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A REVIEW ON COVID VACCINE

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Abstract

The COVID-19 pandemic prompted a global effort to rapidly develop vaccines, leading to the approval and widespread use of several types. This summary explores key COVID-19 vaccines, including messenger RNA vaccines (Pfizer-BioNTech, Moderna), vector-based vaccines (AstraZeneca, Johnson & Johnson), and protein-based vaccines (Novavax). It outlines how these vaccines function, their effectiveness, safety profiles, and the logistical and social challenges related to their distribution and public acceptance. The review also highlights the impact of emerging variants on vaccine performance, the need for booster doses, and future directions in vaccine innovation. The goal is to provide healthcare professionals, researchers, and policymakers with the most current insights into COVID-19 vaccination.

Keywords: COVID-19 vaccines, mRNA vaccines, Vector-based vaccines, Vaccine effectiveness, Booster doses, Vaccine hesitancy.

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Introduction

In December 2019, unsolved pneumonia cases appeared in Wuhan, China, leading to discovery of a new covidvirus. After the virus genetic sequence was released, scientists began studying its protein structures. It was authoritatively named SARrS-CoV-2 by the International Committee on Taxonomy of Viruses, while the WHO chosen the resulting illness as COVID, an abbreviation for Coronavirus Disease 2019 [1].

The expansion of a nonviolent and effective vaccine was essential in addressing the COVID-19 disease, which the WHO officially declared a global crisis in March 2020. By October 22, 2021, there were 322 vaccine candidates under development-128 undergoing clinical trials and 194 in preclinical testing. Protrudinginoculations like those established by Pfizer-BioNTech, Moderna, and Oxford-AstraZeneca were based on the spike (S) protein also called as peplomer of the original viral strain. Although a few occasional side effects have been observed following vaccination, no definitive causal relationship has been recognized. To curb the virus's transmission, actionssuch as distancing socially,wearing masks, remote work, isolation, & quarantine were. Although effective, these interferences also underwritten to increased mental health issues, such as depression and emotional distress [2-5].

Definitions

Vaccine: A vaccine is a biotic tool that trains the immune system by revealing it to deteriorated, inactivated, or limited elements of a pathogen, including its genetic material, allowing the body to improve immunity without causing the illness itself. [6].

Covid Vaccine

A COVID vaccine is considered to shieldin contradiction of the SARrS-CoV-2 virus, which leads to Corona [7]. It works by prompting the immune system using components like inactivated virus, spike proteins, or genetic material (such as mRNA or viral vectors). This helps the body diagnose and fight the virus, significantly lowering the probabilities of severe illness, hospitalization, or death [8].

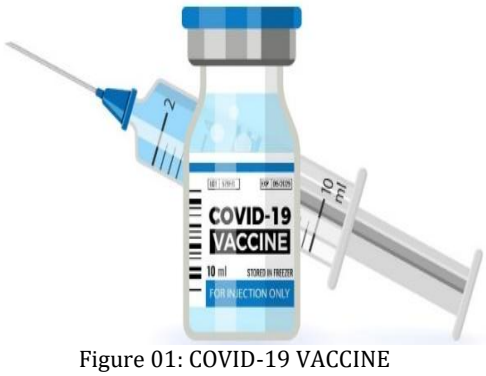

Figure 01: COVID-19 VACCINE

Covid Vaccine Types

1. Messenger RNA Vaccines

Messenger RNA vaccines utilize a small component of messenger RNA inteaching cells to produce a less harmful protein of the virus, usually from the virus's surface. This does not include using the actual virus and has no effect on human DNA, as the mRNA never enters the nucleus. When the protein is made, the body's immune system identifies it as external& releases antibodies. These antibodies persist in the body and enable a quicker and stronger immune response if the real virus is encountered later, helping to prevent illness [9-14].

