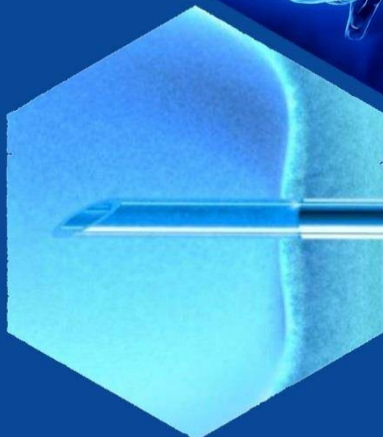
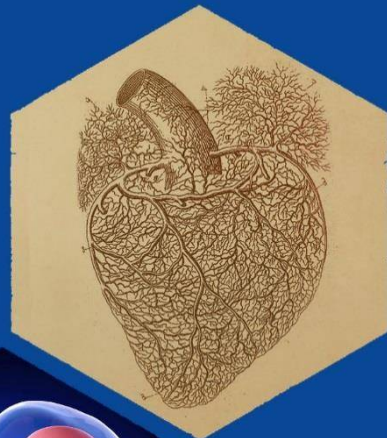


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TRANSFORMATION OF MEDICAL PRACTICE AND HEALTHCARE INFRASTRUCTURE DURING THE FIVE-YEAR COVID-19 GLOBAL CHALLENGE



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Abstract: This review synthesizes global healthcare data from 2020–2025, focusing on the clinical management of high-risk groups such as pregnant women and hematological patients. It evaluates systemic adaptations, including Russia’s three-tier emergency response and the shift toward decentralized clinical trials. The study highlights the impact of viral evolution from Delta to Omicron and addresses rising antimicrobial resistance. Findings emphasize that future biosecurity depends on multidisciplinary collaboration and health equity.

Keywords: COVID-19, healthcare evolution, high-risk groups, biosecurity, clinical outcomes.

ПЯТИЛЕТНИЙ ПУТЬ ТРАНСФОРМАЦИИ МЕДИЦИНЫ И АДАПТАЦИИ СИСТЕМ ЗДРАВООХРАНЕНИЯ К ПАНДЕМИИ COVID-19

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Аннотация: В обзоре обобщены данные о развитии здравоохранения в период 2020–2025 гг. Особое внимание уделено ведению групп высокого риска: беременных женщин и пациентов с гематологическими заболеваниями. Рассматриваются системные изменения, включая российский опыт трехуровневой экстренной помощи и переход к децентрализованным клиническим исследованиям. Анализируется влияние эволюции вируса от штамма Delta до Omicron и проблема роста антибиотикорезистентности.

Сделан вывод, что будущая биологическая безопасность зависит от междисциплинарного взаимодействия и обеспечения равенства в доступности медицинской помощи.

Ключевые слова: COVID-19, эволюция здравоохранения, группы высокого риска, биологическая безопасность, клинические исходы.

ТИББИЁТ ТРАНСФОРМАЦИЯСИ ВА СОҒЛИҚНИ САҚЛАШ ТИЗИМЛАРИНИНГ COVID-19 ПАНДЕМИЯСИГА МОСЛАШИШИНИНГ БЕШ ЙИЛЛИК ЙЎЛИ

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Аннотация: Ушбу шарҳда 2020–2025 йиллар давомида соғлиқни сақлаш соҳасининг ривожланишига оид маълумотлар умумлаштирилган. Юқори хавф гуруҳлари: ҳомиладор аёллар ва гематологик касалликларга чалинган беморларни бошқаришга алоҳида эътибор қаратилган. Тизимли ўзгаришлар, жумладан, Россиянинг уч босқичли шошилинч ёрдам тажрибаси ва децентрализациялашган клиник тадқиқотларга ўтиш масалалари кўриб чиқилган. Вируснинг Delta штаммидан Omicron штаммигача бўлган эволюцияси таъсири ва антибиотикларга чидамлилиқ (резистентлик) ортиши муаммоси таҳлил қилинган. Келажақдаги биологик хавфсизлик фанлараро ҳамкорлик ва тиббий ёрдамдан фойдаланишда тенгликни таъминлашга боғлиқ эканлиги ҳақида хулоса чиқарилган.

