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Vaccines in the Fight Against COVID-19: Mechanisms, Efficacy, and Global Challenges

V. Basil Hans*

Abstract

The SARS-CoV-2 pandemic has created an unparalleled public health problem, necessitating comprehensive prevention. This page discusses COVID-19's evolution, scientific understanding, and quick vaccine production and implementation. It compares the mechanisms, efficacy, and safety profiles of the four major types of COVID-19 vaccines – namely mRNA, viral vector, protein subunit, and inactivated virus vaccines. Each type is evaluated in terms of how it stimulates the immune response, its effectiveness in preventing infection or severe disease, and its known side effects or safety concerns. In addition, the essay delves into the growing issue of vaccine hesitancy, exploring psychological, social, and cultural factors that influence public attitudes. It also highlights the global inequalities in vaccine distribution and access, with a focus on the challenges faced by low- and middle-income countries. Furthermore, it addresses the emergence of novel SARS-CoV-2 variants and the implications for vaccine effectiveness, necessitating the development and administration of booster doses to sustain immunity. The essay concludes by emphasizing that widespread vaccination is critical to controlling the pandemic, and it underlines the need for sustained investment in infectious disease research, public health infrastructure, and international collaboration to prepare for future global health threats.

Keywords: COVID-19, SARS-CoV-2, mRNA vaccines, effectiveness, public health

INTRODUCING CORONAVIRUS

Coronaviruses (CoVs) cause respiratory tract infections in humans. Four common human CoV genera, HCoV-NL63, HCoV-229E, HCoV-OC43, and HCoV-HKU1, cause minor upper respiratory tract symptoms or colds. SARS-CoV, MERS-CoV, and SARS-CoV-2 are new emerging human CoVs that can cause severe lower respiratory infections and are closely linked to bat species [1]. High-pathogenicity CoVs are unpredictable and dangerous. SARS-CoV-2 pneumonia showed the necessity for viral vaccinations.

The spike glycoproteins are the main vaccine targets for animal and human CoV control. The spike (S) protein binds the cell surface receptor and fuses the membrane, allowing viral entrance (Mulaw Belete, 2020). A furin-like cellular protease splits the S protein into S1 and S2. The major method for immunizing against CoV entrance is to generate antibodies that disrupt viral interaction to receptors in the receptor binding domain (RBD) of the S1 subunit. In general, CoV vaccination needs manufacturing, purification, formulation, and administration of immunogenic target(s) to the host animal.

***Author for Correspondence**
V. Basil Hans
E-mail: vhans2011@gmail.com

Research Professor, Department of Management and Commerce, Srinivas University, Mangalore, Karnataka, India

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The rise in COVID-19 cases in Wuhan, Hubei Provence, China prompted national emergency actions. Basic research was rushed. COVID-19 diagnostics and SARS-CoV-2 antivirals are urgently being developed. All these efforts may not be enough to eliminate this new CoV soon. Monitoring the rapid appearance of mutations in the new SARS-CoV-2 and recommending quarantining and border control policies is equally crucial.

CORONAVIRUS HISTORY

Coronaviruses (CoVs) are a group of related viruses that can cause respiratory tract infections in humans, ranging from moderate upper respiratory tract sickness to pneumonia with ARDS and death. The public, medics, and academics studying novel antiviral medications have become more interested in coronaviruses after the COVID-19 epidemic. Veterinary coronaviruses first infected chickens, pigs, and cats. In the mid-1960s, four human coronaviruses (HCoVs) – OC43, 229E, NL63, and HKU1 – were identified [1]. After periodic outbreaks of minor respiratory tract sickness, coronaviruses were rarely known until 2002, when the first lethal coronavirus occurred in Guangdong Province, China.

SARS-CoV was first discovered in a pneumonia patient and has infected nearly 8,000 people in 26 countries, killing 774. SARS coronaviruses were shown to be zoonotic, with bats as the original hosts. Coronaviruses have been studied extensively since then. Middle East respiratory syndrome coronavirus (MERS-CoV) was discovered in 2012 and confirmed as the cause of a severe respiratory syndrome outbreak in the Middle East, where dromedary camels were the original source [2]. In late December 2019, a cluster of pneumonia cases in Wuhan, Hubei Province, China, was caused by SARS-CoV-2, a novel pathogen that is 98% identical to bat coronaviruses revealed in a prior study. In January 2020, the World Health Organization (WHO) declared COVID-19 a Public Health Emergency of International Concern (PHEIC) due to its rapid global expansion.

CORONAVIRUS STRUCTURE AND FUNCTION

Coronaviruses (CoVs) are large, enveloped, positive-sense single-stranded RNA viruses with 26–32 kilobases genomes of the family Coronaviridae and subfamily Orthocoronavirinae [3]. Humans and vertebrates can contract respiratory, gastrointestinal, hepatic, and central nervous system illnesses from these viruses. They pose serious health risks to humans and animals. The International Committee on Taxonomy of Viruses lists 39 coronavirus species in 27 subgenera. Human coronaviruses are alpha- or beta-CoVs. The outbreaks of SARS-CoV in 2002, MERS-CoV in 2012, and SARS-CoV-2, which produces COVID-19, show that freshly generated CoVs from animal reservoirs can travel to humans and between people. Two big polyproteins make up SARS-CoV. ORF3a, ORF6, and ORF7a are dispensable for in vitro viral replication, but ORF5, ORF4b, and ORF7b are crucial for viral persistence and virus-host interactions in vivo.

