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PHYSIOLOGICAL COMPENSATORY RESPONSES OF THE ORGANISM IN HYPOXIA AND THEIR PATHOLOGICAL SIGNIFICANCE

Nasirova Shaxlo Shavkatovna
Assistant, Department of Physiology, Samarkand State Medical University
G'aniyev Suxrob Sa'dullayevich
Samarkand State Medical University, Faculty of Medicine No. 2, Group 204

Abstract. This article analyzes the physiological compensatory responses of the organism under hypoxic conditions and their pathological significance. The mechanisms of acute and chronic adaptation to oxygen deficiency are discussed, including respiratory, cardiovascular, hematological, and cellular responses. Special attention is given to the role of hypoxia-inducible factor-1α (HIF-1α), erythropoiesis stimulation, and metabolic reprogramming toward anaerobic glycolysis. The study also evaluates the transition from adaptive to maladaptive responses, leading to metabolic acidosis, cellular injury, and organ dysfunction. Modern diagnostic approaches for hypoxia assessment are briefly reviewed.

Keywords: hypoxia, compensation, HIF-1α, erythropoiesis, hyperventilation, metabolic acidosis.

Introduction. Hypoxia is a pathological condition characterized by insufficient oxygen supply to tissues. It plays a central role in the pathogenesis of many acute and chronic diseases. In response to oxygen deficiency, the human body activates complex compensatory mechanisms aimed at maintaining cellular metabolism and survival. Initially, these responses are adaptive and protective; however, prolonged hypoxia leads to pathological alterations and organ dysfunction.

Aim of the Study. To analyze physiological compensatory mechanisms in hypoxia and their transition into pathological processes.

Objectives

1. To study different types of hypoxia.
2. To analyze respiratory compensatory mechanisms.
3. To evaluate cardiovascular adaptations.
4. To investigate hematological responses.
5. To assess cellular adaptation via HIF-1α signaling.
6. To determine pathological consequences of prolonged hypoxia.

Main Body. Types of Hypoxia. Hypoxia can be classified into:

- Hypoxic (exogenous) hypoxia
- Hemic (anemic) hypoxia
- Circulatory (ischemic) hypoxia
- Histotoxic hypoxia

Each type affects oxygen delivery and utilization in different ways.

Respiratory Compensation. In hypoxic conditions, peripheral chemoreceptors (carotid and aortic bodies) are activated, stimulating the respiratory center. This leads to hyperventilation. VA↑⇒PaO2↑V_A \uparrow \Rightarrow PaO_2 \uparrowVA ↑⇒PaO2 ↑ This mechanism partially restores arterial oxygen levels and improves tissue oxygenation.

Cardiovascular Adaptation

Hypoxia activates the sympathetic nervous system, resulting in:

- increased heart rate (tachycardia)
- increased cardiac output

- peripheral vasoconstriction in non-essential organs

These changes aim to maintain oxygen delivery to vital organs such as the brain and heart.

Hematological Response. Chronic hypoxia stimulates erythropoietin (EPO) production in the kidneys, leading to increased erythropoiesis. EPO↑⇒RBCs↑⇒O2 transport↑EPO \uparrow \Rightarrow RBCs \uparrow \Rightarrow O_2 \ transport \uparrowEPO↑⇒RBCs↑⇒O2 transport↑ This results in polycythemia, which enhances oxygen-carrying capacity but may increase blood viscosity.

Cellular Adaptation. At the cellular level, hypoxia-inducible factor-1α (HIF-1α) plays a key regulatory role. It promotes:

- increased glycolysis
- suppression of aerobic metabolism
- angiogenesis via VEGF activation

These adaptations help cells survive under low oxygen conditions.

Pathological Significance

Prolonged hypoxia leads to maladaptive changes such as:

- metabolic acidosis
- mitochondrial dysfunction
- oxidative stress
- apoptosis
- organ failure (brain and heart damage)

Thus, adaptive mechanisms may become harmful if oxygen deficiency persists.

Methods of Hypoxia Assessment (continuous text)

Hypoxia is evaluated using a combination of clinical, laboratory, and instrumental methods. Arterial blood gas analysis is used to measure PaO_2, $PaCO_2$, and pH levels, providing direct information about oxygenation status. Pulse oximetry is a non-invasive method used to monitor oxygen saturation (SpO_2). Spirometry assesses respiratory function and ventilatory capacity. Electrocardiography (ECG) and echocardiography are used to evaluate cardiovascular compensatory responses. Complete blood count helps determine hemoglobin concentration and erythrocyte count. Serum lactate levels are used as a marker of anaerobic metabolism. Modern diagnostic approaches also include the assessment of HIF-1α and VEGF as molecular biomarkers of hypoxia.

Results. The analysis shows that hypoxia initially activates compensatory physiological mechanisms aimed at maintaining oxygen delivery. However, prolonged oxygen deficiency leads to decompensation and tissue damage. The brain and myocardium are particularly sensitive to chronic hypoxia.

Discussion. Hypoxia induces a biphasic response: an initial adaptive phase followed by a pathological phase. HIF-1α serves as the central regulator of cellular oxygen homeostasis. Although beneficial in acute conditions, prolonged activation may contribute to fibrosis and pathological angiogenesis.

Conclusion

1. Hypoxia triggers complex compensatory mechanisms in the body.
2. Respiratory, cardiovascular, and hematological systems are primarily involved.
3. HIF-1α is the key regulator of cellular adaptation to hypoxia.
4. Prolonged hypoxia leads to irreversible pathological changes.
5. Early diagnosis is essential for preventing organ damage.

References

1. Guyton A.C., Hall J.E. Textbook of Medical Physiology. 14th ed. – Philadelphia: Elsevier, 2021.
2. West J.B. Respiratory Physiology: The Essentials. 11th ed. – Wolters Kluwer, 2021.
3. Semenza G.L. Hypoxia-inducible factors in physiology and medicine. Cell, 2012.
4. Ratcliffe P.J. Oxygen sensing and hypoxia signaling pathways. Nature, 2013.
5. McMullin M.F. Erythropoietin and hypoxia regulation. British Journal of Haematology, 2016.
6. Robbins S.L., Cotran R.S. Pathologic Basis of Disease. 10th ed. – Elsevier, 2020.
7. Levitzky M.G. Pulmonary Physiology. 9th ed. – McGraw-Hill, 2018.
8. Weir E.K., Archer S.L. Hypoxic pulmonary vasoconstriction and vascular remodeling. Circulation Research, 2010.
9. Safar M.E. Cerebral hypoxia and ischemic injury mechanisms. Stroke, 2002.
10. Ward J.P.T. Physiology of the pulmonary circulation in hypoxia. Respiratory Physiology & Neurobiology, 2007.
11. Semenza G.L. Regulation of oxygen homeostasis by HIF-1. Annual Review of Physiology, 2011.
12. Pinsky M.R. Cardiovascular responses to hypoxia. Critical Care Medicine, 2003.
13. Honoré P.M. Tissue hypoxia in critical illness and sepsis. Intensive Care Medicine, 2008.
14. Johnson R.S. HIF signaling and metabolic adaptation to hypoxia. Nature Reviews Molecular Cell Biology, 2010.
15. Sutton J.R. High-altitude physiology and adaptation. Journal of Applied Physiology, 2000.
16. West J.B., Schoene R.B. High-altitude medicine and physiology. 5th ed. – CRC Press, 2012.
17. Kaelin W.G. Oxygen sensing and disease mechanisms. New England Journal of Medicine, 2013.