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DYSTROPHIC CHANGES OF RAT CEREBRAL NEURONS

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Abstract

Objective. Generalization and systematization of literature data on dystrophic changes in neurons in the rat cerebral cortex.

Methods. The basis of this study was a review of the literature on this topic.

Results. Dystrophic changes constitute an extensive group of neuronal disorders and are manifested at the morphological level by deformation of the perikarions and neuropil, wrinkling or swelling of the cell, and changes in the chromatophilia of the cytoplasm. At the electron microscopic level, disorganization of organelles is observed, reflecting gross violations of the vital processes of the neuron.

Conclusion. Further study of dystrophic changes in neurons at the histological, ultrastructural and molecular levels will serve as a fundamental basis for the search and improvement of new ways of preventing and correcting diseases of the nervous system.

Keywords: neurons, dystrophic changes, cerebral cortex, rats

ДИСТРОФИЧЕСКИЕ ИЗМЕНЕНИЯ НЕЙРОНОВ КОРЫ ГОЛОВНОГО МОЗГА КРЫСЫ

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Резюме

Цель. Обобщение и систематизация данных литературы о дистрофических изменениях нейронов коры головного мозга крысы.

Методика. Основой данного исследования стал обзор литературы по данной теме.

Результаты. Дистрофические изменения составляют обширную группу нарушений нейронов и проявляются на морфологическом уровне деформацией перикарионов и нейропиля, сморщиванием или набуханием клетки, изменениями хроматофилии цитоплазмы. На электронномикроскопическом уровне при этом наблюдается дезорганизация органелл, отражающая грубые нарушения процессов жизнедеятельности нейрона.

Заключение. Дальнейшее изучение дистрофических изменений нейронов на гистологическом, ультраструктурном и молекулярном уровне послужит фундаментальной основой для поисков и совершенствования новых путей профилактики и коррекции заболеваний нервной системы.

Ключевые слова: нейроны, дистрофические изменения, кора головного мозга, крысы

Introduction

When studying the pathology of the central nervous system, the question arises about the interpretation of the revealed changes in nerve cells. When modeling brain damage, various size disorders, thieves of the perikarion of neurons, as well as changes in the degree of chromatophilia of their cytoplasm are revealed. It is important to establish the dependence of the severity and nature of damage to the nervous system as a whole on the structural changes of the neuron, as its morphofunctional unit [1, 4, 16, 17].

There are several classifications of pathological changes in neurons. So, Nissl, on the basis of the peculiarities of changes in the chromatophilic substance, distinguished: axonal reaction, swelling and wrinkling of neurons. A.I. Strukov and S.K. Lapin in 1956 formulated a classification that includes:1) age, 2) functional and reactive (easily reversible), 3) dystrophic (difficult to reverse and irreversible), 4) compensatory and adaptive changes in neurons.

The classification of N.E. Yarygin (1957) is similar to it. In his classification Yarygin distinguished age-related, functional, dystrophic, regenerative and hypertrophic changes in the structures of nervous tissue [1, 2]. At the later stages of postnatal ontogenesis, destructive changes occur in neurons, manifested at the histological level by a decrease in the size and deformation of perikarions, hyperchromatosis, hypochromatosis and cell shrinkage [3].

The purpose of this article is to analyze and systematize information about pathological changes in brain neurons in the experiment.

Dystrophic changes

It is customary to divide dystrophic periods into three phases. In the first phase of dystrophy, metabolic molecular and ultrastructural changes occur. They can only be detected using biochemical, physicochemical, histochemical and electron microscopic methods. These changes are in many cases reversible [15, 19].

In the second phase of tissue dystrophy, metabolic disorders are accompanied by the appearance of morphological changes in tissue structures, which are detected using conventional histological methods (Nissl staining). These include a slight swelling of nerve cells with a diffuse arrangement in their cytoplasm of a chromatophilic substance or a thickening of the cytoplasm of neurons with moderate hyperchromatosis. On the neuropil side, dystrophic changes are manifested by the appearance of varicose thickenings along the axial cylinders with garnetting of neurofibrils, a change in the tinctorial properties of axoplasm and myelin, and swelling of the terminals [4, 20, 21].

In the third phase of the dystrophic process, irreversible changes occur. They are manifested by wrinkling or, conversely, swelling of nerve cells with dissolution of chromatophilic substances in them, disintegration of neurofibrils, disorganization of organelles. The neuropil is vacuolated and fragmented, undergoing granular-lumpy disintegration, and myelin dissolves, as a result of which lipid droplets begin to be detected along the nerve fibers. Synapses swell, collapse, and disappear [5, 17].