Калит сўзлар: COVID-19, соғлиқни сақлаш эволюцияси, юқори хавф гуруҳлари, биологик хавфсизлик, клиник натижалар.

INTRODUCTION

The spread of the novel coronavirus infection, SARS-CoV-2, has emerged as the most extensive and tragic challenge to the global human community in the 21st century. What began as a localized outbreak in late 2019 rapidly transformed into a global crisis, affecting every facet of human life—from national economies to the fundamental principles of healthcare organization. On January 30, 2020, the World Health Organization (WHO) officially designated the situation as a "Public Health Emergency of International Concern," and by March 11 of the same year, the world entered a pandemic phase [1].

Statistical data accumulated by early 2025 allows for a comprehensive assessment of the colossal scale of loss. The number of confirmed infection cases worldwide has exceeded 777 million; however, these figures represent only the tip of the iceberg. A

more objective indicator is "excess mortality," which encompasses not only direct victims of the virus but also indirect losses caused by healthcare system strain, delays in diagnosis, and the disruption of treatment for chronic non-communicable diseases. Experts estimate that during the 2020–2021 period alone, the total number of deaths associated with the pandemic reached 19 million, placing COVID-19 among the deadliest epidemics in human history [1, 2].

Although WHO Director-General Tedros Adhanom Ghebreyesus announced the end of the emergency phase of the pandemic on May 5, 2023, the scientific community emphasizes that the virus has not disappeared; it has transitioned into an endemic pathogen, continuing to mutate and present new challenges [3]. The periodic emergence of new variants, such as Delta and Omicron, along with their sub-lineages, demonstrates the high variability of viral load and the pathogen's ability to evade immune responses [4, 5]. This necessitates a continuous analysis of accumulated experience to develop future biosecurity strategies.

Of particular scientific and practical significance is the study of the pandemic's impact on vulnerable populations. The global crisis exposed critical deficiencies in protecting immunosuppressed individuals, patients with oncological and hematological profiles, and pregnant women [6, 7, 8, 9, 10]. Research indicates that the pandemic provoked not only a biological but also a systemic crisis in healthcare, manifested in a sharp decline in the screening rates of non-communicable diseases and the transformation of clinical trial protocols worldwide [11, 12]. In several regions, this led to a significant increase in mortality from pathologies not directly related to the virus due to limited access to routine high-tech care [13, 14].

During this period, the Russian Federation became a platform for seeking unique organizational solutions. The creation of a three-tier emergency medical care system, the rapid repurposing of multi-profile hospitals, and the implementation of digital patient monitoring technologies made it possible to minimize losses during critical periods [15, 16, 17, 18]. Studying the Russian experience within the context of global trends allows for a comprehensive understanding of the mechanisms of medical adaptation to emergency conditions.

The aim of this literature review is to systematically analyze the evidence-based scientific framework formed over the five-year period (2020–2025). The paper examines key epidemiological aspects and clinical features of the infection in high-risk groups, and analyzes the effectiveness of therapeutic approaches and organizational measures. Special attention is paid to the "lessons learned" from the pandemic—rethinking public health strategies to prepare for potential future infectious threats [17, 18].

Maternal and Perinatal Health in the Context of SARS-CoV-2

The impact of SARS-CoV-2 on pregnant women has been a subject of intense global scrutiny. Early in the pandemic, it was hypothesized that the physiological changes of pregnancy—including altered lung volumes and a shifted immune response—might predispose this group to more severe respiratory complications [19]. Subsequent large-scale studies confirmed that while pregnant individuals do not necessarily have a higher susceptibility to contracting the virus, they are at a

significantly higher risk for severe illness, requiring mechanical ventilation and admission to intensive care units (ICUs) [20].

