Ultrastructure of the choroid plexus epithelium of the brain

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Abstract. An electron microscopy of the brain lateral ventricles vascular plexuses of a bull was conducted. It was established that the vascular plexuses are lined with a single-layer epithelium. The study established that epithelial cells of the vascular bodies are secretory cells. The main function of these cells is to secrete cerebrospinal fluid. It was confirmed that these function determines a main features of their ultrastructural organization. These include the presence of a light nuclear matrix and the basal labyrinth. High mitochondrial activity and hyaline structure in the cytoplasm are also observed. This indicates high energy activity of cells, especially in the phase of cerebrospinal fluid secretion. The observed changes in organelles may be associated with pathological conditions (inflammation or ischemia).

1 Introduction

The mammalian brain is a complex and highly organized organ that plays a key role in regulating the vital functions and behavior of animals. Its main functions can be classified into several categories. First, cognitive functions, including perception, memory, and learning, enable adaptation to a variety of environmental conditions. Specific areas of the brain, such as the cerebral cortex, are actively involved in this activity, allowing mammals to solve complex problems and make decisions.

Secondly, the regulation of motor activity is ensured by motor centers that direct movements and coordinate the relationship between muscles. This is critical for efficient movement, hunting, and interaction with other individuals.

The third key function is the processing of sensory information. The organization of systems such as vision, hearing, and olfactory allow mammals to carefully perceive and interpret signals from the environment.

Finally, the brain is also involved in the regulation of emotional reactions and instinctive behavior, ensuring the survival and successful reproduction of individuals in their natural environment.

The relevance of studying the ultrastructural organization of the animal brain is determined by many factors, including its complexity, diversity of neural networks, and adaptability to changing environmental conditions. The basic mechanisms underlying

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cognition and behavior are largely dependent on microscopic changes in the structure of the brain. A deeper understanding of these processes can have a significant impact on the development of methods for treating neurological diseases, as well as on expanding our knowledge of the mechanisms of evolution.

Modern methods of visualization and morphometric analysis make it possible to study in detail neural connections and elements of cellular architecture, opening new horizons for scientific knowledge. Comparative studies of the brain ultrastructure of different species help not only to elucidate phylogenetic relationships but also to understand how different ecological niches form unique neural configurations.

Thus, studies of the ultrastructural organization of the animal brain are not only relevant but also necessary for a deeper understanding of both the fundamentals of biology and the fundamentals of related disciplines, such as neurophysiology.

The vascular bodies (plexuses) of the brain are areas of the soft membrane invaginating into its cavities. These formations are involved in the secretion of cerebrospinal fluid, the composition of which determines the constancy of the internal environment of the brain. Structural changes in the vascular bodies lead to changes in the composition of the cerebrospinal fluid, which can cause the occurrence of pathologies of the nervous system. To understand the mechanism of their development, clear data on the structure of the choroid plexuses of the brain are necessary. In particular, this concerns their epithelium, which is directly involved in the production of cerebrospinal fluid. Considering the importance of the issue, we set a goal—to establish the ultrastructural organization of the epithelium of the choroid plexuses of the brain.

The ultrastructural organization of the choroid plexus epithelium of the bovine brain is an important aspect that contributes to the understanding of not only the morphological, but also the functional characteristics of this unique organ. The choroid plexus plays a key role in the homeostasis of the central nervous system, providing a barrier function and regulating the exchange of substances between blood and nerve tissue.

The relevance of the study of this topic is due to the need to more deeply study the microanatomy and ultrastructure of the epithelial cells of the choroid plexuses, because various pathologies can have a significant impact on their functional properties. Understanding changes in cellular organization during pathologies can provide new directions for the therapy and prevention of diseases associated with the central nervous system in cattle.

Thus, a detailed study of the ultrastructure of the epithelium of the choroid plexus is not only a pressing scientific problem, but also of practical importance for veterinary medicine, which allows the development of more effective diagnostic and treatment methods aimed at preserving and improving the health of cattle.

2 Materials and methods

Methods for studying the ultrastructural organization of cells and tissues allow us to gain a deeper understanding of the molecular and cellular mechanisms underlying the life activity of organisms. Among such methods, electron microscopy stands out, which provides the ability to visualize structures at the nanoscale, and various types of immunocytochemistry, which can identify and localize specific molecules in cells.

Classical high-resolution electron microscopy opens a window into the world of subcellular structures: mitochondria, ribosomes, and other organelles, detailing their shape and mutual arrangement. Modern methods such as tomography make it possible to create three-dimensional models of cellular ultrastructures, opening up new horizons for research.

