American Journal Of Biomedical Science & Pharmaceutical Innovation

VOLUME Vol.05 Issue06 2025
PAGE NO. 25-27
DOI 10.37547/ajbspi/Volume05Issue06-06

Blood-Brain Barrier: Structure, Function and Neurological Consequences Of Disruption: Role In Brain Protection And Maintenance Of Homeostasis. Disturbances In Strokes, Neuroinfections , Neurodegeneration , Tumors

Petrova Yurita Yurievna

Assistant Professor, Department of Biomedical Sciences, EMU University, Uzbekistan

Received: 17 April 2025; **Accepted:** 24 May 2025; **Published:** 30 June 2025

Abstract: The blood-brain barrier (BBB) is a complex morphofunctional system that ensures selective permeability between the bloodstream and tissues of the central nervous system. This article discusses the anatomical and histological structure of the BBB, its key functions in protecting the brain and maintaining neuronal homeostasis. Particular attention is paid to the mechanisms of barrier function impairment in various pathological conditions - strokes, neuroinfections , neurodegenerative diseases and brain tumors. The consequences of BBB dysfunction and modern approaches to diagnostics and therapy, including pharmacological modulation and targeted drug delivery technologies are analyzed. The presented material emphasizes the importance of maintaining the integrity of the BBB for neuroprotection and treatment of a wide range of neurological disorders.

Keywords: Blood-brain barrier, neurohomeostasis , permeability, stroke, neuroinfections, neurodegenerative diseases, brain tumors, cerebral edema, tight junctions , neuroinflammation.

Introduction: The human central nervous system (CNS) is highly sensitive to changes in the internal and external environment, which necessitates its reliable protection. One of the key structures that ensures the isolation of the brain from potentially harmful substances circulating in the systemic bloodstream is the blood-brain barrier (BBB). This unique structure, formed by tight junctions of endothelial cells of brain capillaries, pericytes, astrocytes and the basement membrane, acts as a selective filter and active regulator of exchange between blood and nervous tissue.

The BBB not only prevents the penetration of toxins, pathogens and immune cells into the brain parenchyma, but also participates in maintaining ionic balance, nutrient delivery, and regulating neuroinflammatory reactions. Violation of the integrity and function of the BBB underlies the pathogenesis of a wide range of neurological diseases, including ischemic and hemorrhagic stroke, neuroinfections , multiple sclerosis, Alzheimer's disease and brain tumors.

Modern concepts of the structure and functions of the BBB, as well as the mechanisms of its disruption, are important not only for diagnostics, but also for the development of new therapeutic approaches, including methods of targeted drug delivery to the central nervous system. The purpose of this article is to systematize existing data on the morphology and functions of the BBB, analyze the neurological consequences of its disruption, and consider promising areas in the restoration and modulation of the barrier function in various diseases.

Purpose of the study

To study the structure and functions of the blood-brain barrier and analyze the consequences of its disruption in various neurological diseases.

Materials and methods

The study used modern literature data, including experimental and clinical studies devoted to the

morphology, functions and disorders of the blood-brain barrier (BBB). The analysis was carried out on the basis of publications obtained from the scientific databases PubMed , Scopus , Web of Science over the past 10 years.

To illustrate the mechanisms of BBB disruption, the results of morphological and biochemical studies on animal models of stroke, neuroinfections and neurodegenerative diseases, as well as data from clinical observations of patients with similar pathologies are considered.

Methods included studying the barrier structure using electron microscopy, immunohistochemical analysis of tight junctions (tight junction proteins), as well as assessment of functional permeability using contrast imaging techniques and inflammatory biomarkers .

RESULTS AND DISCUSSION

The analysis of literature and experimental data confirmed the complex and multi-level structure of the blood-brain barrier (BBB), which ensures its high selectivity and protective function. Endothelial cells with tight junctions (claudin , occludin , ZO-1) form the main physical barrier, supported by astrocytic endothelial cells and pericytes. Violation of the integrity of these components leads to increased permeability of the BBB and the development of neurological complications.

Strokes are associated with significant weakening of tight junctions and activation of matrix metalloproteinases (MMP-9), which is accompanied by vasogenic edema and increased inflammation. These processes contribute to secondary damage to brain tissue and worsen the prognosis. Similarly, in neuroinfections , pathogens and inflammatory mediators destroy the barrier, facilitating access for immune cells, but simultaneously increasing the risk of edema and neuronal damage.

In neurodegenerative diseases such as Alzheimer's disease and multiple sclerosis, BBB dysfunction is associated with impaired β-amyloid transport, increased neuroinflammation , and lymphocyte infiltration into the CNS, which accelerates disease progression.

Tumor growth, especially in glioblastomas , is accompanied by the secretion of factors that destroy the barrier and cause vasogenic edema, which complicates treatment and worsens the quality of life of patients.

Modern diagnostic methods, including contrast MRI and inflammation biomarkers , allow for timely detection of BBB disruptions. Therapeutic strategies aimed at barrier stabilization, MMP inhibition, and targeted drug delivery through temporary BBB opening show promise for improving clinical outcomes.

Thus, maintaining the integrity of the BBB is critical for neuroprotection and effective treatment of many CNS diseases.

CONCLUSION

The blood-brain barrier is a key element of brain protection, ensuring selective transport of substances and maintaining homeostasis of the central nervous system. Disruptions in the integrity and function of the BBB play an important role in the pathogenesis of many neurological diseases, including strokes, neuroinfections, neurodegenerative processes and brain tumors. Understanding the mechanisms of barrier disruption opens up new opportunities for diagnostics and the development of effective therapeutic approaches aimed at restoring and modulating its function. Further research in this area will contribute to improving the treatment and prevention of neurological disorders.

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