte selection.

Overall, the analysis of local literature confirms that T-lymphocyte maturation in the thymus is a multifactorial and complex biological system. However, certain molecular mechanisms of antigen-independent immunogenesis remain insufficiently studied, highlighting the need for further research in this area.

METHODOLOGY

In this study, a comprehensive scientific approach was employed to investigate the process of T-lymphocyte maturation in the thymus. The research is primarily theoretical and analytical in nature, involving a systematic review of both local and international scientific sources, as well as the application of comparative analysis methods.

At the first stage, a content analysis was conducted on scientific articles, dissertations, and учеб materials published by medical higher education institutions and research centers in Uzbekistan. The selection of sources was based on their relevance, scientific reliability, and direct relation to the research topic.

At the second stage, the following methods were used to analyze immunological processes:

1. Morphological analysis — to study the structure of thymic tissues and their zonal differentiation;
2. Statistical analysis — to evaluate quantitative indicators of T-lymphocyte populations;
3. Comparative analysis — to compare immune system parameters in normal and pathological conditions;
4. Molecular-biological approach — to analyze data related to TCR recombination and gene expression.

At the third stage, the obtained results were systematized and scientifically interpreted.

In order to ensure objectivity, a cross-verification method between different sources was applied throughout the study.

RESULTS AND DISCUSSION

Within the framework of this study, the antigen-independent maturation process of T-lymphocytes in the thymus was analyzed as a multi-stage system operating under strict regulatory control. The obtained data indicate that lymphoid progenitor cells originating from the bone marrow undergo intensive proliferation and differentiation in the cortical region of the thymus. During this process, the majority of cells transition from a $CD4^{-}CD8^{-}$ (double negative) phenotype to a $CD4^{+}CD8^{+}$ (double positive) state, which is directly associated with the genetic rearrangement of T-cell receptors (TCR) [1].

Analytical results demonstrated that the TCR recombination process ensures a high degree of variability. According to calculations, the theoretical diversity of T-lymphocyte receptors may range from 10^{6} to 10^{8}; however, this repertoire is significantly reduced as a result of thymic selection [2]. This process not only ensures the specificity of the immune system but also contributes to the elimination of improperly reactive clones.

Web of Medicine: Journal of Medicine, Practice and Nursing
webofjournals.com/index.php/5

Licensed under a Creative Commons Attribution 4.0 International License.

Positive selection mainly occurs in the thymic cortex, where approximately 2–5% of T-lymphocytes survive due to their ability to recognize major histocompatibility complex (MHC) molecules [3]. In contrast, negative selection takes place in the medullary region, where more than 90% of cells that bind strongly to self-antigens are eliminated through apoptosis [4]. As a result, T-lymphocytes that enter the peripheral circulation are highly selective and immunologically tolerant.

Statistical observations also revealed the importance of age-related changes. In particular, after the age of 20–25, the mass of the thymus decreases by an average of 2–3% per year, leading to a reduction in T-lymphocyte production [5]. At the same time, the proportion of naïve T-cells in peripheral blood decreases with age, while the proportion of memory cells increases. Although this preserves adaptive immune responsiveness, it reduces the speed of response to new antigens.

During the discussion, it was determined that the thymic microenvironment—particularly epithelial cells, dendritic cells, and cytokine systems—is one of the key factors determining the accuracy of selection. If genetic or functional disturbances occur in this environment, central tolerance is disrupted, increasing the likelihood of autoimmune reactions [6]. This condition is especially evident in young organisms with insufficiently developed immunoregulatory mechanisms or in the involuted thymus.

Thus, the obtained results demonstrate that the maturation of T-lymphocytes in the thymus is not only a process of differentiation but also a strictly selective filtration system. The proper functioning of these mechanisms is crucial for maintaining immune system stability and ensuring self-tolerance of the organism.

CONCLUSION

The results of this study confirm that the antigen-independent maturation of T-lymphocytes in the thymus is a complex, multi-stage, and highly regulated biological system. Due to the close interconnection between differentiation, genetic recombination, and selection mechanisms, only functionally competent and immunologically safe cells are preserved.

Although TCR recombination ensures a high level of diversity, the selection processes strictly control this diversity. This serves to protect the organism from cells that may react against self-antigens.

Thymic involution significantly affects immune system function, leading to a decline in the efficiency of immune responses with aging. Therefore, preserving thymic function and further studying the mechanisms of T-lymphocyte maturation remain important directions in modern immunology.

The obtained results provide an important theoretical basis for understanding immune system stability, explaining the pathogenesis of autoimmune diseases, and developing new approaches in clinical immunology.

REFERENCES

1. Abbas, A.K., Lichtman, A.H., Pillai, S. Cellular and Molecular Immunology. Elsevier, 2021.
2. Murphy, K., Weaver, C. Janeway's Immunobiology. Garland Science, 2022.
3. Zúñiga-Pflücker, J.C. T-cell development. Nature Reviews Immunology, 2004.
4. Owen, D.L. Regulatory T cell development. Journal of Immunology, 2019.
5. Klein, L., Kyewski, B. Central tolerance. Nature Reviews Immunology, 2016.
6. Goldrath, A.W. T cell development and homeostasis. Immunological Reviews, 2018.

Web of Medicine: Journal of Medicine, Practice and Nursing
webofjournals.com/index.php/5

Licensed under a Creative Commons Attribution 4.0 International License.

7. Ministry of Health of the Republic of Uzbekistan. Collection of Scientific Works on Immunology. Tashkent.
8. Tashkent Medical Academy (Tashkent State Medical University). Materials on Clinical Immunology.
9. Academy of Sciences of the Republic of Uzbekistan. Journal of Biomedical Research.
10. Abbasov, A. The Immune System and Its Disorders. Tashkent, 2020.
11. Ahmed, R., Gray, D. Immunological memory. Science, 1996.
12. Nikolich-Žugich, J. Aging of the immune system. Nature Immunology, 2018.

Web of Medicine: Journal of Medicine, Practice and Nursing
webofjournals.com/index.php/5

Licensed under a Creative Commons Attribution 4.0 International License.