Coronaviruses are predominantly spherical, 80–220 μm in diameter and feature a club-shaped spike fringe on their outer surface. A membrane-bounded virus-specific inner helical nucleocapsid (N), lipid membrane layer, and several envelope proteins with heaving spikes make up every virion (Cavanagh & Britton, 2008). Non-structural proteins commonly combine N protein with genomic RNA for the helical nucleocapsid, which is surrounded by viral membrane proteins. Ether and chloroform kill enveloped viruses, including coronaviruses. A large surface glycoprotein (S), small envelope protein (E), integral membrane glycoprotein (M), and phosphorylated nucleocapsid protein (N) are found in all coronaviruses. Hemagglutinin-esterase protein is the fifth structural glycoprotein in group 2a coronaviruses.

THE SPREAD OF COVID-19

The most common early COVID-19 epidemic estimates were R0 (the fundamental reproductive number), which ranged from 2.2 to 5.7. In a perfectly susceptible community, a typical infectious case will create the basic reproductive number of secondary cases. A pathogen with an R0 below one is predicted to die out in the population. Asymptomatic cases with high viral load and transmissibility have raised R0 values above 10 in some studies. The first few COVID-19 cases outside China were thought to have been imported by Wuhan travelers on a flight to Haneda airport, and most clusters were found in poorly ventilated karaoke boxes or fitness clubs [3].

SARS-CoV-2 arrived in other cities or countries usually due to a single travel incident, followed by rapid and large-scale transmission clusters. Daegu and Tehran, both COVID-19-affected, are known for their Shincheonji and Zanjan congregations. Most epidemiological patterns require longitudinal data to

prove causation, but all evidence points to droplet/aerosol transfer. The rapid identification of community clusters in other or related cities suggested that chain transmission (e.g., one case infecting two or more cases, who infect four or more) rather than isolated travel events should be interpreted more carefully in other countries and cities. Epidemiologists study COVID-19 transmission and epidemiological patterns. Traditional compartmental models model population compartments and transitions but ignore spatial mobility and domain resolution.

COVID-19 SYMPTOMS, DIAGNOSIS

The global SARS-CoV-2 pandemic is a major issue. Worldwide, the 2019-nCoV outbreak is a major public health issue. The SARS-CoV-2 virus is a new β-coronavirus in the family Coronaviridae and order Nidovirales. Coronavirus illness (COVID-19) caused global worry [4]. COVID-19 was declared a pandemic by the WHO on March 11, 2020. Most COVID-19 cases worldwide involve a rapid increase in virus transmission and severe disease.

The structure and genetic sequence of SARS-CoV-2 are quite similar to bat coronaviruses. The virus spreads through speaking, coughing, and sneezing from close contact. After infecting the nasal epithelium, the droplets travel to the respiratory system [5]. The spike protein of SARS-CoV-2 interacts with the entrance receptor, angiotensin-converting enzyme 2, during cell invasion. After membrane fusion, the virus enters the host cell's cytoplasm to start the infection cycle. An annoying sore throat with little swelling indicates COVID-19 beginning. Coughing and sneezing occur, with a dry cough and sputum rising within hours/days following upper respiratory tract stimulation. Damage to the respiratory system causes wheezing and dyspnoea that makes breathing and exhalation difficult. The virus can harm the olfactory nerve and nasal epithelial cells. Esophageal patent cells are susceptible to SARS-CoV-2, which erodes luminal cells and causes loss of smell/taste.

Low-frequency nausea and vomiting suggest acute respiratory distress syndrome. After a few days of coughing and breathing problems, patients commonly feel chest tightness and stabbing pain. About 77.7% of clinically verified individuals have pneumonia. Some patients cough with blood point dysuria. High troponin levels harm the local myocardium. Virus carriers who feel well may develop severe pneumonia with persistent fever after a few days of coughing and breathing difficulties. Bloody urine and cough ensue. Some children aged 4–14 have lung nodules with pleural effusion and atelectasis while being asymptomatic or with mild fever or cough.

COVID-19 PANDEMIC GLOBAL IMPACT

After a protracted conflict between humans and viruses, COVID-19 entered the body as a complex evolutionary result of virus-environment interaction. Initial data suggest the virus's effective components tragedy is closest to its zoonotic origin. The new coronavirus is a Coronaviridae single-stranded RNA. The COVID-19 virus's survivability, infectivity, and resistance in water and the environment have raised global concerns. Viral sickness has become a pandemic, affecting global health, social, educational, and economic sectors [6].

Once COVID-19 is confined internationally, its after-shock effects on the global economy will be determined. The outbreak left the century's financial crisis behind. The epidemic lowered crude oil prices to a record low. Daily to medium enterprises lose money, gender disparity increases, agriculture farming suffers, and daily wagers cry. People want governments to keep them alive and healthy. China's economic disruptions may affect the global supply chain. COVID-19 caused a historic drop in Chinese manufacturing and services in January–February. This affected China's economy and GDP, attracting Europe, Japan, and the US. Quarantines, travel bans, and public closures affect supply and demand. The year 2022 fell 0.5% from late 2021.

VACCINE INTRO

One of the most effective infectious disease control measures is vaccination [7]. Vaccines provide active acquired immunity to infectious diseases. The agent resembles a disease-causing bacterium and

is often weakened or killed. This agent triggers the immune system to attack, destroy, and acquire immunity to it. Vaccines include live-attenuated, killed, subunit, virus-like particle, toxoid, and nucleic acid. varied vaccinations have varied pros, cons, safety problems, and production and quality control procedures.

