COVID-19 and Human Health: Exploring the Complex Interplay of Infection, Intervention, and Immunization

Dr.Mohankumar L[1], Shivashankar Govindan[2], Simonti Basak Sithi[3], Atem Edward Machok Atem[4]
[1,2,3,4]*Acharya & BM Reddy college of Pharmacy*

Abstract: The COVID-19 pandemic has exerted a profound influence on global health, affecting individuals physically, mentally, and socially. This review aims to synthesize current evidence on the multifaceted health impacts of COVID-19, including both the direct consequences of SARS-CoV-2 infection and the indirect effects of public health interventions such as lockdowns. Longitudinal studies have reported significant declines in physical health, exacerbation of chronic conditions, and a rise in mental health issues, notably anxiety and depression, during the early phases of the pandemic. Concurrently, several positive public health outcomes were observed, such as improved hygiene behaviors, reduced rates of respiratory infections, and increased use of telemedicine and digital health technologies.

A major focus of the pandemic response has been the development and global deployment of COVID-19 vaccines. While generally safe and effective, vaccines have been associated with rare adverse events. This review highlights the occurrence of cardiovascular complications, hematologic abnormalities including various forms of anemia, and autoimmune conditions like alopecia areata in certain individuals following vaccination. Specific populations, such as pregnant women and individuals with nutritional deficiencies or autoimmune predispositions, may require careful monitoring and follow-up.

This review underscores the dual nature of the pandemic—as both a public health threat and a driver of systemic healthcare transformation. It calls for a balanced approach that maximizes the benefits of vaccination and pandemic control while ensuring continued research, patient-centered care, and long-term health system resilience.

INTRODUCTION

The COVID-19 pandemic, caused by the novel coronavirus SARS-CoV-2, emerged in late 2019 and rapidly evolved into an unprecedented global public health crisis. Beyond its profound impact on healthcare systems, economies, and societies at large, the pandemic has significantly affected both physical and mental health across populations worldwide. Numerous studies have documented increased incidences of chronic illness, sleep disturbances, and psychological distress, especially during lockdowns and the early stages of the outbreak. These adverse effects were not solely due to the viral infection but also stemmed from stringent containment policies and public health interventions. At the same time, the pandemic catalyzed several positive changes in public health awareness, hygiene practices, and digital transformation in healthcare. It enhanced infection control measures and prompted the rapid adoption of telemedicine, AI technologies, and health behavior modifications such as reduced smoking and improved nutrition. Central to pandemic mitigation was the accelerated development and deployment of COVID-19 vaccines, which have significantly reduced morbidity and mortality [1,2]. Despite the substantial benefits, vaccine deployment also raised questions about safety and adverse reactions. Reports have emerged documenting a spectrum of rare but notable side effects, including cardiovascular events, hematologic abnormalities such as anemia, and autoimmune reactions like alopecia areata. Studies also highlight the need for vigilant pharmacovigilance and patient-specific risk assessment, especially in vulnerable populations such as pregnant women or individuals with predisposing conditions [3].

Given the multifaceted and evolving nature of COVID-19's impact, it is essential to examine both the benefits and potential adverse effects of vaccination and public health responses. This review explores the comprehensive health implications of COVID-19—from general well-being to specific conditions like anemia and alopecia—while emphasizing the importance of balancing disease control with long-term health outcomes and individual safety.

The impact of covid-19 on physical and mental health

In Chinese cities the individual-level health impacts of COVID-19 examined by using a difference-in-differences (DiD) approach with longitudinal data to compare health outcomes before and during the early stages of the pandemic. By leveraging variations in infection and death rates across cities, the researchers found a significant decline in self-perceived physical health, increased reports of chronic illness, worsening sleep quality, and a rise in depressive symptoms. These adverse effects remained consistent across different measures of exposure and even when excluding Wuhan. The findings indicate that physical health deterioration was mainly driven by the pandemic shock itself, while mental health decline was more closely linked to anti-contagion policies, such as lockdowns. This highlights the dual burden of the pandemic—not only from the virus but also from public health interventions. The study underscores the need for integrated support systems, particularly mental health services, during and after crises. [3,4] It also provides valuable insights for future emergency preparedness. The multifaceted impact of COVID-19 emphasizes the importance of balancing disease control with individual well-being.[5]