Immunocytochemical methods, including fluorescent labeling, provide the ability to observe the dynamics of molecules in real time, which is especially important for

understanding the cellular signal and protein interactions. The use of multichannel microscopy in conjunction with flow cytometry significantly expands the capabilities of simultaneously analyzing thousands of cells, making research more productive and informative. Such approaches enrich our knowledge about the functional organization of cells and their response to external stimuli.

The ultrastructural organization of the brain's vascular plexuses was established using the lateral ventricles vascular plexuses of the domestic bull brain. Samples of choroid plexus tissue obtained from three adult individuals who did not have clinical signs of nervous system pathologies during their lifetime were subjected to electron microscopic examination. Processing of tissue samples to produce ultrathin sections was carried out according to generally accepted methods. The sections were obtained on an ultramicrotome (LKB-III, Sweden) and contrasted with a 2.0% aqueous solution of uranyl acetate and a solution of lead citrate. The sections were examined on a Jem-1011 electron microscope (JEOL, Japan) at magnifications of 2500–3000.

3 Results

It has been established that the vascular plexuses of the lateral ventricles of the brain are lined with a single-layer epithelium lying on the basal membrane. The latter separates the epithelial layer from the connective tissue base of the plexuses. Plexus epithelial cells are large cells with a cubic or low-prismatic shape. Their apical part, facing the cavity of the brain ventricle, bears a border formed by many multidirectional cytoplasmic processes. The latter are covered by a boundary membrane formed by a thin layer of glycocalyx.

Forming a single cellular layer, epithelial cells contact each other through simple contacts and with the help of desmosomes. On the basal side of the cell, the cytoplasmic membrane forms numerous invaginations, significantly increasing the surface of the basal part of the cell. Due to invaginations, a special structure is formed—the basal labyrinth.

The nuclei of epithelial cells occupy the central part of their soma. The heterochromatin in their composition is mainly concentrated in the form of a chain of conglomerates lying along the inner karyolemma. Due to this, the nuclear matrix remains electron-light.

We noted significant variability in nuclear shape. Mostly round nuclei were detected. Apparently, the shape of the nucleus of the epithelial cells of the brain plexuses depends on their secretory activity. Thus, in cells with signs of cerebrospinal fluid secretion, the nuclear membrane has strong tortuosity, giving the nuclei an elongated lobed shape (Figure 1).

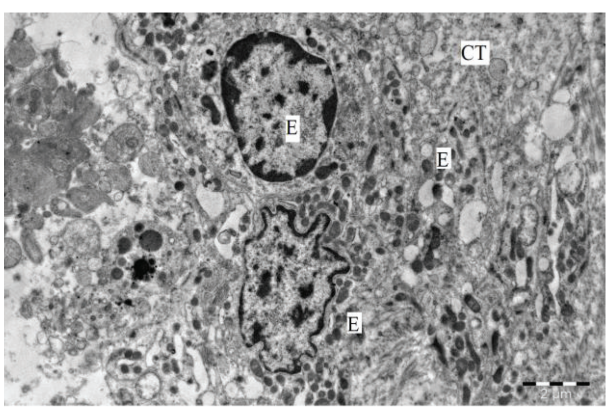

Fig. 1 Ultrastructure of the epithelium of the vascular body of the lateral ventricle of the domestic bull brain. Electron microphotography: E—epithelial cell; CT—connective tissue.

In the cytoplasm of the studied cells, a large number of contractile microfilaments are detected, which are included in the cytoplasm of the microvilli. Apparently, their presence determines the possibility of oscillatory movements by the microvilli. In addition to the cytoskeletal elements, a small number of ribosomes and polyribosomes were visualized in the cytoplasm, and small electron-dense lysosomes were sometimes encountered. A small number of short channels of the granular endoplasmic reticulum and small round mitochondria with a light matrix were also detected.

In the case of increased functional activity of epithelial cells in the phase of cerebrospinal fluid secretion, changes in the structural organization of their organelles were observed. First of all, this concerns the hypertrophy of the Golgi apparatus and granular endoplasmic reticulum, which causes the appearance of a large number of vacuoles containing a flocculent substance in the cytoplasm (Figure 2). At the same time, in the basal part of the cell, clusters of mitochondria with a dark matrix are detected, which is typical for intracellular processes that occur with a high energy expenditure (Figure 3). The electron density of the cytoplasm increases in the apical part of the cell. Microvilli intertwining with each other form labyrinths, and in the spaces between them, cerebrospinal fluid secreted by the cells is detected.

