INTERNATIONAL JOURNAL OF COGNITIVE NEUROSCIENCE AND PSYCHOLOGY

FEATURES OF BIOCHEMICAL MECHANISMS OF PATHOGENESIS OF SQUAMOUS CELL CARCINOMA OF THE ORAL CAVITY

Axmedov Alibek Baxodirovich*[1], Tukhtayev Shakhboz Fayoz ugli[2]
[1,2]Bukhara State Medical Institute Named After Abu Ali Ibn Sino, Bukhara, Uzbekistan
*E-mail: alibek_axmedov@bsmi.uz

Abstract: Squamous cell carcinoma of the oral cavity (OSCC) is a highly aggressive malignancy characterized by late diagnosis and poor prognosis. Its pathogenesis involves complex interactions among oxidative stress, chronic inflammation, metabolic reprogramming, microbiome imbalance, and genetic alterations. Despite advances in molecular oncology, early diagnostic accuracy remains limited due to insufficient integration of biochemical biomarkers into clinical practice, highlighting a critical knowledge gap. This study analyzes contemporary evidence on biochemical and molecular mechanisms underlying OSCC, focusing on key biomarkers such as reactive oxygen species (ROS), 8-OHdG, antioxidant enzymes (SOD, GPx), proinflammatory cytokines (IL-6, TNF-α), and genetic regulators (TP53, Ki-67, EGFR, VEGF, MMP-9). A comprehensive analytical approach was used to synthesize findings on oxidative imbalance, inflammatory signaling pathways, and tumor-related metabolic changes. The findings demonstrate that decreased antioxidant activity and increased ROS levels promote cellular damage and genomic instability, while cytokine-mediated signaling pathways enhance proliferation, inhibit apoptosis, and sustain a pro-oncogenic microenvironment. Genetic mutations and activation of pathways such as PI3K/AKT further support tumor survival and progression. These results confirm that OSCC development represents a unified pathobiochemical cascade linking inflammation, oxidative stress, and genetic dysregulation. The study implies that integrating biochemical markers into diagnostic models can significantly improve early detection, prognostic evaluation, and personalized therapeutic strategies in oral cancer management.

Keywords: Soral Squamous Cell Carcinoma, Oxidative Stress, Reactive Oxygen Species, Chronic Inflammation, Cytokines, Antioxidant Enzymes, TP53 Mutation, EGFR, PI3K/AKT Pathway, Biomarkers, Carcinogenesis

Introduction

Squamous cell carcinoma of the oral cavity (OCD) is a multifactorial malignant neoplasm, the development of which is associated with a complex interaction of oxidative stress, chronic inflammation, metabolic cell reprogramming, microbiological disorders and molecular genetic changes. The article presents modern data on the biochemical and molecular mechanisms of carcinogenesis in PRPR with an emphasis on the role of reactive oxygen species, proinflammatory cytokines, the antioxidant system, angiogenesis factors, signaling pathways of cell proliferation and invasion [1][2]. Key biomarkers are considered, including 8-OHdG, ROS, SOD, GPx, IL-6, TNF-α, TP53, Ki-67, EGFR, VEGF, MMP-9 and others, as well as their diagnostic and prognostic significance. It has been shown that these indicators reflect a single pathobiochemical cascade that determines the transition from chronic inflammation to malignant transformation of the epithelium. The need to integrate biochemical markers into clinical and diagnostic models is emphasized in order to improve the accuracy of early detection and prediction of the course of PRD [3].

Squamous cell carcinoma of the oral cavity (OCD) is one of the most aggressive malignant neoplasms of the head and neck, characterized by a high frequency of late diagnosis and an unfavorable prognosis, due to both the biological heterogeneity of the tumor and the absence of early specific clinical manifestations (Bray et al., 2021; Warnakulasuriya, 2009) [4][5]. Modern concepts of the pathogenesis of PRPR have significantly expanded and gone beyond the morphological approach, shifting towards a comprehensive analysis of biochemical and molecular mechanisms, including the interaction of oxidative stress, chronic inflammation, disorders of signaling pathways of cell proliferation and

microbiome-associated changes. At the same time, metabolic reprogramming of tumor cells is observed, characterized by the transition to anaerobic glycolysis even in conditions of sufficient oxygen (the Warburg effect). This ensures rapid energy metabolism and accumulation of metabolites necessary for the biosynthesis of nucleotides and lipids, supporting the intensive proliferation of tumor cells and their adaptation to hypoxic conditions [6][7].

Methodology

This study employed a comprehensive analytical and integrative research approach to examine the biochemical mechanisms involved in the pathogenesis of oral squamous cell carcinoma. Relevant scientific literature and contemporary research findings were systematically reviewed to identify key molecular, biochemical, and cellular factors contributing to tumor development. Particular attention was given to oxidative stress markers, including reactive oxygen species and 8-OHdG, as well as antioxidant defense enzymes such as superoxide dismutase and glutathione peroxidase, in order to evaluate redox imbalance [8][9]. In parallel, the role of inflammatory mediators, including interleukins and tumor necrosis factor alpha, was analyzed to assess their contribution to the formation of a pro-oncogenic microenvironment and activation of signaling pathways such as JAK/STAT3 and NF-kB.