According to the findings of Rasmussen SA et al. (2020, 2022), the hypercoagulable state inherent in pregnancy, combined with the systemic inflammatory response triggered by COVID-19, creates a synergistic risk for thromboembolic events [30]. In the Russian Federation, research led by Belokrinskaya T.E. highlighted that maternal mortality was predominantly associated with late-stage presentations and the presence of comorbid conditions such as obesity and gestational diabetes [5]. Furthermore, the risk of preterm birth was found to be twice as high in infected patients compared to the general population, often due to medical necessity rather than spontaneous labor [21].

A critical area of concern remains the possibility of vertical transmission. While initial reports suggested that the placental barrier was largely effective, more recent evidence provided by Vivanti AJ et al. (2020) documented definitive cases of transplacental transmission, characterized by neonatal viremia and placental inflammation [13]. Long-term follow-up studies in 2024–2025 have begun to explore the "post-COVID" health trajectories of children born to infected mothers, focusing on neurodevelopmental and immunological outcomes, which underscores the need for continued pediatric surveillance [7, 14].

Hematological Malignancies and Immunocompromised States

Patients with hematological malignancies (HM) represent one of the most fragile cohorts in the face of COVID-19. The underlying disease-driven immunosuppression, exacerbated by cytotoxic chemotherapy or monoclonal antibody treatments (such as anti-CD20 therapy), severely impairs the host's ability to clear the virus [20].

Clinical data indicates that mortality rates among HM patients were disproportionately high during the early waves of the pandemic. Garcia-Suarez J. (2020) reported that the severity of COVID-19 in these patients was influenced by the specific type of malignancy, with the highest risks observed in those with acute myeloid leukemia and aggressive lymphomas [20].

The introduction of mass vaccination brought only partial relief to this group. As highlighted in 2025 studies by Caracciolo D. and Sherman AC., patients with hematological cancers often exhibit a suboptimal serological response to mRNA and viral vector vaccines [18, 19]. This "immune escape" phenomenon is particularly evident in those undergoing B-cell depleting therapies, where the absence of a robust antibody response necessitates the use of prolonged antiviral treatments and prophylactic administration of long-acting monoclonal antibodies [21]. These findings have led to a paradigm shift in hematological care, emphasizing the transition from universal protocols to highly individualized management strategies that prioritize viral prevention alongside oncological treatment [21, 22, 23].

The "Syndemic" Nature of COVID-19 and Global Inequality

The impact of COVID-19 cannot be viewed merely as a biological phenomenon; it must be understood as a "syndemic"—a term that describes the interaction between a viral pathogen and pre-existing social and economic inequalities. As noted in the analysis of global health trends [24, 25], the pandemic disproportionately affected

populations with limited access to resources. In many regions, the surge in COVID-19 cases led to a "crowding out" effect, where resources for maternal health, emergency surgery, and chronic disease management were diverted to infectious disease wards.

According to World Health Organization reports (2025), the disruption of routine services for non-communicable diseases (NCDs) resulted in a secondary wave of mortality that, in some territories, rivaled the direct mortality from the virus itself [29]. Ala A. et al. (2021) demonstrated that socioeconomic determinants, such as housing density and employment in "essential" low-wage sectors, were stronger predictors of mortality than age or genetics in certain urban populations [23, 24, 25].

Oncological Care: The Crisis of Delayed Diagnosis

The suspension of elective medical services hit the field of oncology particularly hard. For almost two years, screening programs for breast, colorectal, and cervical cancers were either halted or significantly curtailed to reduce the risk of nosocomial transmission.

Research indicated that even a six-month delay in screening could result in a significant "stage shift," where patients who could have been treated with curative intent are instead diagnosed at palliative stages. This lag in diagnosis represents a "ticking time bomb" for healthcare systems, which are now facing a surge in advanced-stage malignancies that require more intensive and costly treatments than would have been necessary in 2019 [26, 27].

