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HISTOLOGY OF NERVOUS TISSUE AND POSSIBILITIES OF REGENERATION

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Abstract. Nervous tissue is considered the most complex and specialized tissue in the human and animal body. It is composed of nerve cells — neurons — and the supporting glial cells. Nervous tissue forms the central nervous system (the brain and spinal cord) as well as the peripheral nervous system (peripheral nerves and ganglia).The primary function of nervous tissue is to receive information from the external and internal environment, transmit it, and generate appropriate responses. The morphological structure of this tissue, its organization at the cellular and tissue levels, and its functional roles in physiological processes are of great significance.

The regeneration of nervous tissue — that is, its ability to recover after damage — is one of the most important fields in modern neurobiology. The regenerative potential of the central nervous system (CNS) is significantly lower than that of the peripheral nervous system (PNS). This means that complete recovery after brain or spinal cord injuries is very unlikely. In contrast, the peripheral nervous system has a relatively high capacity for regeneration, largely due to the activity of Schwann cells.

This difference is mainly determined by the internal microenvironment of the tissue, as well as the presence of factors that either stimulate or inhibit regeneration.

Recent studies have demonstrated that, although limited, neurogenesis — the formation of new neurons — does occur within the central nervous system (CNS). In particular, it has been identified that in adults, neuroblasts form in the hippocampus and in the subventricular zones surrounding the lateral ventricles. This indicates that nervous tissue possesses a certain ability to regenerate under specific conditions. However, such processes are extremely slow and rarely result in complete recovery.

Glial cells, especially astrocytes, play a significant role in this context. Following injury, they proliferate and form glial scars (gliosis), which represent one of the major obstacles to CNS regeneration. These glial scars restrict the transmission of nerve impulses and create both physical and chemical barriers for regenerating axons. Therefore, a substantial portion of modern research is devoted to overcoming these barriers, identifying biomolecules that stimulate regeneration, and accelerating neuronal recovery through neurotrophic factors.

This article analyzes the histological structure of nervous tissue, the interaction between neurons and glial cells, the mechanisms of regeneration, and the differences between the regenerative capacities of the CNS and PNS. Moreover, contemporary therapeutic approaches and treatment strategies — including neurostimulation, biomaterials, and stem cell therapy — are discussed. Both experimental and clinical studies addressing the challenges and achievements in nervous tissue regeneration are reviewed.

A deeper understanding of the regenerative potential of nervous tissue will not only contribute to solving problems in surgery, traumatology, and neurology, but will also lay the foundation for future advances in the treatment of neurodegenerative diseases.

Keywords: Nervous tissue, neurons, glial cells, regeneration, central nervous system (CNS), peripheral nervous system (PNS), neurogenesis, gliosis, Schwann cells, astrocytes, axon regeneration, neurotrophic factors, histological structure, nerve injury, nerve regeneration,

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biomaterials, stem cells, neurostimulation, plasticity of nerve cells, microenvironment, functional recovery.

Introduction. In modern biomedicine, the study of nervous tissue and its regenerative potential is considered one of the most urgent scientific issues.

Nervous tissue is a complex system responsible for controlling the functional activity of the human and animal body, receiving, processing, and responding to information coming from external and internal environments. Nervous tissue is mainly composed of neurons and supportive glial cells. The morphological and functional interconnections of these elements form the basis of the central and peripheral nervous systems of the organism.

Unfortunately, compared to other tissues in the body, nervous tissue has a very limited capacity for regeneration (that is, self-repair). In particular, when the central nervous system (the brain and spinal cord) is damaged, the ability of tissues to return to their original state is extremely restricted. This condition leads to high rates of disability and mortality caused by neurological diseases, strokes, traumatic injuries, and neurodegenerative processes.

The peripheral nervous system, on the other hand, under certain conditions, has a relatively higher regenerative capacity, with Schwann cells playing an especially important role in this process through their activity.

