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ONCOLOGICAL COMPLICATIONS AFTER COVID-19: MODERN VIEWS, PATHOGENETIC MECHANISMS, AND CLINICAL SIGNIFICANCE

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Annotation

The COVID-19 pandemic has significantly impacted global healthcare systems and raised concerns about long-term oncological consequences. This study analyzes post-COVID oncological complications, focusing on molecular and immunological mechanisms. Chronic inflammation, immune dysregulation, oxidative stress, and epigenetic alterations are identified as major contributors to carcinogenesis. Additionally, delays in diagnosis and treatment during the pandemic have worsened cancer outcomes.

Keywords: COVID-19, carcinogenesis, immune dysregulation, oxidative stress

COVID-19 DAN KEYINGI ONKOLOGIK ASORATLAR: ZAMONAVIY QARASHLAR, PATOGENETIK MEXANIZMLAR VA KLINIK AHAMIYATI

ANNOTATSIYA

COVID-19 infeksiyasi global sog‘liqni saqlash tizimiga sezilarli ta’sir ko‘rsatib, uzoq muddatli asoratlar, jumladan onkologik xavf bilan bog‘liq muammolarni yuzaga chiqardi. Ushbu maqolada post-COVID davrida yuzaga keladigan onkologik asoratlar, ularning molekulyar va immunologik mexanizmlari hamda klinik oqibatlari tizimli ravishda tahlil qilindi. Natijalar shuni ko‘rsatadiki, surunkali yallig‘lanish, immun disbalans, oksidativ stress va epigenetik o‘zgarishlar karsinogenez jarayonlarini faollashtirishi mumkin. Shuningdek, pandemiya davridagi diagnostik kechikishlar ham onkologik kasalliklar prognoziga salbiy ta’sir ko‘rsatgan.

Kalit so‘zlar: COVID-19, karsinogenez, immun disfunksiya, oksidativ stress

ОНКОЛОГИЧЕСКИЕ ОСЛОЖНЕНИЯ ПОСЛЕ COVID-19: СОВРЕМЕННЫЕ ВЗГЛЯДЫ, ПАТОГЕНЕТИЧЕСКИЕ МЕХАНИЗМЫ И КЛИНИЧЕСКОЕ ЗНАЧЕНИЕ.

Аннотация

Инфекция COVID-19 оказала значительное влияние на глобальную систему здравоохранения, вызвав опасения по поводу долгосрочных осложнений, включая онкологические риски. В данной статье систематически рассматриваются онкологические осложнения, возникающие в постковидный период, их молекулярные и иммунологические механизмы, а также клинические последствия. Результаты показывают, что хроническое воспаление, иммунный дисбаланс, окислительный стресс и эпигенетические изменения могут активировать процессы канцерогенеза. Задержки в диагностике во время пандемии также негативно повлияли на прогноз онкологических заболеваний.

Ключевые слова: COVID-19, канцерогенез, иммунная дисфункция, окислительный стресс

Introduction:

COVID-19 has emerged as one of the most significant global public health challenges of the 21st century. Initially characterized as an acute respiratory infection, it is now widely recognized as a systemic disease with multisystem involvement, affecting the cardiovascular, neurological, endocrine, and immune systems.In recent years, increasing attention has been directed toward the long-term consequences of COVID-19, commonly referred to as “post-COVID syndrome” or “Long COVID.” This condition encompasses a wide spectrum of clinical manifestations, including persistent fatigue, respiratory dysfunction, neurological impairments, and, notably, immune dysregulation.Of particular importance is the profound alteration of the immune system observed in post-COVID patients. Persistent immune activation and chronic low-grade inflammation can disrupt physiological homeostasis, creating a microenvironment conducive to pathological processes. It is well established that chronic inflammation and impaired immune surveillance are key drivers of carcinogenesis. Therefore, the potential association between COVID-19 and increased oncological risk has become an area of growing scientific interest.Moreover, COVID-19–related molecular alterations, such as enhanced oxidative stress, DNA damage, epigenetic modifications, and dysregulation of the cell cycle, may further contribute to malignant transformation. Emerging evidence suggests that SARS-CoV-2 may interfere with intracellular signaling pathways, thereby influencing cellular proliferation and apoptosis.In addition to biological mechanisms, the pandemic has significantly disrupted healthcare systems worldwide. The reallocation of medical resources, temporary suspension of cancer screening programs, and delays in diagnostic and therapeutic procedures have resulted in a substantial decline in early cancer detection. Consequently, many malignancies have been diagnosed at more advanced stages, negatively impacting patient outcomes.