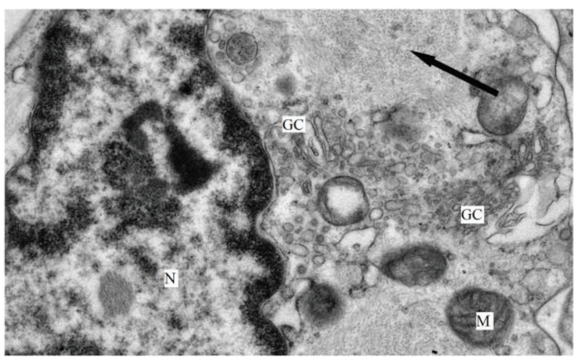

Fig. 2 Ultrastructure of the apical part of the epithelial cell of the vascular body of the lateral ventricle of the brain of a domestic bull during the period of functional activity. Electron micrography: N – Nucleus; M – mitochondria; GC – Golgi complex; ↑ – contractile microfilaments.

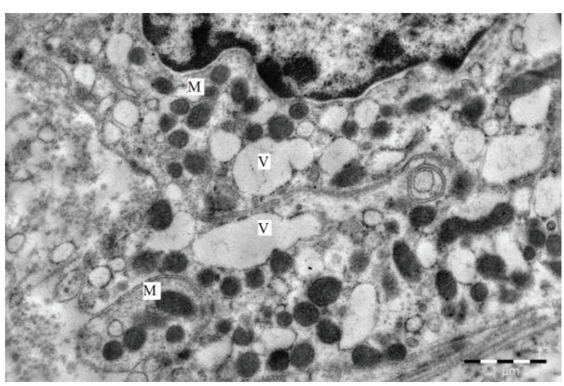

Fig. 3 Ultrastructure of the basal part of the epithelial cell of the vascular body of the lateral ventricle of the domestic bull brain during the period of functional activity. Electron microphotography: V — vacuoles; M—mitochondria.

4 Discussion

The relevance of studying the ultrastructural organization of organs in the context of assessing their functions is beyond doubt, especially taking into account modern scientific achievements. Ultrastructural analysis provides unique opportunities for understanding the histological and cellular changes that occur in organs under the influence of various factors, such as diseases, stress, and toxic effects.

Studying the microanatomy of individual cells and tissues allows not only to identify changes at the cellular level but also to demonstrate how these changes can affect the function of the entire organ. For example, abnormalities in the structure of membranes, mitochondria, or the endoplasmic reticulum can significantly disrupt metabolic processes and consequently lead to functional failures.

Modern imaging techniques, such as electron microscopy, allow researchers to obtain detailed images of the ultrastructure of cells, which makes it possible to accurately assess morphofunctional changes. These data are critical for the development of new approaches to the diagnosis and treatment of diseases, as well as for understanding the normal functioning of organs under various physiological conditions.

The epithelium of the choroid plexus of the brain of cattle is an important component of the central nervous system, responsible for the synthesis and secretion of cerebrospinal fluid, as well as for the barrier function that protects the brain from toxic substances and foreign agents. Research into the structure and function of this epithelium began with the first anatomical descriptions, but considerable time was devoted to functional aspects.

Since the end of the 20th century, scientific work has begun to delve into the molecular mechanisms that regulate the activity and permeability of the epithelium, in particular, due to the introduction of immunofluorescence and electron microscopy techniques. An important direction has become the study of the dynamics of changes in the structure of epithelial cells under various pathological conditions, such as inflammation and ischemia.

Historically, work on the choroid plexus in cattle has contributed to a deeper understanding of not only the physiology of cattle but also the general principles of the functioning of the choroid plexus in other mammals, including humans. This type of research continues to be relevant in modern scientific research.

The history of studying the ultrastructural organization of the cattle brain goes back several decades, starting with the first studies conducted in the middle of the 20th century. Since then, scientists have sought to understand the specific features of the neuropsychology of these animals, their behavior and learning ability, using the achievements of electron microscopy.

In the early stages of research, the emphasis was on identifying the morphological characteristics of cells and their connections. The use of staining and ultrathin sectioning techniques has made it possible to study neurons and glial cells in detail, proposing new hypotheses about their role in information processing. Anatomical studies combined with physiological experiments have revealed that the behavioral complexities of cattle can be explained by their complex brain organization.