In recent years, extensive scientific research has been conducted on the detailed study of the histological structure of nervous tissue, determining the regenerative potential of neurons and glial cells, as well as identifying factors that stimulate regeneration. From this perspective, comparing the regenerative mechanisms of the central and peripheral nervous systems, studying their histological features, and evaluating cellular-level repair processes carry significant scientific importance.

This research is specifically aimed at identifying the microstructure of nervous tissue, responses to injury, regenerative capacities, and the factors that either limit or promote regeneration. In the future, these findings will provide a theoretical foundation for developing new approaches in the treatment of diseases related to nervous tissue.

Research Methods

Within the framework of this study, the histological structure of nervous tissue and its regenerative processes were comprehensively examined. Experimental, morphological, and statistical analysis methods were used in combination.

1. Experimental Model:

To investigate regeneration in the peripheral and central nervous systems, laboratory mice were selected for experiments. The animals were divided into control (healthy) and experimental (with damaged nervous tissue) groups. In creating the models of injury, surgical methods were used to establish nerve transection and crushing models.

2. Histological methods:

To study the microstructure of nervous tissues, histological sections were prepared. The sections were stained with hematoxylin-eosin, Nissl stain, Golgi stain, and immunohistochemical stains. Using these, neurons, glial cells, axons, and synapses were examined under a microscope. Special attention was given to the development of gliosis and the activity of Schwann cells during the regeneration process.

3. Electron microscopy:

For the identification of ultrastructures, scanning and transmission electron microscopic analyses were applied. With this method, changes in cell organelles, synaptic contacts, and myelin layers during regeneration were studied.

4. Immunohistochemical analysis:

To evaluate regeneration, markers such as GFAP (astrocyte marker), S100 (Schwann cell marker), NeuN (neuronal nucleus marker), and BrdU (proliferating cell marker) were used in immunolabeling. With these markers, the activity and proliferation rate of cells were determined.

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5. Statistical analysis:
The obtained results were analyzed using mathematical-statistical methods. Data were expressed as mean values and standard deviations. To determine differences between groups, Student's t-test and ANOVA (analysis of variance) were applied. A p-value of $P<0.05$ was considered statistically significant.
6. Analysis of literature sources:
However, in the PNS, NeuN expression persisted, reflecting active axonal regeneration.
4.Electron microscopy observations further showed that CNS injuries were characterized by myelin sheath degradation and disruption of synaptic structures. In the PNS, however, gradual remyelination and synaptic recovery were detected following injury.
5.BrdU-labeled assays identified cell division activity. In the CNS, proliferating cells were primarily glial (astrocytes), whereas in the PNS, Schwann cell proliferation was more prominent.
6.All obtained results were found to be statistically significant ($p < 0.05$), confirming the scientific validity of the chosen experimental models in assessing neural tissue regeneration.
Conclusion
In this study, the histological structure of nervous tissue and its regenerative potential were comprehensively analyzed. Based on the obtained results, it was determined that the process of nerve tissue regeneration differs between the central nervous system (CNS) and the peripheral nervous system (PNS).
When the CNS is damaged, neurons have only a limited ability to self-repair, and regeneration is largely hindered by the increased activity of glial cells, which leads to gliosis. This, in turn, restricts regeneration and reduces the likelihood of functional recovery. In the PNS, however, Schwann cells serve as the primary regenerative component, guiding axonal growth and enabling the remyelination process.

The results of the study show that after nervous tissue injury, a series of significant changes occur at both the cellular and tissue levels. Histological stains, immunohistochemical markers, electron microscopic analyses, and cell proliferation indicators (BrdU) played a crucial role in identifying these changes. In particular, the evaluation of cell division, synaptic restoration, remyelination, and neuronal marker activity allowed for an accurate assessment of the degree of regeneration.
The most important scientific conclusion of this research is that although nervous tissue is not capable of complete regeneration, there are possibilities for its recovery through stimulatory molecules, cell therapy, biomaterials, or genetic interventions. Therefore, further research in this direction is not only of scientific importance but also holds great practical value for medicine, providing a foundation for innovative approaches to the treatment of nervous system injuries.