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MOLECULAR-GENETIC MECHANISMS OF MALIGNANT TUMOR DEVELOPMENT: THE PROCESS OF TRANSFORMATION OF PROTO-ONCOGENES INTO ONCOGENES.

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Abstract: The development of malignant tumors is a complex molecular-genetic process, which is based on the disruption of genes that control cell proliferation and differentiation. This article analyzes the mechanisms of the transformation of proto-oncogenes into oncogenes, including point mutations, gene amplification, chromosomal translocations, and the effects of viruses. Also, the activation of cell signaling pathways and their interaction with tumor suppressor genes are studied. These changes at the molecular level determine the main stages of tumor development and are of great importance in the development of modern oncological diagnostics and targeted therapies.

Keywords: Malignant tumors, proto-oncogene, oncogene, molecular-genetics, mutation, gene amplification, chromosome translocation, cell proliferation, apoptosis, signal transduction. Malignant neoplasms are one of the most pressing problems of modern medicine and are one of the main causes of human death. The

increase in the incidence of oncological diseases in recent years has further strengthened the need for a thorough study of the mechanisms of their origin. The development of malignant tumors is a complex biological process, which occurs as a result of the interaction of genetic, epigenetic and environmental factors. Normal cell growth and division are under strict genetic control. Proto-oncogenes, tumor suppressor genes, and DNA repair systems play an important role in this process. Proto-oncogenes are usually normal genes that regulate cell proliferation, differentiation, and survival. However,

under the influence of various mutagenic factors, these genes can undergo structural or functional changes and become oncogenes. The transformation of proto-oncogenes into oncogenes leads to disruption of intracellular signal transduction systems, and as a result, uncontrolled cell division begins. This process is one of the initial and most important stages of tumor development. Therefore, the study of these mechanisms is of great importance not only for understanding the pathogenesis of the disease, but also for early diagnosis and the development of effective treatment methods. This article scientifically analyzes the molecular-genetic basis of the development of malignant tumors, in particular the mechanisms of the transformation of proto-oncogenes into oncogenes and their impact on cell biology.

The study of the molecular and genetic mechanisms of malignant tumor development has been one of the most rapidly developing areas of biology and medicine in recent decades. The scientific literature on the subject emphasizes the disruption of genes that control cell growth and division, in particular the conversion of proto-oncogenes into oncogenes, as the main cause of tumor formation.

Molecular Biology of the Cell provides a detailed overview of the molecular basis of the cell cycle, signal transduction pathways, and genetic regulatory systems. This resource identifies proto-oncogenes as important genes that control normal cell function, and emphasizes that their mutation leads to uncontrolled cell proliferation.

The Biology of Cancer provides an in-depth analysis of the molecular basis of cancer. The author argues that activation of oncogenes, inactivation of tumor suppressor genes, and

disruption of DNA repair systems are key factors in the development of cancer. It is scientifically explained that the key stages of tumor development are: In particular, the conversion of proto-oncogenes such as RAS and

MYC into oncogenes is central to tumor biology. Robbins and Cotran's Pathologic Basis of Disease provides a clinical perspective on pathological processes, including the morphological and molecular changes in tumors. This resource identifies mechanisms such as genetic mutations, chromosomal translocations, and gene amplification as the main etiological factors in tumor development. The Hallmarks of Cancer concept is one of the fundamental theories in modern oncology, which systematically describes the basic biological properties of tumor cells. According to this approach, tumor cells have the ability to continuously proliferate, evade apoptosis, stimulate angiogenesis, and metastasize.