The cytoplasm of some neurons is filled with vacuoles, both small and large, that is why the cell takes on a "foamed" or cellular appearance [12]. Destructive forms of neurons with impaired metabolism are eliminated by microglial cells. In this case, on histological preparations, the phenomena of satellitosis are often observed, in which glial cells are located on the surface of a neuron and neuronophagy (penetration of glial cells into the body of a dying neuron) (Fig. 1) [1, 4, 5].

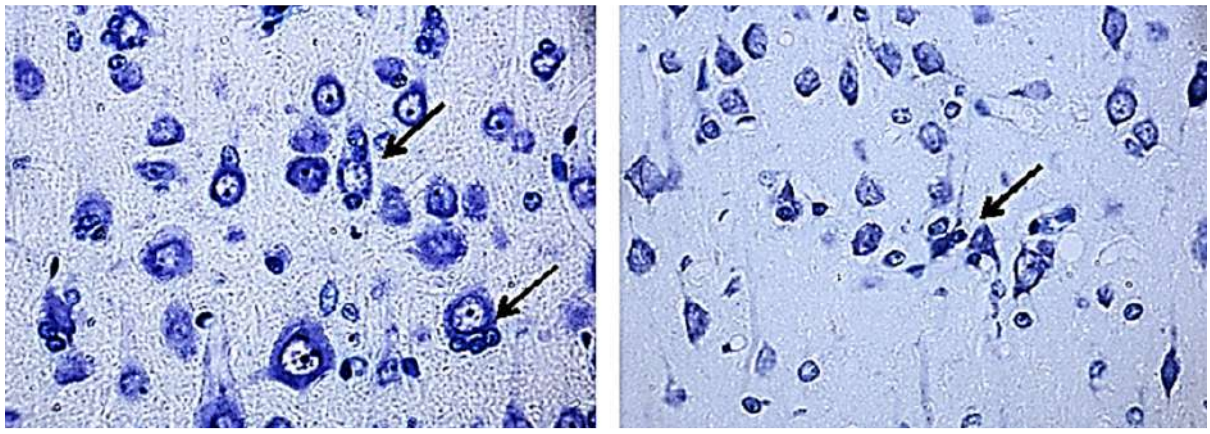

Fig. 1. Satellite and neuronophagy of rat neocortex neurons. Indicated by arrows. Nissl staining. Digital micrograph. Magnification ×400

Dystrophic changes in neurons are often accompanied by deformation of the perikarions and neuropil, most likely associated with a violation of the cytoskeleton (Fig. 2) [6, 7]. In experimental pathology, shrunken, swollen neurons, as well as cells with pericellular edema, are often found among the neurons of the cerebral cortex.

Hyperchromic shrunken neurons are very common in cerebral cortex damage. Their number, as a rule, significantly increases already at the 15th minute of the cessation of the oxygen supply. In hyperchromic shrunken neurons, deformation of the perikarions occurs, possibly under the influence of a violation of the water-electrolyte balance.

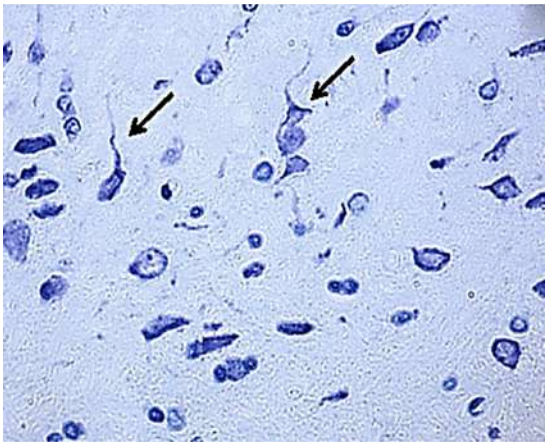

Fig. 2. Deformation of the perikarions and neuropil of neurons in the rat neocortex. Indicated by arrows. Nissl staining. Digital micrograph. Magnification ×400

Their sizes, in comparison with normochromic neurons, are significantly reduced, the cytoplasm is intensely stained with thionine according to the Nissl method [4, 5, 8-12] (Fig. 3, 4).