Modern technologies, such as functional magnetic resonance imaging and molecular biology, have opened up new horizons in the study of the nervous system. Analysis of brain ultrastructure not only allows us to gain a deeper understanding of the cognitive abilities of these animals but also visualizes the changes that occur in various disorders, which has significant implications for veterinary medicine and animal husbandry.

5 Conclusion

Studying the ultrastructural organization of the brain is one of the most pressing and challenging areas of modern neuroscience. This process involves analyzing the microscopic structure of neurons, glial cells, and their interactions, which can shed light on the mechanisms underlying cognitive functions and behavior.

Modern technologies such as electron and confocal microscopy allow researchers to visualize the brain at a level that was previously inaccessible. These advances make it possible to study the complex networks of synaptic communication as well as the dynamics of the extracellular matrix, which plays a key role in the maintenance and modification of neural structures.

The study of the ultrastructural organization of the brain of cattle is an important area of comparative neurobiology since it provides an opportunity to better understand the mechanisms of functioning of the nervous system of not only animals but also humans. The relevance of this direction of science is emphasized by both biomedical and zootechnical aspects.

Ultrastructural studies performed using electron microscopy techniques make it possible to identify the morphological features of neurons, glia, and the vascular system of the cattle brain. These data are of significant importance for the development of new methods for diagnosing and treating neurological diseases in animals, as well as for improving the conditions of their maintenance and feeding.

In addition, the study of the brain of cattle contributes to the understanding of evolutionary processes as well as the adaptation of the nervous system to certain environmental conditions. Thus, the relevance of studying the ultrastructural organization of the brain of cattle lies not only in scientific knowledge but also in the practical application of the knowledge gained to improve the welfare of animals and improve agricultural productivity.

Thus, the epithelial cells of the vascular bodies are secretory cells, the main function of which is the release of cerebrospinal fluid. The function performed determines a number of features of their ultrastructural organization. These primarily include a light nuclear matrix, indicating a high level of synthetic activity, as well as the presence of structures that increase the surface of the membrane, represented by its protrusions in the form of apical microvilli and invaginations that form the basal labyrinth.

References

1. D. E. Kudryavtseva, O. V. Rasputina, Bulletin of NSAU (Novosibirsk State Agrarian University), **2(71),** 220-228 (2024)
2. E. A. Akhramenko, N. E. Musienko, Ultrastructure of mitochondria in neurons of the prefrontal cortex of the brain under conditions of distant tumor growth, Proceedings of the III International Morphological Scientific and Practical Competition-Conference of Students and Young Scientists "Morphological Sciences - the Fundamental Basis of Medicine": abstracts of reports of the III International Morphological Scientific and Practical Competition-Conference of Students and Young Scientists of the Novosibirsk State Medical University, dedicated to the 100th anniversary of Professor T.D. Nikitina, December 13, 2018, Novosibirsk, Russia (2018)
3. A. V. Akhmadeev, L. B. Kalimullina, Morphology, **157(2-3)**, 22 (2020)
4. G. F. Dobrovolsky; G. F. Dobrovolsky, Ultrastructure of the membranes and paravasal structures of the arteries of the brain (Sputnik +, Moscow, 2011)

5. V. V. Semchenko, R. P. Samuseva, M. V. Moiseeva, Z. L. Kolosova, International histological nomenclature (Omsk Medical Academy, Omsk, 1999).
6. B. Weekley, Electron Microscopy for Beginners (Mir Publishing House, Moscow, 1975)
7. B.M. Abushov, Annals of Clinical and Experimental Neurology, **5(2)**, 29-33 (2011)
8. A. V. Zaerko, S. M. Zimatkin, A. E. Kononchik, E. M. Fedina, Ultrastructure of histaminergic neurons in the rat brain in postnatal ontogenesis. Actual problems of medicine: materials of the annual final scientific and practical conference, January 25, 2019, Grodno, Belarus (2019)
9. A.A. Makarova, A.A. Polilov, Zoological journal, **92(5)**, 523 (2013)
10. E.I. Bon', N.E. Maksimovich, S.M. Zimatkin, O.B. Ostrovskaya, V.Yu. Smirnov, M.Al. Nosovich, K.A. Khrapovitskaya, Ulyanovsk Medical and Biological Journal, **1,** 137-144 (2023)
11. I.Kh. Gasanova, N.V. Devyatova, V.N. Kunitsa, Z.Kh. Gasanli, Eurasian Scientific Association, **8-2 (78)**, 113-116 (2021)