Positive Impacts of the COVID-19 Pandemic and Public Health Measures on Healthcare

Despite the significant challenges brought by the COVID-19 pandemic, this review identifies several positive outcomes within the healthcare sector. Public health awareness improved, with better hygiene practices, widespread mask usage, and increased responsiveness to health advisories.[6] Lockdowns led to a drop in respiratory infections like influenza and fewer trauma-related hospital admissions. Maternal and fetal health outcomes improved, possibly due to reduced exposure to infections and heightened health consciousness. [7,8] The pandemic also encouraged many individuals to reduce or quit smoking. More time at home brought greater attention to mental, relational, and sexual health.[9] Importantly, the crisis accelerated healthcare innovation, including the adoption of AI, robotics, and telehealth. These changes reflect a shift toward more proactive, tech-enabled, and holistic healthcare systems. Overall, the pandemic served as a catalyst for long-term improvements in health behavior and system resilience. Recognizing these gains is crucial for strengthening preparedness for future crises.[10]

Adverse reactions of different COVID-19 vaccines among healthcare professionals

This qualitative study explored healthcare professionals' (HCPs) perceptions, attitudes, motivations, expectations, and experiences with COVID-19 vaccines in Mosul, Iraq. Through face-to-face semi-structured interviews with 25 HCPs, the researchers conducted a thematic analysis to gain deeper insight into vaccine-related views.[11] Participants generally perceived vaccines as essential tools in controlling the pandemic and were primarily motivated by scientific evidence and public health considerations. While initial expectations included concerns about severe side effects, most reported only mild to moderate reactions, with similar outcomes after both doses. [12,13] Variations in opinions about vaccine safety and efficacy were linked to the type of vaccine and available data. Notably, HCPs displayed resilience against misinformation and relied on scientific knowledge when making vaccination decisions.[14] The study concluded that adverse reactions were milder than anticipated, reinforcing HCPs' confidence in vaccines. Acceptance was firmly rooted in evidence-based reasoning. This highlights the crucial role of informed healthcare professionals in promoting vaccine uptake and public trust in immunization efforts.[15]

Cardiovascular events following coronavirus disease 2019 vaccination in adults

This large population-based cohort study from Sweden assessed the risk of various cardiovascular and cerebrovascular events following COVID-19 vaccination, using nationwide health registry data. The study confirmed a rare but elevated risk of myocarditis and pericarditis after mRNA vaccination, particularly in young males.[16] However, it found no consistent evidence linking COVID-19 vaccines to increased risks of myocardial infarction, ischemic stroke, hemorrhagic stroke, or venous thromboembolism.[17,18] These findings suggest that most major cardiovascular and cerebrovascular complications are not significantly associated with the vaccines. The data strongly support the continued use of COVID-19 vaccines, highlighting their benefits in preventing severe illness and death. The slight increase in myocarditis and pericarditis is outweighed by the overall public health advantages of vaccination.[19]These results reinforce earlier safety findings and provide reassurance about vaccine safety in the general adult

population. Public health strategies promoting vaccination remain well-founded. The study contributes important real-world evidence to vaccine safety surveillance.[20]

COVID-19 vaccination and birth outcomes of 186,990 women vaccinated before pregnancy

Here's a concise summary of the study titled "COVID-19 vaccination and birth outcomes of 186,990 women vaccinated before pregnancy: an England-wide cohort study" published in The Lancet Regional Health – Europe: This study examined whether receiving a COVID-19 vaccine within 12 months before conception affected pregnancy and birth outcomes, using linked electronic health records from nearly 187,000 pregnancies in England.[21] It found that pre-pregnancy vaccination was associated with a lower risk of very or extremely preterm birth, small-for-gestational-age term babies, and stillbirth—especially when mRNA vaccines were used. [22,23] Notably, mRNA vaccines did not increase the risk of venous thromboembolism (VTE), while viral-vector vaccines showed a modestly higher VTE risk. Overall, mRNA vaccines were associated with better maternal and neonatal outcomes and demonstrated a more favorable safety profile. Despite the increased VTE risk, viral-vector vaccines still showed benefits compared to no vaccination.[24] The findings support vaccination prior to pregnancy as a protective factor for birth outcomes. These results reinforce the public health recommendation to vaccinate women of reproductive age. This study was funded by major UK research bodies and health institutions.[25]