Four vaccine functioning principles have been discovered, each observing key conditions for an effective vaccine. These essential principles/state standards apply to any biopharmaceutical for humans or animals. The reduction of clinical symptoms and microbial shedding is a significant marker of vaccination efficacy. Vaccines target the immune system, not microorganisms. Lab tests show no direct immunological effects from vaccines. Each immune response is caused by non-specific stimuli and foreign antigens and is not intended.

Vaccines provide active acquired immunity to infectious diseases. The agent resembles a disease-causing bacterium and is often weakened or killed. This agent triggers the immune system to attack, destroy, and acquire immunity to it. Many viral illnesses are prevented by vaccines. Vaccines include live-attenuated, killed, subunit, virus-like particle, toxoid, and nucleic acid. Some nucleic acid vaccines incorporate genetic coding from the disease-causing virus. Genes allow the body to manufacture a bit of the target virus, triggering an immunological response.

COVID-19 VACCINE TYPES

Nine emergency SARS-CoV-2 vaccines have been licensed, including those created and evaluated by Chinese institutes and enterprises. Protein-based and iDNA vaccines are in large trials, and little is known about their S-protein-specific immune responses via these rich platforms. Thus, this discussion will focus on ivt-RNA and adenovirus vaccines, which have the most side effects and efficacy evidence [8].

Immunogenicity is broadly defined here. The word describes all immunological responses caused by the most common vaccinations (inactivated-CoV-based vaccines are not covered). Low-dose side effects, including fever, headache, and exhaustion, vaccine-escapable, heightened COVID-19 severity, and rare, highly implausible responses, like blood clots, severe skin or organ idiotypes, or myocarditis, are remembered [9]. Most vaccines induce SARS-CoV-2 S-protein-specific IgG, T helper 1 (Th1) cytokine production, and S-protein-specific CD4+ and CD8+ T-cell responses, but 10% of infected people still develop vaccine-escapable COVID-19. Immune responses varied between the two vaccination platforms due to their differing mechanisms of action. Antiviral antibodies should be evoked quickly and sustained at high concentrations to neutralize virus infectivity soon after exposure during incubation. Cellular and other responses are usually a backup system.

mRNA Vaccines

The quick discovery of COVID-19 mRNA vaccines has advanced vaccine design. Pfizer-BioNTech and Moderna have developed potential vaccines using lipid nanoparticle-encapsulated modified mRNA to deliver the SARS-CoV-2 spike protein to human cells. The mRNA vaccines were created using improvements in RNA synthesis, nanoparticle formulations, and rational RNA vaccine design. The firms' two mRNA vaccines are leading COVID-19 vaccines in safety and efficacy [10]. Other COVID-19 vaccine options based on live attenuated viruses, protein subunits, inactivated viruses, and viral vectors are being developed. However, high-transmissibility variations may reduce the efficacy of virus-based vaccinations [11]. With unprecedented urgency, mRNA vaccines offer hope for COVID-19 pandemic mitigation. Within eight months of the SARSCoV-2 sequence being uploaded, Moderna's mRNA-1273 and Pfizer and BioNTech's BNT162b got emergency use authorization. Both the mRNA-1273 and BNT162b candidate vaccines generated neutralizing antibodies in macaques and humans, protecting them against severe COVID-19 and reducing transmission. These technological advances ushered in a new age of vaccine development, and substantial COVID-19 mRNA vaccine production and deployment are underway. As vaccine implementation continues, questions remain about mRNA vaccine architecture, safety and immunogenicity data, delivery, manufacture, characterization, and distribution technology.

Vector-Virus Vaccines

The recent year saw COVID-19 vaccines developed using viral vector–based platforms alone or in combination. Replicating, attenuating, or nonreplicating virus vectors are used in this category of manufactured vaccinations. Since a single dosage induces a significant antibody and T cell immunological response for protection, viral particles encoding immune-recognized antigens are eagerly expected.

The main benefits of viral vector–based vaccines include host cell antigen expression and the potential to create neutralizing antibodies (NAbs) and T cell-mediated immunity. Adenoviral and vesicular stomatitis viral vector vaccines elicited S protein-specific immune responses intramuscularly, according to recent studies. Human cells lack mechanistic commonalities with these systems, improving safety. In addition, they efficiently express S protein. DC stimulation induces nAbs and T cell responses [12].

Animal and human trials have shown the safety and efficacy of these novel vaccinations. Existing vector vaccination technologies use evolving variant S proteins. The vaccination platforms and stage of COVID-19 vaccines based on them are detailed here, with a focus on clinical trials compared to other disease vectors. Adeno vectors that worked for other infectious diseases are being studied for COVID-19 vaccines [13].

Protein-Subunit Vaccines

Purified protein subunit vaccines are effective against infectious illnesses. Without live pathogens, subunit vaccinations are safer than live attenuated or inactivated vaccines. If not complexed with powerful adjuvants to boost antigen-specific immune responses, they are less effective than virulent vaccines. Moderately effective protein subunit vaccines, including those for hepatitis B and recombinant human papillomavirus were produced via extensive trial-and-error expression system and purification techniques and enormous industry-scale production. SARS-CoV-2 became a pandemic in 2020. To fight COVID-19, RNA, inactivated viral, and protein-based subunit vaccines were developed quickly. With strong product pipelines, workforces, and technical skills from anti-hepatitis B virus vaccine research, protein subunit vaccines have gained popularity [14]. The generalized model for protein subunit vaccine design includes native-state antigen, adjuvant for bioactivity and potency augmentation, and delivery mechanism for simultaneous host co-administration. Immune tests target structural proteins such as spike glycoprotein, membrane glycoprotein, envelope protein, and nucleoprotein. The strength of trimeric S-based vaccine-induced neutralizing antibody (nAb) responses matters. Many vaccine candidates have undergone clinical trials; CORBEVAX is authorized in India and pending US process validation. Yeast, mammalian, insect cell, and bacterial pipeline candidates have different expression and purification systems. Expression systems may already yield targets with clinical-grade quality equal to those from mammal and insect cell systems. New immunoadjuvants may improve pipeline efficacy and safety. After the 2020 COVID-19 pandemic, comprehensive prevention initiatives were implemented, including quick vaccine platform development. Phase I trials of SARS-CoV-2 vaccines using pseudo-type virions took longer.