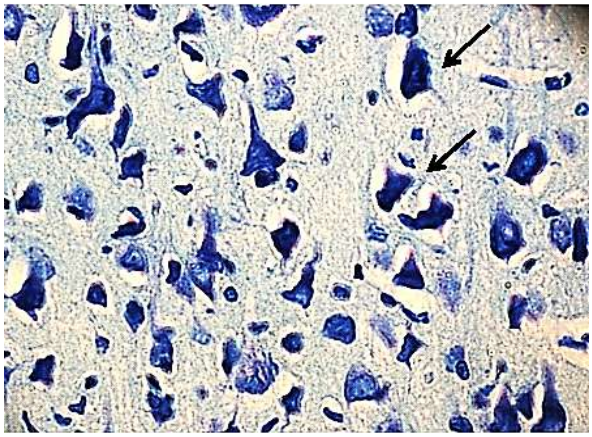

Fig. 3. Hyperchromic shrunken neurons in the rat neocortex with 15-minute total cerebral ischemia. Indicated by arrows. Nissl staining. Digital micrograph. Magnification ×400

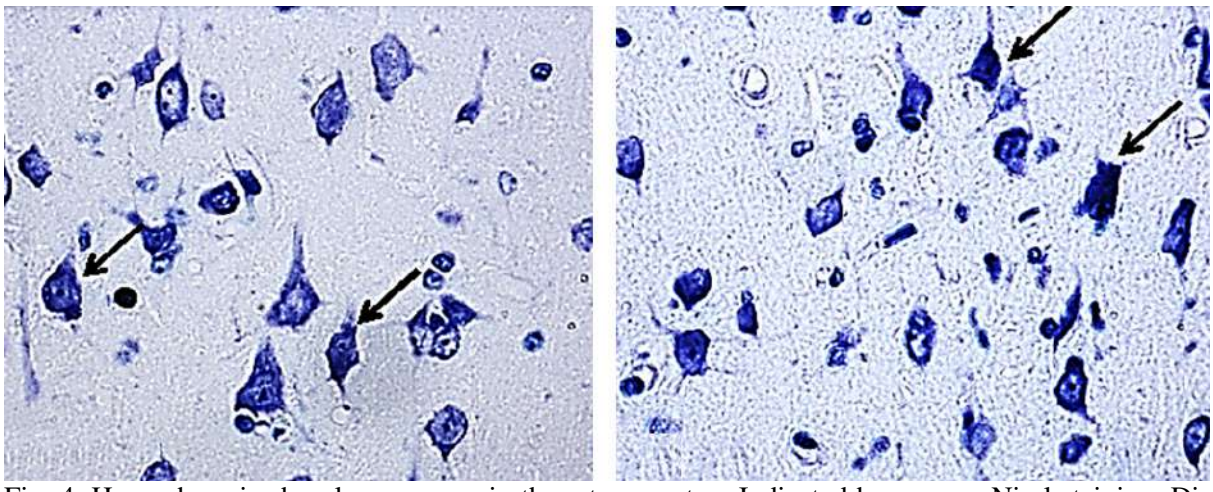

Fig. 4. Hyperchromic shrunken neurons in the rat neocortex. Indicated by arrows. Nissl staining. Digital micrograph. Magnification ×400

In addition to hyperchromic shrunken neurons, there are also hypochromic shrunken cells (Fig. 5).

The pale staining of their cytoplasm with thionine according to the Nissl method is possibly associated

with the disintegration of the cisterns of the granular endoplasmic reticulum. This type of neurons is formed either from hyperchromic shrunken neurons during their further involution, or from hypochromic cells. One of the forms of neuronal dystrophy is their acute swelling. At the same time, neurons increase in volume (sometimes by 2-4 times). The nucleus also swells and takes on an eccentric arrangement.

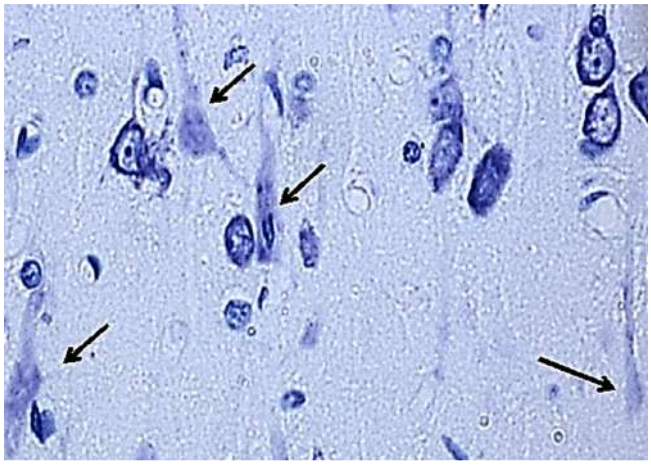

Fig. 5. Hypochromic shrunken neurons of the parietal cortex of 2.5-year-old rats. Indicated by arrows. Nissl staining. Digital micrograph. Magnification ×400

On histological preparations, the cytoplasm of swollen neurons is painted pale and has a fine-grained appearance. Acute swelling of neurons is reversible, but some of them still undergo necrobiosis and die (Fig. 6) [1, 12-14].