Covid-19 impact in relation to anemia

COVID-19 (Coronavirus Disease 2019) is a contagious illness caused by the SARs-CoV-19. It was reported in Wuhan, China, in Dec 2019 and later the virus rapidly spread globally hence prompt the WHO to declare it a global pandemic in Match 2020. [26]. The global rollout of COVID-19 vaccines has been instrumental in controlling the pandemic.The COVID-19 pandemic has led to widespread vaccination efforts to mitigate the virus's impact. .COVID-19 vaccines have significantly reduced morbidity and mortality associated with SARS-CoV-2. While generally safe, rare adverse events have been reported, including hematologic abnormalities (Anemia). This review examines the effects of COVID-19 vaccines on anemia, focusing on clinical presentations before and after vaccination.

Anemia is a condition characterized by a decrease in the number of red blood cells (RBCs) or hemoglobin concentration below the normal reference range, resulting in a reduced oxygen-carrying capacity of the blood. It affects approximately 1.62 billion people globally, making it a major public health concern, especially in developing countries [WHO 2008]. Clinical manifestations of anemia vary depending on severity and rate of onset, but commonly include fatigue, pallor, shortness of breath, and reduced exercise tolerance. [27]

Anemia following COVID-19 vaccination is a rare but reported adverse event. The etiology is multifactorial and mostly linked to immune-mediated mechanisms rather than direct effects of the vaccine components. Some causes include, (i) Vaccine-Induced Immune Thrombotic Thrombocytopenia (VITT): Although primarily characterized by thrombocytopenia and thrombosis, VITT can cause secondary anemia due to hemolysis or bleeding complications. VITT is an immune reaction to platelet factor 4 (PF4) triggered by adenovirus vector vaccines. This immune activation can indirectly lead to anemia (Greinacher et al., 2021).[28] (ii) Autoimmune Hemolytic Anemia (AIHA) AIHA is a rare occurrence that's characterized by the immune system attacking red blood cell surface antigens, leading to an acquired hemolysis. This reduces the lifespan of the Red Blood Cells (RBC) from the normal 120 days.

Several case reports have documented AIHA following COVID-19 vaccination. In a reported case, a middle-aged woman with no known autoimmune disease was diagnosed with AIHA two months after receiving the First Dose of COVISHIELD vaccine (Oxford-AstraZeneca COVID-19 vacine). The patient received oral steroids and blood transfusion and later discharged from the hospital after 21 days. No relapse was reported after a six months monitoring. Post-vaccination surveillance is crucial, as early identification and intervention can improve patient outcomes. Continued research into the mechanisms underlying vaccine-induced AIHA will help refine vaccination strategies and ensure patient safety. [29] The first-line treatment for AIHA typically involves corticosteroids, most commonly *prednisone*. These