Live-Attenuated or Inactivated Vaccines

Inactivated vaccinations include a non-replicating virus. Inactivated vaccinations against RNA viruses are safer and easier to develop. SARS-CoV-2 inactivated vaccines were created quickly and approved for emergency use. Inactivated vaccinations can be used as boosters since they do not require viral shedding to raise systemic and mucosal immunity and have fewer negative effects. For virus pandemic strain variants, inactivated vaccinations are less flexible than live attenuated vaccines. Inactivated vaccinations have unknown long-term consequences [15]. Due to its ease, inactivated vaccine manufacturing is appealing for the SARS-CoV-2 pandemic and future GSKs with unknown viral strains to build effective vaccines quickly. This live attenuated vaccination targeting common SARS-CoV-2 strains rather than the spike protein’s genetic sequence or structure is expected to complement and enhance the diverse techniques under development. The massive amount of data

collected during the COVID-19 pandemic will help develop better pandemic-fighting techniques. Fighting new viruses will be difficult. COVID-19 is the first such epidemic. There may be other obstacles. Currently, variants emerge and outcompete each other. Will the evolution for fitness in transmissibility and virulence spontaneously ebb? Development of next-generation live attenuated COVID-19 viruses is underway.

THE VACCINE DEVELOPMENT PROCESS

COVID-19 vaccination and prevention (masking and distancing) are one of the few ways to fight the pandemic. As worldwide COVID-19 vaccinations are introduced, concerns have been raised about vaccine production speed and safety. This describes the vaccine development process and US emergency COVID-19 vaccinations [16].

The vaccine development process includes research and discovery, preclinical, clinical, Biologics License Application (BLA), and post-BLA. Scientists conceptualize and undertake lab research at this level. Animal models are used in preclinical research to study pathogen immune responses. More animal testing and study are done. Every animal study is analyzed and reported to the FDA. It may take months or years to determine how long the vaccination protects and how many booster shots are needed. The committee must also decide how to make vaccine isolation preparations and how to boost immunity [17].

The FDA receives all preclinical testing data, reports, and meeting records at this period. This IND provides an executive summary and background of the vaccination product and its experimental formulation for human clinical use. Preclinical, toxicological, and live viruses and other length shedding experiments are also discussed. Safety and clinical safety facts for human vaccine usage, justification, and regulatory submissions outside the U.S. are offered. Because SARS-CoV-2 information is still developing, the vaccine for humans must be flexible.

Trials Before Clinical Use

An effective vaccination to stop the global SARS-CoV-2 epidemic is urgently needed. Despite the hurdles, vaccination candidates and those under development can help us avoid the pandemic. This report described the basic vaccine candidate development processes and their obstacles. If well-established and cared for, these studies can help build an infectious disease strategy [18].

A new betacoronavirus, SARS-CoV-2, infects human cells by binding to ACE2. The spike (S) glycoprotein of SARS-CoV-2 is essential for viral entrance into target cells. Human ACE2 (hACE2)-transgenic mice, ferrets, and nonhuman monkey infection models are chosen for vaccination safety and efficacy testing in preclinical animals. These animal models assessed the safety, immunogenicity, and protective effectiveness of a prototype SARS-CoV-2 inactivated vaccine. A complete viral inactivated candidate vaccine showed safety, immunogenicity, and protective effectiveness. In hACE2-transgenic mice and Rhesus macaques, inactivated vaccination against SARS-CoV-2 infection reduced lung viral burden upon challenge. These vaccine development studies highlight pathogenic SARS-CoV-2 infection development.

Phases of Clinical Trials

Candidate vaccines undergo four clinical trials before approval. Phase 1 is a safety and immunogenicity trial in a small number of individuals (up to 100). Phase 2 expands the original evaluation to hundreds of more heterogeneous cohorts, addresses safety issues, including subpopulation reactogenicity, and explores dose and route. Phase 3 studies (thousands to tens of thousands) evaluate a vaccine candidate's ability to prevent clinical illness and infection in post-licensure populations. Phase 4 or postmarketing trials evaluate safety and efficacy in larger groups under regular use [19]. Vaccine safety can be answered in different ways. Avoiding chemicals in blood-derived vaccinations and containing solely antigens may be safest. Live-attenuated vaccinations react more than others. If possible, test candidate vaccinations in the same or similar population. Even with a vaccine that has

been previously studied in a population similar in age, racial distribution, etc., careful attention should be paid to how some populations may, or may not, be similar (e.g., poor nutritional status) and to differences in behavior/exposure or other factors that could lead to different rates of serious unintended consequences after vaccination. Similar vaccinations for closely related infections should be studied concurrently. Check fi ends for associated absence. Phase 1 and phase 2 trials of a candidate vaccine should be conducted in the population where the final trials and vaccination use are intended, including verbal autopsy. After research design, statistical methods, and analysis are approved by competent review and monitoring bodies, clinical cases and unexposed controls should be interviewed and examined for safety. Implementation requires well-trained field teams that communicate and work with national, endemic, and afflicted country authorities.