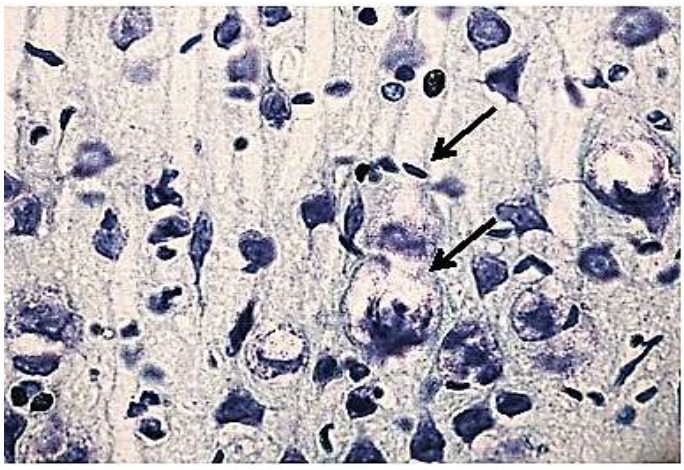

Fig. 6. Swollen neurons in the rat neocortex during 30-minute total cerebral ischemia. Indicated by arrows. Nissl staining. Digital micrograph. Magnification ×400

At the electron microscopic level, the destruction of organelles occurs. Thus, in the cytoplasm of dystrophically altered neurons, mitochondria devoid of cristae are observed. A decrease in the relative number of mitochondria, the number and length of their cristae, which is accompanied by a decrease in the cytoplasm of these neurons in the activity of the enzymes of aerobic oxidation of carbohydrates in the Krebs cycle and the enzyme involved in the transfer of electrons is an important link between the end products of the decay of the carbon skeleton and the respiratory chain. This indicates a progressively reduced functional activity of mitochondria and energy supply of neurons [17-21].

Disorganization of the endoplasmic reticulum and the Golgi complex is observed. Their cisterns expand significantly and can take the form of vacuoles (Fig. 8).

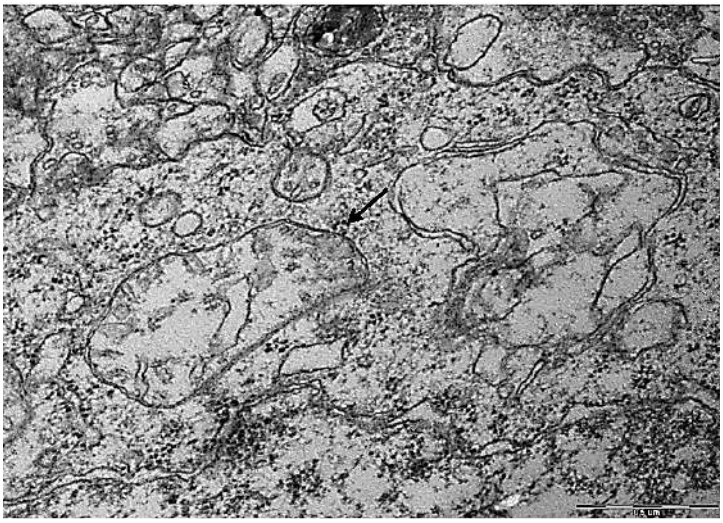

Fig. 7. Fragments of the nucleus and cytoplasm of neurons of the inner pyramidal layer of the rat neocortex. The mitochondrion deprived of cristae is indicated by an arrow. Scale bar: 0.5 мм. Electronogram. Magnification: ×50,000