Methodological Revolution in Clinical Trials

The pandemic served as a catalyst for a radical transformation in the way medical science is conducted. Before 2020, clinical trials were heavily centralized, requiring patients to make frequent visits to specialized research centers. Lockdown measures made this model obsolete overnight, threatening the continuity of thousands of life-saving trials [4].

McDonald K. (2023) highlighted that screening rates for clinical trials plummeted by over 70% in the first half of 2020 [6]. To save the research pipeline, regulatory bodies and pharmaceutical companies adopted "Decentralized Clinical Trials" (DCTs). This shift involved: **Telemedicine:** Replacing in-person consultations with virtual assessments; **Remote Monitoring:** Utilizing wearable devices to track patient vitals in real-time; **Direct-to-Patient Logistics:** Shipping investigational medicinal products directly to patients' homes.

As emphasized by Saini KS. (2020) and Watson OJ. (2022), these adaptations not only ensured the survival of clinical research during the pandemic but also laid the groundwork for a more inclusive and efficient research ecosystem in the future [8, 9]. The ability to conduct "virtual" trials allows for the recruitment of participants from geographically remote or underserved areas, potentially reducing the historical bias in clinical data.

The Digital Leap and Telehealth Integration

The necessity of social distancing accelerated the adoption of digital health tools by at least a decade. In many countries, including the Russian Federation, the rapid implementation of digital monitoring platforms allowed for the home-based management of mild and moderate cases, preserving hospital beds for those in critical

condition [28, 30]. However, this digital leap also exposed the "digital divide," where elderly patients without reliable internet access were at risk of being excluded from the new healthcare landscape – a challenge that remains a priority for public health policy in 2025 [32, 33].

Organizational Strategies and Emergency Response Systems The experience of the Russian Federation in countering the SARS-CoV-2 pandemic represents a unique example of large-scale mobilization of a state healthcare system. One of the key pillars of this mobilization was the creation of a three-tier emergency medical care system, described in detail in the works of Teplov V.M. and colleagues [28]. This model allowed for the effective distribution of patient flows depending on the severity of their condition, which was critically important in the context of an explosive increase in morbidity. At the first level, primary sorting and care for patients with mild forms were carried out, while the second and third levels provided high-tech support and intensive care for the most severe patients. Ulumbekova G.E. emphasizes that such centralization of resource management became a decisive factor in reducing mortality during peak periods of the pandemic [15].

Hospital Adaptation and Digital Integration The transformation of multi-profile hospitals into specialized infectious disease hospitals required not only the restructuring of engineering networks but also a change in the entire logistics of care. Vechorko V.I., using the example of the largest Moscow clinics, demonstrated the effectiveness of dividing hospitals into "red" and "clean" zones, which minimized the risks of nosocomial infection [15]. Parallel to the physical reconstruction of hospitals, digital technologies were implemented. The use of telemedicine platforms and remote monitoring systems allowed doctors to control the condition of thousands of patients undergoing home treatment and promptly make decisions on hospitalization if indicators worsened. This digital breakthrough, recorded in studies from 2022–2024, laid the foundation for the future digitalization of the entire Russian medical system [28, 34, 35].

Evolution of Viral Variants and Diagnostic Challenges The clinical picture of the disease in Russia underwent significant changes as the dominant genovariants of the virus changed. Sharavina Yu.A. and co-authors conducted a comparative analysis of the course of infection caused by the Delta and Omicron variants [34]. Studies showed that the Delta variant was characterized by more severe lung tissue damage and a high frequency of cytokine storm, while Omicron was distinguished by increased contagiousness but a milder course in vaccinated individuals. Nevertheless, as Orlov A.A. notes in 2024 works, the variability of viral load even within a single strain created serious difficulties for standard diagnostics, requiring constant improvement of test systems and biomaterial sampling protocols [35].