work by suppressing the immune system, thereby reducing antibody production and the destruction of red blood cells. Corticosteroids achieve a response in approximately 70–85% of AIHA patients. The usual starting dose is 1 mg/kg/day of prednisone. [30][31] In cases of severe anemia or symptomatic patients, red blood cell transfusions may be necessary to stabilize the patient, despite the potential risk of ongoing hemolysis. Cross-matching can be challenging due to the presence of autoantibodies. Transfusion should be used judiciously in AIHA and only when absolutely necessary, typically under close monitoring.[32] Long-term follow-up is essential in AIHA to monitor for relapse or steroid dependence. In this case, the patient was followed up for six months without relapse, indicating successful management.[69] Recurrences have been reported after treatment with Some patients experiencing the relapses, particularly those with underlying conditions or severe initial cases.[33,34,35,36,37] (ii) Nutritional Anemia is a condition characterized by a reduction in red blood cell count or hemoglobin concentration due to inadequate intake, absorption, or utilization of nutrients essential for erythropoiesis. The most common forms are iron deficiency anemia (IDA), folate deficiency anemia, and vitamin B12 deficiency anemia. Iron deficiency anemia is the most prevalent and is often linked to poor dietary intake, chronic blood loss, or increased physiological demands, such as during pregnancy or adolescence. [33,38] A study published in *The Lancet Global Health* (Kassebaum et al., 2014) estimates that iron deficiency is responsible for about 50% of all anemia cases worldwide. The World Health Organization (WHO) also highlights that anemia affects over 1.6 billion people globally, with the highest burden among women of reproductive age and young children. Inadequate iron intake, low bioavailability of dietary iron (especially in plant-based diets), and parasitic infections are major contributing factors in developing countries.[34] Effective interventions include dietary diversification, iron and folic acid supplementation, food fortification, and infection control measures. A meta-analysis by Peña-Rosas et al. (2015), published in the *Cochrane Database of Systematic Reviews*, confirmed the efficacy of iron supplementation in reducing the prevalence of anemia, particularly in pregnant women.[39,40] Overall, addressing nutritional anemia requires a multi-sectoral approach involving public health, agriculture, and education to improve dietary habits and reduce the burden of micro-nutrient deficiencies.

A large Korean cohort study found an increased incidence of nutritional anemia in vaccinated individuals compared to non-vaccinated controls, particularly within the first three months post-vaccination. [41] Based on this large Korean population-based cohort study, the incidence rates of nutritional anemia together were found to be significantly higher in vaccinated individuals compared to non-vaccinated individuals. The study also noted that mRNA vaccines were associated with a higher risk of nutritional anemia and compared to viral vector vaccines, while the risk of coagulation defects was similarly increased in both vaccine types. The study also highlights that Women had a higher risk of nutritional anemia than men as well as The risk of nutritional anemia also increased with age. Further research is needed to fully understand the mechanisms behind these hematologic abnormalities following COVID-19 vaccination and to assess long-term outcomes.[42]

RELATIONSHIP BETWEEN COVID-19 VACCINES AND HAIR LOSS (ALOPECIA AREATA)

The outbreak lead to development of vaccines such as Pfizer-BioNtech, Johnson & Johnson and Moderna which reduced the severe cases and deaths, through widespread vaccination. [42] These vaccines have reduced the morbidity and mortality associated with SARS-Cov-2 and are generally safe, but some rare adverse events were reported.[43] COVID-19 Vaccination has been linked with difference patterns of hair loss, such as Alopecia Areata (AA) and its more severe forms like Alopecia Totalis and Alopecia Universalis.[44],[45]. Alopecia areata (AA) is a T cell-mediated autoimmune condition marked by recurrent episodes of circular, non-scarring hair loss. It can develop at any age in genetically predisposed individuals, often triggered by unidentified environmental factors, with a lifetime prevalence estimated at 2.1%.[46]. It has noted that there is rise in the incidences of AA after COVID-19 vaccination. As per the Centers for Disease Control and Prevention (CDC) in the United States, 116 cases of AA were reported following the administration of Pfizer/BioNTech and Moderna vaccines. Similarly, in the United Kingdom, 154 cases were documented, primarily after Pfizer/BioNTech and AstraZeneca vaccinations. The

onset of AA varies i.e. occurring from just few days after vaccination to several weeks post-completion of the vaccine series. [47]