Regulation Approval

Dr. A's research team is pleased that Elizabeth Askew's team has submitted COVID-19 vaccine documentation to the FDA and volunteered for nursing home immunization campaigns. Since the COVID-19 epidemic has raised more points than expected, the team wants Elizabeth Askew's guidance on what is crucial.

The Journal of Infectious Diseases published the first definitive but discouraging vaccine data [20]. National governments create Cooperating Agencies (CAs) like Health Canada and the FDA. EU and UK CAs are poorly documented. BioNTech and Moderna reportedly have no information on the concerns or regulatory approval timetable. More significantly, the vaccination adenovirus vector is unknown. Approval difficulties have allowed the COVID-19 pandemic to remain in several countries after 95% of people were vaccinated. Inactivated virus vaccinees benefit little from vaccinations with 20 strains without screening tests. Safety and efficacy follow-up discussions have asked how to survey revealed harmful effects since causation may take years or decades to prove. When most other reasons are excluded and no vaccine adverse effect is frequent enough to detect signals, this issue will become more challenging. Indeed, emerging strains in vaccinated people threaten broad efficacy. Without comparing national vaccination and screening reports, terrible scenarios, like Brazil, Russia, and the UK, may dispute the statistical benefits of vaccination and herd immunity.

Second, address regular unanticipated resignation letters, media coverage, and "fake news". Such departures and obituaries demonstrate the stakes. They raise ethical questions about disclosing unfavorable consequences [21]. COVID-19 is a global conundrum with unanticipated pros and cons. The hazards of lethal "fake news" in strategic health communications should be quantitatively characterized. Discuss how to reject or downplay the one-day "cut-off" purchase offers.

COVID-19 VACCINE EFFICACY AND SAFETY

To address the COVID-19 pandemic caused by severe acute respiratory syndrome coronavirus 2, vaccinations have been developed quickly. Five SARS-CoV-2 candidate vaccines have emergency public health use authorization. Biological COVID-19 vaccines are novel. Their efficiency and safety vary substantially. This analysis gives immunization program managers and public health contracting organizations a new way to interpret COVID-19 vaccine efficacy and safety data. Not all COVID-19 vaccinations are equivalent. COVID-19 vaccination efficacy and safety should be maintained. Monitoring emerging variants is crucial [22]. Vaccinated people need safety surveillance. COVID-19 vaccinations should not be overstated or underestimated. Health authorities should offer timely, fair, honest, balanced, and clear COVID-19 vaccination information to maintain public confidence.

A COVID-19 vaccination may confer acquired protection against coronavirus illness 2019. AstraZeneca, Janssen, Pfizer, and NOVAVAX vaccines were authorized for public use under emergency. Vaccine research and development are distinct. Vaccine development is crucial to fighting COVID-19. SARS-CoV-2 vaccines may prevent infection, illness, and transmission. Phase 3 clinical trials struggle to assess the most significant efficacy outcome, protection against serious illness and death. It cannot be argued that developers and researchers did not disclose level A efficacy/efficacy

data when licensing immunizations despite a wealth of evidence. Publicly available vaccines must be tested for safety.

Randomized clinical trials and post licensure data assess vaccine safety. Interpreting COVID-19 vaccination safety is difficult. Safety was proven by Pfizer and Moderna vaccines. The Johnson & Johnson vaccination had little safety data. Other vaccines lack safety data. Monitoring adverse events after immunization (AEFIs) is essential for public confidence in mass vaccination. The majority of AEFIs are resolved naturally. Health authorities must communicate AEFI risks quickly. Communicate AEFIs accurately.

VACCINATION PLANS AND CAMPAIGNS

COVID-19 vaccination is the best hope for public health and pandemic reversal. After the vaccine launch in December 2020, scale, empirical learning, and adaption occurred quickly. Creating settings for immunization against a virus that has caused so much carnage is commendable, as is the developmental agencies and governments' focus on learning from this launch phase [23]. The largest mass immunization in history, with notable exceptions, warrants renewed attention in immunization. The immunization has been mandated in some countries and protested by others. Vaccination programs, policies, and strategies should be scrutinized, according to this research.

Vaccines have traditionally targeted viruses like COVID-19. Thus, mass immunizing against an infectious disease is well-known. Countries use that collective knowledge differently. After years of extensive vaccination against deadly diseases, others are returning to normal. Covariate differences include population, government quality, health system access, digital infrastructure, and vaccine views. Early simulations predicted a universal exit could not occur until 2022. However, systems countries pioneered immunization. Mass immunization is unprecedented. The world's best hope to contain COVID-19 was vaccination. Global equity and routine vaccine availability depend on understanding vaccination plans and rollouts.

PUBLIC PERCEPTION AND VACCINE HESITANCY

As COVID-19 vaccinations are introduced, many variables must be considered to ensure public acceptance. Reluctance or refusal to get vaccinated despite availability is a barrier to vaccine uptake that public health academics recognizes as a problem. A recent study of vaccine hesitancy in England and Wales found that a lack of trust in government, pharmaceutical companies, and health professionals predicted hesitancy, but younger and lower-income people were more likely to adopt misinformation and conspiracy beliefs. The study used mixed approaches in multiple steps.

A qualitative study employing focus groups collected data on hesitation factors before developing the survey. A repeated cross-section study in England and Wales with 7037 respondents used these survey items. Independent one-on-one interviews with vaccine-hesitant adults and a public health communications specialist supplemented and questioned the previous studies. We used an environmental approach and a social framing Political Theory of Choice model to examine individual-level confidence, uncertainty, and trust factors, information seeking behavior and sources, and contextual structural influences on hesitancy. Using unsolicited responses from a comparable qualitative investigation of lockdown compliance in England and Wales, it explored belief systems about behavior change interventions needed to spread information about behavior change programs [24].

