

Structural Aspects of Rats' Hippocampus Neurons Under Experimental Respiratory Hypoxia

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Submitted: 2026, Aug 18; Accepted: 2026, Sep 21; Published: 2026, Sep 30

Citation: Bon, E. I., Maksimovich, N. Ye., Feduto, M. A., Zimatkin, S. M., Pushkina, S. A. (2026). Structural Aspects of Rats' Hippocampus Neurons Under Experimental Respiratory Hypoxia. *Hypertens OA*, 2(2), 01-03.

Abstract

A study of the rat hippocampus under conditions of experimental respiratory hypoxia revealed pathomorphological changes in neurons at both observation points (30 and 60 minutes). These alterations were characterized by perikaryon swelling (increased size) with preserved cell shape and cytoplasmic hypochromia. The severity of the pathomorphological changes progressed as the duration of the hypoxic exposure increased.

Keywords: Respiratory Hypoxia, Brain, Neurons

1. Introduction

Acute respiratory failure is a pathological syndrome characterized by limited airflow in the airways and, consequently, decreased blood oxygenation [1]. Various causes can lead to the development of acute respiratory failure, including spasm, swelling, inflammatory infiltration, obstruction of the airways by sputum, mucus, foreign bodies, etc. (obstructive respiratory failure).

This condition leads to disruption of the body's vital functions as a whole, disrupting organ and tissue function [2]. Changes primarily occur in body structures with the highest metabolic rates, such as the brain, leading to not only functional but also morphological

changes in cells of varying magnitude and severity, including cell death.

We aim to study the consequences of acute respiratory hypoxia in rats, focusing on the hippocampus, which is responsible for spatial navigation, memory, emotion, and attention. The developmental changes in hippocampal neurons, depending on the rate of development and the duration of acute hypoxic conditions, are poorly understood [3-5]. There is no clear understanding of the nature of hippocampal neuronal changes in acute partial obstructive respiratory failure. Our goal is to study the effects of respiratory hypoxia on hippocampal neurons in rats.

Target – to study the effect of respiratory hypoxia on rat hippocampal neurons.

2. Materials and methods of research

The study was experimental in nature and was conducted on mongrel albino rats (18 males, weighing 250-300 g) divided into three groups (n=6) – one control and two experimental groups – in compliance with the requirements of Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes.

Rats in the experimental groups were subjected to obstructive respiratory hypoxia by partial tracheal compression. After achieving the required depth of intravenous sodium thiopental anesthesia (40 mg/kg), the animals were secured on a dissecting table, prone. After a midline neck incision from the chin to the sternum, the neck muscles were bluntly dissected down to the trachea. A 1.5 mm diameter plastic wire was placed below the cricoid cartilage of the larynx, ligated, and then removed. Tracheal lumen narrowing reached 65%, with a residual patency of 35%. Animals were sacrificed by decapitation after 30 minutes (Group 2) and 60 minutes (Group 3).

The control group consisted of sham-operated rats, with all stages of the surgery reproduced without tracheal compression (Group 1).

The brains were removed in the cold and fixed in Carnoy's fluid. Serial frontal paraffin sections (7 μ m thick) were then cut and stained using the Nissl method. The location of the pyramidal layer

of the CA1 hippocampal field was determined using a stereotaxic atlas [6].

Visual and morphometric assessment of neurons was performed using ImageWarp image analysis software (Bitflow, USA).

In each animal, 30 neurons in the pyramidal layer of the CA1 hippocampal field were examined, determining their size, shape, and degree of chromatophilia.

The obtained quantitative continuous data were processed using nonparametric statistical methods and the licensed Statistica 10.0 software for Windows (StatSoft, Inc., USA). The data are presented as Me (LQ; UQ), where Me is the median, LQ is the lower quartile value, and UQ is the upper quartile value. Differences between the control and experimental groups were considered significant at $p < 0.05$ (Mann-Whitney U-test with Bonferroni correction) [7].

3. Study results

In the control group, the area of neurons in the pyramidal layer of the CA1 field of the hippocampus of the rat brain was 78.4 (74.9; 81.5) μ m². They had a rounded shape (form factor – 0.9 (0.9; 0.9) units, elongation factor – 1.1 (1.1; 1.2) units), distinct smooth contours of the cellular and nuclear membranes.

In animals with 30-minute and 60-minute acute partial obstructive respiratory hypoxia, changes in the area of neurons in the pyramidal layer of the CA1 field of the hippocampus of the rat brain were established (Table).

Groups	Indicators		
	area (μ m ²)	form factor (units)	elongation factor (units)
control	78.4 (74.9; 81.5)	0.9 (0.9; 0.9)	1.1 (1.1; 1.2)
hypoxia 30 min	97.4* (96.7; 102.8)	0.9 (0.9; 0.9)	1.1 (1.1; 1.2)
hypoxia 60 min	109.8*# (104.6; 111.2)	0.9 (0.9; 0.9)	1.1 (1.1; 1.2)

Note: * – the differences are significant compared to the control group ($p < 0.05$);

– the differences are significant compared to the «hypoxia 30 min» group ($p < 0.05$).

Table 1: Area and shape indices of neurons in the pyramidal layer of the CA1 field of the hippocampus of rats with acute partial obstructive respiratory hypoxia

In rats exposed to 30 minutes of acute partial obstructive respiratory hypoxia, a 24% increase in the area of neurons in the pyramidal layer of the hippocampal field CA1 was observed compared to the control group ($p < 0.05$).