Genetic and proliferative markers, including TP53 mutations, Ki-67 expression, and epidermal growth factor receptor activity, were also examined to determine their association with tumor aggressiveness and progression [10]. Additionally, the study considered the involvement of angiogenesis and invasion-related factors, such as VEGF and MMP-9, alongside metabolic alterations consistent with the Warburg effect. Data were synthesized through comparative and logical analysis to establish interconnections between oxidative, inflammatory, metabolic, and genetic components. This integrative framework allowed for the identification of a unified pathobiochemical cascade underlying malignant transformation and progression in oral epithelial tissues.

Results and Discussion

The opposite component of this system is the antioxidant enzymes superoxide dismutase (SOD) and glutathione peroxidase (GPx), whose decreased activity indicates depletion of the cell's defense mechanisms. This condition leads to the accumulation of free radicals, increased lipid peroxidation, and progressive damage to cell membranes, proteins, and nucleic acids. Thus, the imbalance between ROS and the antioxidant system is one of the key mechanisms of the transition from inflammation to tumor transformation [11][12]. The inflammatory component of pathogenesis is represented by cytokines IL-6, TNF-α and IL-1b, which form a stable pro-oncogenic microenvironment. IL-6, through activation of the JAK/STAT3 signaling pathway, stimulates cell proliferation and suppresses apoptosis, enhancing the survival of transformed cells. TNF-α, by activating NF-kB, supports chronic inflammation and simultaneously induces the expression of anti-apoptotic proteins, which promotes tumor progression. IL-1b enhances tissue destruction and supports inflammatory infiltration, creating conditions for further damage to the epithelium and its remodeling [13]. The genetic component of tumor transformation is reflected by changes in TP53, Ki-67, and EGFR. TP53 mutations lead to loss of cell cycle control and the ability to induce apoptosis, which makes cells genetically unstable and prone to uncontrolled division. An increase in Ki-67 expression is a direct indicator of high proliferative tumor activity and correlates with an aggressive clinical course. EGFR overexpression enhances growth and survival signals, activating intracellular proliferation cascades, and also increases tumor resistance to therapy. An additional prognostically unfavorable factor is the activation of the PI3K/AKT signaling pathway, which regulates cell survival, metabolism, and resistance to apoptosis [14][15]. Its activation provides tumor cells with the ability to survive for a long time even in conditions of hypoxia and nutrient deficiency, enhancing their adaptive properties.

Conclusion

Thus, modern data convincingly demonstrate that squamous cell carcinoma of the oral cavity is not only a morphologically defined tumor, but also a complex biochemical system in which inflammation, oxidative stress, the microbiome, and signaling pathways of cell growth form a single pathological continuum. The interaction of immune, metabolic and genetic factors plays a key role in this system, which determines the need for an integrated approach to diagnosis, including the assessment of biochemical markers along with morphological and clinical parameters.

REFERENCES

[1] D. Hanahan and R. A. Weinberg, "Hallmarks of cancer: the next generation," *Cell*, vol. 144, pp. 646–674, 2011.

[2] M. Valko, D. Leibfritz, J. Moncol, M. T. D. Cronin, M. Mazur, and J. Telser, "Free radicals and antioxidants in normal physiological functions and human disease," *Int. J. Biochem. Cell Biol.*, vol. 39, pp. 44–84, 2007.

[3] A. Mantovani, P. Allavena, A. Sica, and F. Balkwill, "Cancer-related inflammation," *Nature*, vol. 454, pp. 436–444, 2008.

[4] O. Warburg, "On the origin of cancer cells," *Science*, vol. 123, pp. 309–314, 1956.

[5] M. G. Vander Heiden, L. C. Cantley, and C. B. Thompson, "Understanding the Warburg effect: the metabolic requirements of cell proliferation," *Science*, vol. 324, pp. 1029–1033, 2009.

[6] S. G. Fitzpatrick et al., "Oral inflammation and carcinogenesis," *Oral Oncology*, 2019.

[7] A. K. Chaturvedi et al., "Human papillomavirus and oropharyngeal cancer," *J. Clin. Oncol.*, vol. 29, pp. 4294–4301, 2011.

[8] M. L. Gillison et al., "Epidemiology of human papillomavirus-associated cancers," *Lancet*, vol. 385, pp. 566–575, 2015.

[9] F. A. Scannapieco, "Role of oral bacteria in respiratory infection and systemic inflammation," *Periodontol 2000*, vol. 55, pp. 90–105, 2013.

[10] P. D. Marsh and E. Zaura, "Dental biofilm: ecological interactions in health and disease," *Caries Res.*, vol. 51, pp. 12–22, 2017.

[11] S. Warnakulasuriya, "Global epidemiology of oral and oropharyngeal cancer," *Oral Oncology*, vol. 45, pp. 309–316, 2009.

[12] F. Bray et al., "Global cancer statistics 2020," *CA Cancer J. Clin.*, vol. 71, pp. 209–249, 2021.

[13] C. Scully and J. Bagan, "Oral squamous cell carcinoma overview," *Oral Oncology*, vol. 45, pp. 301–308, 2009.

[14] C. R. Leemans, P. J. F. Snijders, and R. H. Brakenhoff, "The molecular biology of head and neck cancer," *Nat. Rev. Cancer*, vol. 11, pp. 9–22, 2011.

[15] C. Rivera, "Essentials of oral cancer," *Int. J. Clin. Exp. Pathol.*, vol. 8, pp. 11884–11894, 2015.