The global vaccination development process was accelerated unprecedentedly. Due to the detrimental effects of bad uptake policies, vaccine-hesitancy research must involve the public. Social structures impact information environments and the opportunities and constraints of deliberating on information, hence studying our hierarchically structured societies can help explain modern behaviors like vaccine hesitation.

GLOBAL VACCINATION CAMPAIGN

The global COVID-19 epidemic is unprecedented. Over 181 million COVID-19 illnesses and 3.9 million deaths were reported worldwide in early July 2021. Rather than eliminating SARS-CoV-2 globally, many nations are still fighting repeated waves of COVID-19. The more prudent goal is transition to endemicity. Several extremely successful COVID-19 vaccines were widely used within 12 months of the pandemic, with about 3.04 billion doses provided globally. However, countries of all income levels struggle to implement immunization programs. 23.4% of the worldwide population has gotten a COVID-19 vaccine, compared to 0.9% in low-income nations. This gap is due to vaccination distribution and country resource inequality. COVID-19 morbidity and death are exacerbated by vaccination access, availability, and distribution inequalities. Socioeconomic inequalities in health literacy, community COVID-19 testing, and contact tracing, isolation, and quarantine exacerbate these consequences [25]. Global mass vaccination must seek broad access to an ample vaccine supply and an equitable distribution procedure that prioritizes at-risk individuals everywhere, regardless of country income. Whether universal vaccination will attain population immunity and stop transmission is unknown. Epidemiology theory predicts herd immunity, a multi-population state in which the percentage of people immune to a disease (via vaccination or disease) is high enough to stop community transmission and protect unvaccinated people. The vaccine effectiveness and infection's basic reproductive number (R0) determine the level of immunization needed to develop herd immunity for a given transmission and illness incidence. Herd immunity depends on whether vaccinations can stop Serotype I infection, replication, and shedding in both symptomatic and asymptomatic infection [26]. Fully vaccinated people may operate as asymptomatic reservoirs of reverse zoonotic infection transmission when the risk of symptomatic and/or severe COVID-19 sickness reduces. With new variations demonstrating significant immune escape from natural infection and several vaccinations, these challenges must be addressed urgently. Real-world observation in highly vaccinated groups will reveal whether herd immunity is possible.

The COVAX Initiative

COVID-19 Vaccines Global Access accelerates vaccine production and fair access worldwide. It aimed to distribute 2 billion COVID-19 vaccines evenly by 2021 when it debuted in April 2020. About 90 countries were eligible for the facility, but only 44 received 1.4 billion doses by late June 2021, expecting delays. The project provided its first immunizations to African nations in February 2021. The primary supporters anticipated providing 600 million pills to Africa by late 2021. By June 2021, 115 million doses were expected to reach Africa.

Africa has 2% of the global COVID-19 vaccination supply. New COVID-19 variants to replace current vaccines worry the global vaccination supply chain with restricted shipping routes. Distributing vaccines to Africa will be difficult since some governments lack laboratories to undertake vaccine safety monitoring. Despite the initiative, Africa lags Europe and North America in vaccination for various reasons.

Insufficient vaccine supplies led most developed countries to ban vaccine exports. With some high-income countries' immunization rates above 30%, vaccines outside China were available in 70 countries by early March 2021, mostly in high- and upper-middle-income countries. By May 21, just 15 million pills had been transported to low-income countries, with only five receiving at least 1 million. Due to high-income countries over purchasing doses and vaccination export limitations, 10 countries have not received any. Africa received 150 million doses and fewer than 5% coverage, significantly below the aim of 10% coverage by September 2021. Vaccine stockpiling affects global equity.

Equity in Vaccine Distribution

COVID-19 vaccination distribution systems should be fair for moral and practical reasons [27]. The fastest comeback to pre-pandemic conditions is global vaccination. Limiting vaccination to wealthier countries increases the danger of vaccine-evading variations. Distribution should be based on need, not wealth or politics, for equity.

Countries began extensive COVID-19 mRNA immunization efforts in December 2020. These vaccines were regarded as a great advance in the fight against COVID-19, and they have helped several wealthy countries that received substantial doses. Now, there is a growing realization that combating COVID-19 and avoiding the formation of additional variations under selective pressure from vaccinations will need equitable vaccine delivery to all countries globally as soon as possible. Without enough vaccines to attain broad immunity, vaccine-evading variations may arise in unprotected communities and reinfect vaccinated people, endangering global health gains.

Equity in vaccine distribution raises moral considerations about legal systems, concepts, and ideas and how these might be used to provide prompt COVID-19 vaccinations for all. First, the text discusses moral issues. Second, it explores how international law and other legal procedures raise equality problems and how these may influence national judgments.

Populations need equitable vaccine and treatment access to benefit from research. It helps the tool shed flaws. Once safe, experimental technology must be available to individuals exposed to it to be effective. These moral and legal requirements are called "the right to research."

