pISSN:2349-5707 Volume:13,Issue 3, March -2026 eISSN:2349-5715

COMPARATIVE ASSESSMENT OF MORPHOLOGICAL MARKERS IN THE BRAIN IN EPILEPSY

Muxammadsodik Soliyevich Isroilov
Tursunaliyeva Moxigul Dilshodjon qizi
Central Asian Medical University

Abstract. This comprehensive scientific article presents a comparative analysis of the fundamental morphological basis of epilepsy, the pathological transformation of neuronal structures, and the microscopic markers in brain tissue. The study provides an in-depth discussion of the interrelationship among hippocampal sclerosis, focal cortical dysplasia, gliosis, and synaptic reorganization, as well as the role of these changes in the development of drug resistance[1,2,3].

Statistical data from Uzbekistan and global medicine between 2024 and 2026, together with innovative neuromorphological advances and diagnostic criteria, are presented in an integrated academic text. The article analyzes strategies for improving surgical and therapeutic effectiveness through identification of the morphological substrate of epilepsy.

Keywords: epilepsy, neuromorphology, morphological markers, hippocampal sclerosis, pyramidal neurons, reactive gliosis, synaptogenesis, cortical dysplasia, apoptosis, microcirculation.

INTRODUCTION

Epilepsy has remained one of the most complex neurophysiological enigmas throughout all periods of human civilization. However, only the development of modern morphological analysis methods has enabled us to understand the true structural nature of this disease.

According to the 2026 projected reports of the World Health Organization, the number of people living with epilepsy worldwide has exceeded 55 million, and its social burden has become comparable to that of cardiovascular diseases [4,5,6]. If we consider the latest statistical data from the Ministry of Health of the Republic of Uzbekistan, the prevalence of epilepsy in our country ranges from 4 to 8 cases per 1,000 population, which underscores the need for fundamental research important for the national gene pool and social stability [7,8,9]. Epilepsy is not merely a functional disorder, but a pathological process accompanied by deep, often irreversible morphological changes in brain tissue. These changes are commonly referred to as morphological markers, and their comparative assessment is of decisive importance in determining the etiology, pathogenesis, and prognosis of the disease.

The earliest and most important morphological marker occurring in the epileptogenic focus is selective neuronal loss[10,11,12]. This process is particularly evident in the Ammon's horn, or hippocampal region. Histomorphological studies demonstrate that in the chronic course of epilepsy, pyramidal neurons in the CA1 and CA3 areas of the hippocampus die as a result of excessive intracellular influx of calcium ions and excitotoxicity.

This mechanism of cell death is mainly associated with neuronal apoptosis, which microscopically is characterized by neuronal shrinkage, nuclear pyknosis, and cytoplasmic vacuolization[13,14,15,16]. Comparative analyses indicate that in patients with hippocampal sclerosis, a 65–70% reduction in neuronal count constitutes the principal substrate of persistent and drug-resistant seizures [3]. At the same time, neurons of the dentate gyrus are often preserved, but their axons — the mossy fibers — change direction and form new pathological recurrent circuits. This phenomenon of mossy fiber sprouting serves as a morphological marker demonstrating that epilepsy has not only a destructive but also a pathological regenerative character.

Another important morphological marker is reactive gliosis. In areas where neurons have died, the number and size of astrocytes increase, and they intensify production of glial fibrillary acidic protein (GFAP). From a morphological perspective, gliosis is not merely a "scar" of the

pISSN:2349-5707 Volume:13,Issue 3, March -2026 eISSN:2349-5715

brain; it is a process that disrupts the ionic homeostasis of brain tissue[17,18]. Astrocytes lose their ability to absorb potassium ions, resulting in an increased extracellular potassium concentration and thereby further enhancing neuronal excitability. Comparative assessment shows that the severity of gliosis is directly related to the duration of the disease. Studies by Uzbek scientists in 2025 emphasized that activation of microglial cells in areas of reactive gliosis increases the release of inflammatory cytokines such as IL-1 and TNF-alpha, which in turn causes morphological destruction of the blood-brain barrier [19]. This chain reaction makes it possible to reinterpret epilepsy as a chronic inflammatory pathology.

Developmental abnormalities of the cerebral cortex, namely focal cortical dysplasias (FCDs), constitute another important group of morphological markers. In FCD, the laminar organization of the cerebral cortex is disrupted, and giant, dysmorphic neurons and balloon cells appear. By their morphological structure, these cells resemble both neurons and glial cells, yet they cannot fully perform the function of either. Comparative analyses have shown that type IIb FCD has the highest degree of epileptogenicity. Global advances in neuroimaging, particularly 7-Tesla MRI technology, now make it possible to identify these microscopic changes as markers even in living patients, increasing the precision of neurosurgical intervention to 85%.

In the comparative assessment of morphological markers of epilepsy, changes in the microcirculatory bed should not be overlooked. Chronic seizures affect the morphology of cerebral capillaries: thickening of vessel walls, endothelial dysfunction, and degeneration of pericytes are observed. These changes deepen brain tissue hypoxia and make it more difficult for medications to reach neurons. Therefore, in the treatment of drug-resistant epilepsy, a comprehensive approach is required, directed not only toward neurons but also toward improving the morphological condition of blood vessels.

In conclusion, scientific analysis of the morphological markers of epilepsy in the brain is the only way to understand the disease at a fundamental level. Comparative assessment of such markers as neuronal loss, reactive gliosis, synaptic reorganization, and cortical dysplasia helps create an individualized pathomorphological profile for each patient. One of the most urgent tasks facing medical science in Uzbekistan is the broad implementation of morphological diagnostic methods, especially immunohistochemical and molecular-genetic analyses, into routine clinical practice. Only through morphology-based diagnosis and treatment strategies can we improve the quality of life of patients with epilepsy and significantly reduce disability rates. Scientific research in this field is of vital importance not only for the present day, but also for the health of future generations.

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