Scientific reports published by the National Cancer Institute and the World Health Organization also provide up-to-date information on the epidemiology of cancer, genetic risk factors, and modern treatment strategies. These sources emphasize that the development of targeted therapy and genetic diagnostics has ushered in a new era in oncology. In general, the analysis of the literature shows that the development

of malignant tumors is a complex multi-step process, which is based on genetic changes, disruption of signaling pathways, and uncontrolled activation of the cell cycle. In-depth study of the mechanisms of the transformation of proto-oncogenes into oncogenes is one of the most important scientific directions of modern oncology. In preparing this article, scientific and theoretical approaches were used to shed light on the molecular and genetic mechanisms of malignant tumor development. The methodological basis of the research work was a systematic review of scientific literature in the fields of modern oncology, molecular biology and medical genetics. The method of analysis was chosen. First of all, scientific sources on the topic - textbooks, monographs, international scientific articles, as well as information from the World Health Organization and the National Cancer Institute – were studied. At this stage, the main criteria for selecting literature were their scientific reliability, relevance, and publication in recent years. During the analysis, a comparative method was used to compare the normal physiological state of proto-oncogenes and changes in their transformation into oncogenes. This approach allowed for a deeper understanding of the role of mechanisms such as genetic mutations, chromosomal translocations, and gene amplification in tumor development.

Also, based on a molecular-genetic approach, intracellular signaling pathways (RAS/RAF/MEK, PIK/AKT/mTOR and JAK/STAT) were analyzed.

Activation and disruption of these pathways were considered as one of the main

stages in the transformation of proto-oncogenes into oncogenes. The methodological approach also used a systematic analysis method, and the step-by-step sequence of tumor development - from DNA damage to metastasis – was comprehensively studied. This helped to shed light on the multi-stage and complex nature of tumors. In general, the methods used in the research work were based on theoretical-biological analysis, which made it possible to scientifically substantiate and systematize the molecular-genetic mechanisms of malignant tumor development.

The development of malignant tumors is a complex multi-step process, the main essence of which is associated with the disruption of the stability of the cell genome. Analysis of the reviewed literature shows that the conversion of proto- oncogenes into oncogenes is a central molecular event in tumor transformation.

This process leads to uncontrolled activation of cell proliferation, which leads to

the disruption of normal tissue structure. Scientific sources indicate that the activation of proto-oncogenes occurs through several mechanisms: point mutations, gene amplification, chromosomal translocations, and epigenetic changes. As a result of these mechanisms, the intracellular signaling systems are constantly activated. In

particular, the widespread occurrence of oncogenic forms of genes such as RAS, MYC and HER2 in various malignant tumors further increases the clinical significance of this process. Analyses show that the activation of oncogenes is often accompanied by the inactivation of tumor suppressor genes (for example, p53 and RB).

This dual genetic disorder leads to cell cycle deregulation, impaired apoptosis mechanisms and increased genetic instability. As a result, the cell loses its normal biological functions and acquires invasive and metastatic properties. Also, disruption of signal transduction pathways plays an important role in tumor pathogenesis. Continuous activation of pathways such as RAS/RAF/MEK/ERK and PI3K/AKT/mTOR enhances cell growth and increases resistance to apoptotic signals. This significantly increases the viability of tumor cells. Based on the analysis of the literature, it can be noted that the transformation of proto-oncogenes into oncogenes occurs not as a single genetic change, but as a set of several molecular events. Therefore, tumor development is considered a complex process based on the "multi-hit" model. In general, the studied data show that a deep understanding of the molecular basis of malignant tumor development is of great importance in the development of early diagnosis, prognosis and targeted therapy methods in modern oncology.

Conclusion: The development of malignant tumors is a complex molecular-genetic process, which is based on the disruption of genetic mechanisms that control cell growth, division and apoptosis. The conducted analyses show that the transformation of proto-oncogenes into oncogenes is one of the most important stages of tumor transformation. The transformation of proto-oncogenes into oncogenes is carried out through point mutations, gene amplification, chromosomal translocations and epigenetic changes. As a result of these changes, the intracellular signaling systems are constantly activated, leading to uncontrolled proliferation andleads to genetic instability. Also, inactivation of tumor suppressor genes and disruption of signaling pathways further accelerate tumor development. These processes lead to the loss of normal biological functions of the cell, the formation of the ability to invade and metastasize. In general, a deep study of the mechanisms of the transformation of proto-oncogenes into oncogenes is of significant scientific and practical importance in understanding the pathogenesis of malignant tumors, expanding the possibilities of early diagnosis, and developing targeted treatment methods.

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