MONITORING AND SIDE EFFECTS AFTER VACCINATION

COVID-19 vaccines have been given over 689 million times as of May 19, 2023. Vaccines were designed and used quickly to combat COVID-19, with ongoing postvaccination surveillance. Individuals who had recently received vaccine components were asked about postvaccination side effects such as fever, headache, lymphadenopathy, and lip swelling. In Korean healthcare professionals aged 18–60, mRNA or viral vector-based COVID-19 vaccines (first-dose immunizing and second-dose boosting) caused a range of adverse effects in both genders. Mild to moderate local or systemic adverse effects were mostly on the day of immunization, self-limiting within 1-3 days, and readily treated after HPV vaccination [27]. No trials have examined the impact of non-steroidal anti-inflammatory medicine on COVID-19 vaccine side effects, unlike HPV immunization. Common adverse effects after J&J and AstraZeneca viral vector-based vaccinations were more similar than those after Moderna/mRNA and Pfizer/mRNA vaccines, which had diverse types, frequencies, severity, and onset timings [28]. Each vaccine type had adverse effects a month later. The need to know postvaccination symptoms was stressed before vaccination, and exposed vaccinations were a virus' genetically encoded protein corona recorded as a phenome library to account for side effects. Most adverse effects greater than a month after immunization have complex safety profiles.

CONCERNING VARIANTS AND VACCINE EFFECTIVENESS

The COVID-19 pandemic is caused by SARS-CoV-2. Respiratory droplets spread it, making it very contagious. SARS-CoV-2 infects via aerosols and respiratory droplets. After a 12–14-day incubation period, COVID-19 symptoms can range from asymptomatic to severe pneumonia and multisystem organ failure. SARS-CoV-2's rapid mutation rate and viral evolution affect diagnostic tests and vaccinations [29]. Mutations in the spike protein (S protein) receptor-binding motif affect viral transmissibility. SARS-CoV-2 variants with great transmissibility have been found in people and spread worldwide. Some mutations have caused local epidemics, enhanced community transmission, and stimulated study into sickness severity. SARS-CoV-2's surface protein, S, is targeted for COVID-19 vaccine development. Antibodies against the S protein, particularly its receptor-binding domain, are the main COVID-19 protective factor. A polyclonal antibody response generates SARS-CoV-2-neutralizing antibodies. Months after infection, many recovered patients have high SARS-CoV-2 neutralizing antibody levels. The first-generation entire inactivated virus, recombinant RBD-subunit, adenoviral-vectored, and mRNA vaccines are in efficacy testing. Engineering and testing second-generation vaccinations continue. All the vaccines above provide similar protection. Despite the vaccine's protective impact, the virus's high mutation rate remains. Recent research suggest that SARS-CoV-2 variations may have lowered vaccine effectiveness due to genetic alterations relative to the original Wuhan strain.

COVID-19 VACCINE FUTURE

The COVID-19 pandemic has affected public health, healthcare, and socioeconomic conditions worldwide. This epidemic caused tremendous illness and mortality, forcing governments to close towns, regions, and countries to stop its spread. To speed up COVID-19 vaccine development and distribution, national and international cooperative activities have been undertaken [1]. Vaccines must be widely distributed to end this pandemic.

The first emergency COVID-19 vaccine, Pfizer-BioNTech, was approved in December 2021. Many countries authorized and deployed dozens of vaccines, including inactivated virus, viral vector, mRNA, and protein subunit vaccines. Preclinical and clinical trials of viral vectors, DNA, and mRNA for NTB vaccine development are underway. In tandem, these global cooperative efforts created opportunities and raised questions for future vaccine research projects.

Future COVID-19 vaccine research and administration will face many obstacles. (1) Assessing candidate vaccination efficacy and efficiency is challenging without a standard. (2) Long-term vaccination effects are uncertain. (3) Immunization booster schedules should be investigated to boost vaccination efficacy. (4) Although vaccinations are available, none have been licensed and widely utilized in low- and middle-income countries, thus vaccine deployment inequalities may persist. (5) Emerging SARS-CoV-2 mutations have reduced vaccination efficacy and require new vaccines. (6) Mass production, storage, and distribution of licensed vaccines are expensive. For vaccine mass administration monitoring and safety, a surveillance system must record immunization data, including breakthrough infections and variations. (7) Masks and social distance will help reduce SARS-CoV-2 transmission. (8) To prevent the resurgence of COVID-19, proactive global efforts should focus on effective and immediate vaccine allocations to poorer countries, proper vaccine storage, transport, and use, tracking new SARS-CoV-2 variants, and vaccine booster development.

COVID-19 MANAGEMENT VIA PUBLIC HEALTH

Public health helps control SARS-CoV-2 and COVID-19. Special people, communities, institutions, locations, and ecosystems are targeted to prevent and control SARS-CoV-2 and COVID-19. This involves supporting vaccination campaigns, optimizing healthcare capacity, and monitoring and evaluating initiatives. Public health organizations give state authorities legislation, recommendations, and guidelines to customize and implement specific interventions. Information and communication with the public have occurred during policy design, risk assessment, campaign implementation, and expectation setting. Protecting people and communities from COVID-19 and its variations remains a national concern. Preventing COVID-19 cases, hospitalizations, and deaths and limiting its economic and social burden are goals. This ensures equal access to primary FDA-approved vaccines, demographic group prioritization, and transparent vaccination communication. Vaccine effectiveness in reducing infection and hospitalization is monitored and adjusted. Investigations are underway for very effective SARS-CoV-2 vaccines and therapies. We model and interpret demographic group risks alongside ethical and law specialists. International vaccine dose sharing is actively pursued depending on population needs [30]. Public health helps control SARS-CoV-2 and COVID-19. Planning and policy activities at all levels are integrated under rising public expectations. Data centralization and improved IT support are preparedness measures [30]. To prevent and control SARS-CoV-2 and COVID-19, initiatives target unique populations, communities, institutions, settings, and environments.