In a reported case by Matsuda et al. It describes a 37-year-old woman who developed a persistent low-grade fever (37.2°C) on the 13th day after the first dose of Pfizer-BioNtech Vaccine. 22 days later after first Dose she developed coin-sized hair loss and later widely spread within a week.[48] The patient responded well to Corticosteroid therapy and there was a significant hair regrowth by 310 days after vaccination.[48,49,50,51,52] In another report, Ganjei et al. Presented two cases of hair loss following the Oxford/AstraZeneca vaccine. Of the two patients, one did have a prior history of Alopecia Areata (AA). [93] One patient was a 23-year-old woman who developed a localized hair loss 1-weak after receiving the first Dose of Oxford/AstraZeneca vaccine and later on a test performed confirmed alopecia areata leading to immediate treatment with Betamethasone 0.1% and pimecrolimus 0.1% creams. However, after 3-weeks, she had a total hair loss on her scalp and eyebrows. Lab tests were mostly normal except for elevated anti-TPO levels (Anti-Thyroid Peroxidase) and biopsy confirmed the diagnosis. She was treated with systemic Corticosteroids for 3-months, with future plans to taper her medications after hair regrowth. (Tofacitinib was offered as an alternative but declined due to cost.) Another patient was a 26-year-old woman with a history of alopecia araeta (AA) who developed a generalized scalp hair loss 2-weeks after receiving the second Dose of Oxford?AstraZeneca COVID-19 vaccine. Initially, only patchy alopecia was noted but the condition later progressed to diffuse hair loss over a month. She had a prior COVID-19 infection a year before. A physical diagnosis confirmed diffuse hair loss without scarring and lab tests showed increased Anti-TPO levels. She was treated with systemic cortisteroid (Oral Prednisolone, 300 mg monthly) for 3-months. (She declined Tofacitinib due to high costs, similar to the first case) [53] The possible mechanism associated with vaccine-associated alopecia areata (AA) is immune response that's triggered by COVID-19 vaccines. These vaccines induce the production of the SARS-CoV-2 spike protein, which can potentially lead to a phenomenon known as *molecular mimicry*. This occurs when structural similarities between viral proteins and human proteins cause the immune system to mistakenly target the body's own tissues. In this case, the immune response may produce pathologic autoantibodies that attack components of the hair follicle, particularly the hair bulb. Adjuvants present in the vaccines may further contribute to this autoimmune response. Individuals with a genetic predisposition may be more susceptible to this mechanism, which is similar to the immune-mediated pathway observed in vaccine-induced thrombotic thrombocytopenia.[47][53] COVID-19 vaccination may also increases levels of proinflammatory cytokines such as interleukin-6, interferon-gamma, and tumor necrosis factor-alpha. These cytokines can disrupt hair follicle function and immune privilege which contributes to development or worsening of Alopecia Areata (AA).[47] Vaccine-associated hair loss generally has a favorable prognosis, with most cases responding well to topical corticosteroids and other conventional treatments. Hair regrowth was observed within months, with no reported progression to scarring alopecia. [48]. The occurrence of this side effect is extremely rare compared to the vast number of vaccinations worldwide. The benefits of COVID-19 vaccination especially in preventing severe disease and mortality by-far outweighs the risks of rare adverse effects like hair loss. [54] The recurrence of Alopecia Araeta have been reported in some patients with Some patients experiencing new onset, worsening, or recurrence of AA after infection or vaccination. [55,56,57,58,59,60,61]

CONCLUSION

The COVID-19 pandemic has profoundly reshaped the global health landscape, leaving lasting effects on both physical and mental well-being. While the virus itself caused widespread illness and mortality, the measures taken to control its spread—such as lockdowns and social distancing—also contributed to increased psychological distress and deterioration in overall health. On the positive side, the pandemic acted as a catalyst for enhanced public health awareness, improved hygiene practices, and significant advancements in digital healthcare technologies.

Vaccination efforts have played a pivotal role in controlling the pandemic, significantly reducing severe disease and death. However, the emergence of rare but notable adverse events, such as anemia,

cardiovascular complications, and autoimmune reactions like alopecia areata, highlights the importance of ongoing surveillance and patient-centered care. These effects, although uncommon, call for personalized risk assessment and informed decision-making, particularly in vulnerable populations.

Overall, the pandemic experience underscores the need for an integrated and resilient healthcare system that not only focuses on disease prevention but also prioritizes mental health, safety, and long-term well-being. As the world prepares for future public health emergencies, the lessons learned from COVID-19 must inform policies that balance effective intervention with compassionate, inclusive healthcare delivery.

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