Materials and Methods

This study is based on a comprehensive literature review approach aimed at analyzing the potential oncological consequences of COVID-19 infection. A systematic search of scientific publications was conducted using internationally recognized databases, including PubMed, Scopus, Web of Science, and Google Scholar.The search strategy included combinations of keywords such as “COVID-19,” “Long COVID,” “post-COVID syndrome,” “oncology,” “cancer risk,” “carcinogenesis,” “immune dysregulation,” and “inflammation.” Only peer-reviewed articles published in English between 2020 and 2025 were considered for inclusion in this review.Inclusion criteria were defined as follows:

-Studies investigating the long-term biological effects of COVID-19

-Articles addressing immune, molecular, or cellular mechanisms linked to carcinogenesis

-Clinical studies reporting cancer incidence or progression after SARS-CoV-2 infection

-Review articles providing updated scientific insights into post-COVID complications

Exclusion criteria included non-peer-reviewed sources, case reports with insufficient clinical data, and studies unrelated to oncological outcomes.

The selected literature was analyzed qualitatively, focusing on key mechanisms such as immune dysregulation, chronic inflammation, oxidative stress, DNA damage, and epigenetic modifications. Particular attention was given to studies discussing the interaction between viral infection and tumor microenvironment changes.Data synthesis was performed through comparative analysis of findings across different studies to identify consistent patterns and hypotheses regarding post-COVID oncological risks. No primary patient data were collected; therefore, ethical approval was not required for this study.

Results

The reviewed literature indicates that infection with COVID-19 is associated with multiple long-term biological alterations that may potentially contribute to oncological risk. Across different studies, several consistent pathological patterns were identified.

1. Immune dysregulation

A significant number of studies reported persistent immune system imbalance in post-COVID patients. This includes reduced T-cell function, altered cytokine profiles, and prolonged activation of pro-inflammatory pathways. Such immune dysfunction may weaken tumor immune surveillance, increasing susceptibility to malignant transformation.

2. Chronic inflammation

One of the most frequently reported findings is the presence of sustained low-grade inflammation after SARS-CoV-2 infection. Elevated levels of inflammatory markers such as IL-6, TNF-α, and CRP were observed in post-COVID conditions. Chronic inflammation is widely recognized as a key factor in carcinogenesis due to its role in promoting DNA damage and cellular proliferation.

3. Oxidative stress and DNA damage

Several studies highlight increased oxidative stress in infected individuals. Excess reactive oxygen species (ROS) may induce DNA strand breaks, genomic instability, and mutations, all of which are critical steps in cancer development.

4. Epigenetic and cellular alterations

Evidence suggests that COVID-19 may induce epigenetic modifications, including changes in DNA methylation and histone regulation. These alterations can disrupt normal gene expression, particularly in genes involved in cell cycle regulation and apoptosis.

5. Healthcare disruption and delayed diagnosis

Apart from biological mechanisms, a large number of studies reported indirect effects of the pandemic on cancer outcomes. Delayed screening, reduced hospital visits, and interrupted diagnostic services contributed to later-stage cancer detection in many patients.

6. Increased vulnerability in cancer patients

Patients with pre-existing malignancies were found to be at higher risk of severe COVID-19 outcomes, including higher mortality rates and complications due to immunosuppression and treatment interruptions.Overall, the literature suggests that post-COVID biological changes combined with healthcare system disruptions may create conditions that could potentially influence cancer development and progression. However, most findings remain observational, and direct causal relationships require further investigation.

Conversation

Results from the literature review indicate that COVID-19 infection may have long-term biological and clinical effects that go beyond the acute stage of infection. There is currently little direct causative evidence connecting COVID-19 to carcinogenesis, however several indirect processes have been suggested that could raise the risk of cancer.

Persistent immunological dysregulation is one of the most significant pathways. Long-term changes in both innate and adaptive immunity, such as T-cell fatigue and aberrant cytokine production, are frequently seen in post-COVID patients. The body may be less able to recognize and eradicate altered cells as a result of this compromised immune surveillance, which raises the possibility of tumor growth.

Another important factor in this process is chronic inflammation. Pro-inflammatory cytokines like TNF-α and IL-6 that are elevated over time produce a milieu that encourages angiogenesis, prevents apoptosis, and favors cellular proliferation. These mechanisms are well-known characteristics of the biology of cancer.

Furthermore, genomic instability may be exacerbated by oxidative stress brought on by viral infection. DNA, proteins, and cellular membranes can be harmed by reactive oxygen species, which might result in mutations that could start or accelerate malignant transformation. Additionally, new research suggests that SARS-CoV-2 infection may cause epigenetic modifications, which can modify the patterns of gene expression related to tumor suppression and cell cycle regulation.

Conclusion

According to the existing literature, COVID-19 infection may result in long-term biological changes such as immunological dysregulation, chronic inflammation, oxidative stress, and epigenetic modifications. Although these processes may play a role in carcinogenesis, direct causal evidence is sparse. Indirect consequences, such as postponing cancer detection during the pandemic, may have a more immediate impact on oncology outcomes. Overall, further long-term research is needed to elucidate the connection between COVID-19 and cancer risk.

Recommendations

Long-term cohort studies should be done to assess post-COVID oncology outcomes.

Regular cancer screening programs should be strengthened, particularly for high-risk populations.

Patients with persisting symptoms following COVID should be monitored on a continuing basis.

Further research is required to explain the molecular pathways between COVID-19 and carcinogenesis.

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