LEARNING FROM THE PANDEMIC

The COVID-19 pandemic exposed pandemic preparedness gaps [31]. The 2014–2015 Ebola pandemic prompted requests for better viral detection, containment, and research. These proposals were ignored in the US, while other nations invested extensively. Most nations sadly overestimated their abilities. Scientists warned of the potential spillover of zoonotic coronaviruses for years before SARS-CoV-2, and some governments were better prepared. However, surveillance was insufficient for the wealthy. A global response was needed. This ambitious goal changed from detecting afoot poultry to manufacturing and distributing many effective vaccines to poor regions as the pandemic intensified.

The construction of the world's largest vaccine innovation and supply organization [32] and distribution warehouse sparked this global response. Unfortunately, these organizations were unprepared to meet the sudden demand for billions of doses of a new sophisticated vaccine that would not profit pharmaceutical firms. The UK pre-purchased 100 million Astra-Zeneca vaccine doses, demonstrating the US and European rush to manufacturing tactics. Given its habit of selecting what not to do, Merck's exit from the vaccination competition was as startling as its prior entry. The FDA's strict yet complicated release and vaccination requirements and advice to start immunization within a week of licensure favored the corrupt. Large-scale biological product manufacturers, like India and Brazil, began mass vaccination campaigns before the pressurized and laborious development of effectiveness and safety data could be done democratically. The 1960s ethical ideals of vaccine research with children may have been strengthened by this epidemic. The appallingly inequitable global distribution of vaccines was unfixable in some cases – 1.4 billion people incapable of immunization beyond 20% – but most nations were unaware of this.

THE ETHICS OF VACCINE DISTRIBUTION

We have discussed vaccine types, dangers versus benefits, and approaches to encourage vaccination. We now focus on the ethical implications of vaccination and vaccine distribution strategies, as many vulnerable populations have unmet health care needs and prioritizing them in the vaccine rollout poses ethical issues. Even in the best of circumstances, health care resource distribution can unfairly punish disadvantaged social groups [33]. Limited vaccination supply makes fair distribution extremely challenging. What is the status of Covid vaccine distribution and deployment given media coverage and efforts to vaccinate everyone? Global vaccine allocation ethics were issued by an international group of ethicists on September 3, 2020 [34]. The UK became the first country to license and distribute a Covid vaccine on December 13, starting a race to vaccinate people. Approaches vary widely between nations. Advanced countries, like the UK and Israel, acted early, facilitating speedy adoption. Other countries, like the EU, had vaccine delays. There were immediate concerns about inequitable access in low-income nations, political elite priority, health worker prioritization, and regulatory agencies slowing vaccine introduction. Public discourse emphasized fairness and transparency. While ethics dominated the priority argument, ethical implementation plans were expected. An extensive literature exists on vaccine distribution ethics in areas like childhood vaccination, but less on Covid vaccine administration and rollout. This study examines distribution, access, and prioritizing ethics. While the focus is on the UK, same considerations apply to other countries.

INTERNATIONAL VACCINE RESEARCH COLLABORATION

Dr. Anthony Almeida G. Ferreira Oliveira's findings emphasize the need to abandon COVID-19 vaccine nationalism. He believes global vaccine coverage can only be achieved via worldwide solidarity and collaboration. Scientific funding approaches that guarantee global manufacturing conditions, knowledge transfer, installations, rapid vaccine building, and purchasing capacity should be preferred to traditional and frequently detrimental market-driven mechanisms [35]. If such methods are not implemented promptly, vaccine waiting times in developing and undeveloped nations may be considerable, causing human and economic disasters. Unfair allocation can inflict human and economic harm and nurture new SARS-CoV-2 strains.

During the COVID-19 epidemic, scientists have labored day and night to produce a safe and effective vaccination against SARS-CoV-2. Several experimental or clinical SARS-CoV-2 vaccines may have the most potential. COVID-19 vaccine candidates and platforms in preclinical or clinical research as of late March 2020. Information about each platform includes its nationality, sponsor, collaboration partners, targets, development stage (preclinical, clinical, or commercial), method of administration, and a brief target description. Review of COVID-19 vaccines [36].

Beyond potential vaccines, ongoing vaccination platforms that could be reformulated against COVID-19 are mentioned. The global SARS-CoV-2 immunization effort is quickly ramped up by industry, academia, government, and research institutes. Foreign countries should continue to develop

their own technologies to avoid overreliance on others' competence in productive capacity, quality control, regulation testing, delivery, and vaccine target retrofitting.

CONCLUSION

COVID-19, caused by SARS-CoV-2, is a global health issue. SARS-CoV-2 has disrupted the world despite national and international containment attempts, unlike SARS-CoV and MERS-CoV. Despite the extraordinary rapid development of SARS-CoV-2 vaccinations, public vaccine reluctance is widespread. This page reviews SARS-CoV-2 outbreaks, clinically used vaccinations, and preclinical and clinical vaccines. Understanding is the first step to trusting science and scientists. Society must supply quality information to satisfy the public's curiosity, and social responsibility builds trust [37].

Within two doses, SARS-CoV-2 vaccination should protect against infection, severe sickness, and hospitalization. A massive global effort to find safe and effective vaccines will likely control the COVID-19 pandemic [38]. However, variations of concern endanger the efficacy of vaccines and monoclonal antibodies against SARS-CoV-2. The current SARS-CoV-2 vaccines are safe and effective in preventing infection, sickness, transmission, hospitalization, and mortality. New SARS-CoV-2 mutations discovered in the second half of 2020 have reduced vaccination efficacy. COVID-19 vaccine is rapidly spreading worldwide, and over 80% of the population should have SARS-CoV-2 immunity. It is becoming clear that preventing the COVID-19 pandemic will require immunization, public health measures like masks and social distance, and effective therapies.

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