After 60 minutes of acute obstructive respiratory hypoxia, a 40% increase in the area of neurons in the pyramidal layer of the hippocampal field CA1 was observed compared to the control group ($p < 0.05$) and by 12% ($p < 0.05$) compared to the 30-minute period of acute hypoxia, indicating a progressive increase in cellular swelling caused by impaired potential-determining ion transport.

There were no changes in the shape of neurons in the pyramidal layer of the CA1 field of the hippocampus in either time period studied in rats with acute partial obstructive respiratory hypoxia ($p > 0.05$), as evidenced by the absence of differences in the form factor ($p > 0.05$) and elongation factor ($p > 0.05$).

In the control group, up to 94% of the population of neurons in the pyramidal layer of the CA1 field of the hippocampus of rats were normochromic cells, while the remaining neurons were hyperchromic (5%) and hyperchromic shrunken (1%) cells (Fig. 1).

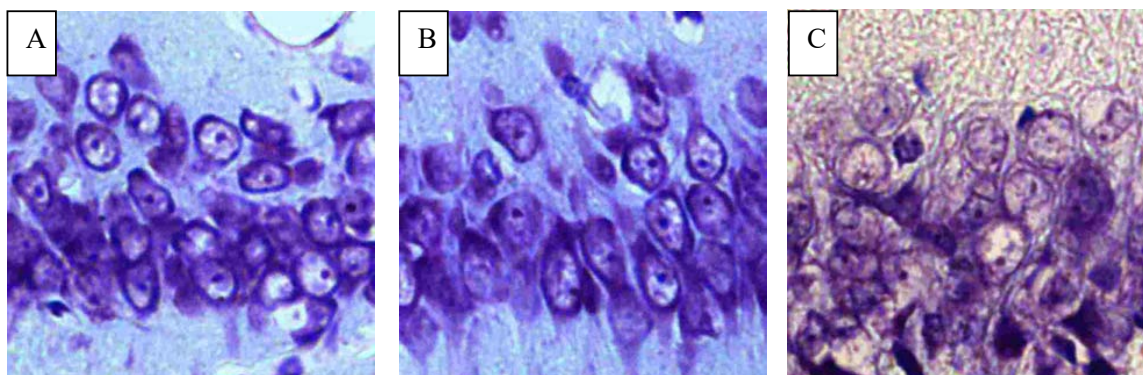


Figure 1: Neurons of the pyramidal layer of the CA1 field of the hippocampus of rats with acute partial obstructive respiratory hypoxia. Digital micrograph. Nissl staining. Magnifying lens x40.

A – control group (predominance of normochromic neurons);

B – 30 minutes of acute partial obstructive respiratory hypoxia (predominance of hypochromic neurons with signs of swelling and shadow cells);

C – 60 minutes of acute partial obstructive respiratory hypoxia (predominance of hypochromic neurons with signs of swelling and shadow cells).

In contrast to the control group, in the experimental group with 30-minute acute partial obstructive respiratory hypoxia, hypochromic (up to 60%, $p < 0.05$) and hyperchromic (up to 20%, $p < 0.05$) neurons predominated, and normochromic neurons (up to 15%, $p < 0.05$) and shadow cells (up to 5%, $p < 0.05$) were also detected.

After 60 minutes of acute partial obstructive respiratory hypoxia, normochromic neurons were not detected ($p < 0.05$), and the majority of cells were hypochromic neurons (70%, $p < 0.05$) and shadow cells (20%, $p < 0.05$), while the number of hyperchromic neurons slightly decreased (up to 10%, $p < 0.05$), in contrast to rats with 30-minute acute partial obstructive respiratory hypoxia.

A study of the effects of acute partial obstructive respiratory hypoxia on hippocampal neurons in rats revealed data not previously described in the literature, namely, an increase in cell size (swelling) without changes in shape and hypochromia during both study periods, with worsening indicators as the hypoxic period was extended to 60 minutes. This is due to a gradual decrease in cellular energy supply, the accumulation of ions and products of incomplete oxidation of organic matter in the cytosol, followed by hyperosmolarity and the development of cytotoxic edema, characteristic of liquefactive necrosis.

4. Conclusion

Thus, the extrapolation of the obtained experimental data to humans will aid in assessing the nature of hippocampal damage in acute respiratory failure caused by airway obstruction of varying duration. These findings are significant for developing and determining therapeutic strategies to manage hippocampal dysfunctions associated with this pathology.

References

1. Adrogué, H. J., & Tobin, M. J. (1997). *Respiratory failure*. Cambridge, Mass: Blackwell Science.
2. Guo, M. F., Yu, J. Z., & Ma, C. G. (2011). Mechanisms related to neuron injury and death in cerebral hypoxic ischaemia. *Folia Neuropathol*, 49(2), 78-87.
3. Romano, A. D., Serviddio, G., de Mattheis, A., Bellanti, F., & Vendemiale, G. (2010). Oxidative stress and aging. *Journal of nephrology*, 23(S15), S29-S36.
4. Bon, E. I. N., Maksimovich, Y., & Zimatkin, S. M. (2020). Histological changes in neurons of the parietal cortex of the brain of rats with subtotal and total ischemia. *Bulletin of the Smolensk State Medical Academy*, 23-17.
5. Feduto, M. A., Maksimovich, N. Y., Bon, E. I., & Zimatkin, S. M. (2023). Modeling of cerebral anoxia of respiratory genesis in rats. *Archives of Urology and Nephrology*, 1, 1-4.
6. Paxinos, G., & Watson, C. (2013). *The rat brain in stereotaxic coordinates*. Academic press.
7. Brown, B. M., Newcombe, R. G., & Zhao, Y. (2009). Non-null semi-parametric inference for the Mann–Whitney measure. *Journal of Nonparametric Statistics*, 21(6), 743-755.

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