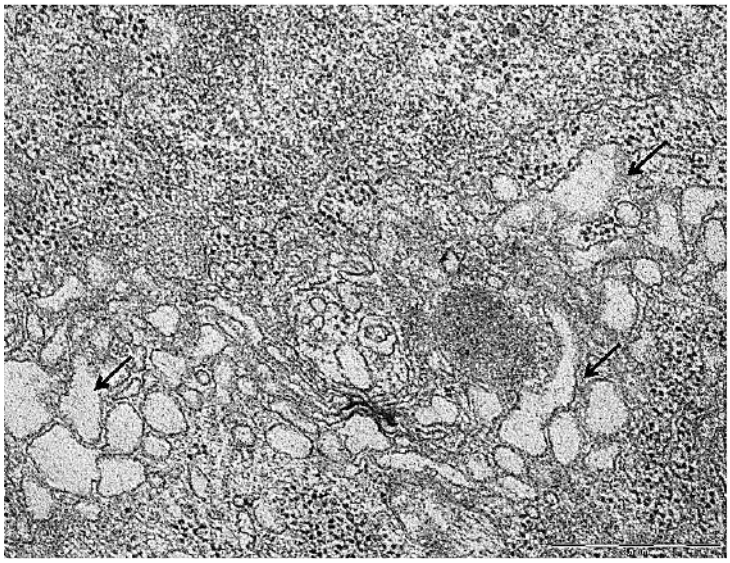

Fig. 8. Fragments of the nucleus and cytoplasm of neurons of the inner pyramidal layer of the rat neocortex. Expanded tanks of the Golgi complex (indicated by an arrow). Scale bar: 0.5 мм. Electronogram. Magnification: ×50,000

Due to the developing energy deficit, the ribosomes lose their connection with the cisterns of the endoplasmic reticulum and are located in the cytoplasm in the form of separate clusters (Fig. 9).

The above changes indicate significant disturbances in neuronal metabolism accompanying morphological changes. The shrinking of neurons, as well as their swelling as a result of edema of the perikarions, can be associated with gross violations of the water-electrolyte balance caused by impaired permeability of the cytolemma to ions due to severe energy deficiency, which, in turn, is associated with the reduction of cristae in mitochondria [15, 16]. Lack of energy leads to deactivation of synthetic processes, which is reflected in the disorganization and vacuolization of the cisterns of the endoplasmic reticulum and the Golgi complex. Free ribosomes in the cytoplasm are incapable of protein synthesis for export. The proteins formed by their means are used by the cells for their own needs, and in the event of an aggravation of the energy deficit, they remain unclaimed at all. The accumulation of these proteins in the cytoplasm of the neuron contributes to a further increase in acidosis and hypoxia, ultimately leading to the destruction of the cell [10, 12, 15 16].

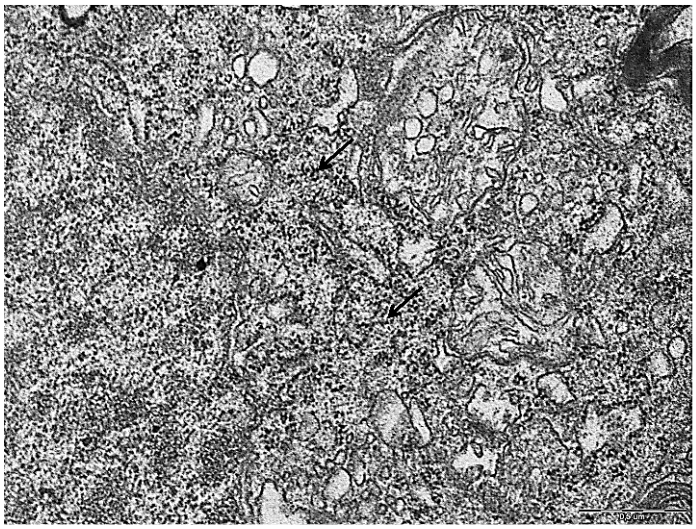

Fig. 9. Fragments of the nucleus and cytoplasm of neurons of the inner pyramidal layer of the rat neocortex. Free ribosomes (indicated by arrows). Scale bar: 0.5 мм. Electronogram. Magnification: ×50,000

Conclusion

Thus, dystrophic changes constitute an extensive group of neuronal disorders and are manifested at the morphological level by deformation of the perikarya and neuropil, wrinkling or swelling of the cell, and changes in the chromatophilia of the cytoplasm. At the electron microscopic level, disorganization of organelles is observed, reflecting gross violations of the vital processes of the neuron. Further study of dystrophic changes in neurons at the histological, ultrastructural and molecular levels will serve as a fundamental basis for the search and improvement of new ways of preventing and correcting diseases of the nervous system.

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