Pharmacotherapeutic Approaches and Multimodal Therapy Drug therapy for COVID-19 in Russia evolved along with the accumulation of evidence. At the beginning of the pandemic, emphasis was placed on the empirical use of antivirals, but over time, the focus shifted toward pathogenetic treatment. Brovko M.Yu. describes a successful experience using tofacitinib in patients with moderate disease, which prevented the development of severe respiratory distress syndrome in a significant

portion of patients [21]. An important aspect was the fight against complications. Korkhmazov V.T. draws attention to the specifics of mortality among elderly patients (over 75 years old), indicating that polymorbidity required a multimodal approach combining anticoagulant support, glycemia correction, and prevention of bacterial superinfections [22].

The Problem of Antibiotic Resistance in the Post-Pandemic Era One of the most alarming problems that emerged as a consequence of the pandemic is the rise of antibiotic resistance. Mokhov A.S., in his 2022 studies, emphasizes that the massive and often unjustified use of broad-spectrum antibiotics during the first waves of the pandemic led to the selection of resistant strains of microorganisms [17]. This created a long-term threat to intensive care units, where doctors increasingly face pan-resistant infections. Rethinking the role of the microbiota and implementing antimicrobial stewardship programs have become essential lessons that must be considered when preparing for future epidemic threats. This Russian experience confirms the global trend toward the need for stricter regulation of the turnover of antimicrobial drugs [17, 21, 22].

Rethinking Lessons from Previous Pandemics As the global community reflects on the challenges posed by SARS-CoV-2, significant parallels have been drawn with previous infectious disease outbreaks, most notably the HIV/AIDS pandemic. According to Auerbach JD. et al. (2023), the fundamental lessons derived from decades of HIV research—specifically the need to anticipate health inequalities and create enabling environments—were often overlooked in the early stages of the COVID-19 response [27]. The researchers emphasize that for future pandemic preparedness, it is vital to move beyond purely biomedical interventions and address the social, political, and economic drivers of disease [26].

Addressing Health Disparities and the "Social Gradient" The pandemic highlighted a stark "social gradient" in health outcomes. Research conducted between 2020 and 2025 by international groups has shown that inequality manifested both within countries and between them [25, 32]. Factors such as overcrowded housing, reliance on manual labor, and lack of universal health coverage acted as catalysts for viral spread. As noted by Ezezika O. et al. (2024), the "vaccine divide" and the uneven distribution of diagnostic tools further polarized global health, suggesting that a multidisciplinary effort is required to bridge these gaps before the next pathogen emerges [25].

Interdisciplinary Collaboration and Biosecurity Future preparedness depends on the ability of polarized viewpoints to find common ground. Fauci AS. (2025) and Tollefson D. (2025) argue that the rapid evolution of viral variants will continue to present challenges for the development of vaccines and therapeutics [26, 33]. Therefore, the next generation of public health policy must utilize interdisciplinary data, combining microbiology, epidemiology, and behavioral science. As emphasized in the closing sections of the analyzed documents, fostering a dialogue between various scientific domains is not just an academic exercise but a necessity for national and international biosecurity [27, 33].

CONCLUSION.

The COVID-19 pandemic has served as a transformative catalyst for global medicine, revealing both the vulnerabilities of healthcare systems and their capacity for rapid innovation. This review highlights that while the acute phase has transitioned into an endemic state, the long-term management of high-risk groups—including pregnant women, oncology patients, and the elderly—remains a critical priority. The evolution of the virus from Delta to Omicron necessitated a continuous adaptation of diagnostic and therapeutic protocols, as demonstrated by the successful integration of pathogenetic treatments and digital monitoring. Ultimately, the pandemic underscores the urgency of addressing antimicrobial resistance and socioeconomic disparities. Future preparedness must be rooted in multidisciplinary collaboration and global equity, ensuring that the lessons learned from 2020–2025 are translated into resilient, proactive biosecurity strategies.

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