Mechanism

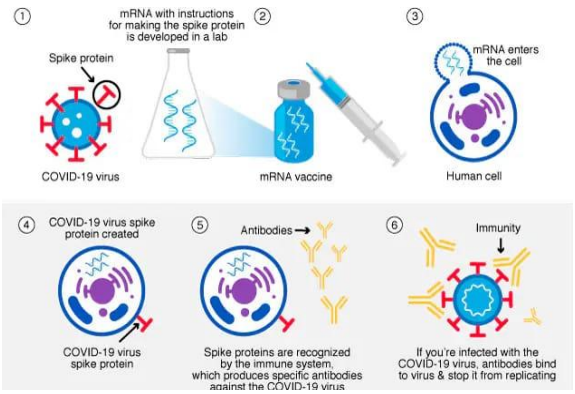

Figure 02: Mechanism of mRNA vaccine

(a) Pfizer-BioNTech Vaccine

The Pfizer-BioNTech corona vaccine, under brand Comirnaty, is the 1st Corona vaccine to obtain Emergency Use Authorization in 2020 December due to its high effectiveness against symptomatic infection. Later, in August 2021, it gained full FDA approval for use in individuals aged 16 and above. This vaccine uses mRNA technology, a modern approach in the field of vaccine development[15-17].

Figure: 03 Pfizer-BioNTech vaccine

Composition

The Pfizer-BioNTech Corona vaccine is composed of messenger RNA and various lipids, including PEG-2000, cholesterol, and other lipid compounds. It also contains stabilizers such as tromethamine, tromethamine hydrochloride, and sucrose. For children between 06 months and 4 years, NaCl is included as an additional ingredient [18].

Dosage Guidelines

The Pfizer-BioNTech Corona vaccine is authorized in emergency use for children aged 06 months to 11 years, although its effectiveness may vary among individuals [19][20].

For children of age 06 to 4 years: Unvaccinated: 3 doses are recommended over at least 3 months. The 1st two were given 3 weeks apart, and the 3rd follows 8 weeks after the second [21].

After one prior [22], two more doses are needed—one 3 weeks after the first, and the next at least 8 weeks later.

For children aged 06 to 11 years:With one previous dose: [23] Two additional doses are required—spaced 3 weeks and then 8 weeks apart.

With two or more doses: [24] only one more dose is needed, given at least 8 weeks after the last.

Immunocompromised Children

May need extra doses, as advised by a healthcare provider. For children aged 5 to 11 who haven't received the 2024–2025 vaccine formula: One dose should be given at least 2 months after their last Corona vaccination.The Pfizer-BioNTech Corona vaccine is approved in emergency use for children aged 1 to 11 years to help avoid COVID-19 disease. However, its effectiveness may vary, and it might not offer protection to every individual [25].

Side Effects

Children experiences effects like fainting, irritability, reduced appetite, tiredness, vomiting, stomach pain, or unusually pale and cool skin. Common reactions to the Pfizer-BioNTech Corona vaccine include swelling or pain at the injection site, fatigue, headache, muscle and joint pains, chills, and fever. In rare cases, more serious issues like allergic reactions or heart inflammation have also been reported [26-27].

(b) Moderna Corona Vaccine

Moderna Corona vaccine, also called as Spikevax, received full FDA approval in January 2022 for adults aged 18 and above. This followed its initial Emergency Use Authorization in 2020 December, in a whilenext to the Pfizer-BioNTech corona vaccine. Like Pfizer's,Moderna vaccine uses Messenger RNA expertise and showed strong effectiveness in preventing symptomatic COVID-19 [28].

Figure 04-Moderna Corona Vaccine

Composition

The Moderna vaccine consists modified mRNA that codes for the peplomer proteins of the SARrS-CoV-2 virus. It also includes ingredients like PEG 2000 Di methyl glycol, C44H88NOP, cholesterol, tromethamine, tromethamine hydrochloride, acetic acid, sodium acetate, and sucrose [29].

Dosage Guidelines

For child's ageing 24 weeks to 4 years old who have not been vaccinated, the Moderna corona vaccine is given in 2 doses, spaced one month apart. If a child previously received an older, unauthorized Moderna dose, one updated dose is given after a month. Another updated dose for 2024–2025 is given no less than8 weeks after last dosage.

For children aged 5 to 11 years, regardless of their vaccination history, a single dose of the 2024–2025 Moderna vaccine is recommended. If a prior vaccine is no longer authorized, a two-month gap from the last dose is required.Immunocompromised children aged 6 months to 11 years should receive at least three doses, one month apart, with at least one dose being the 2024–2025 version [30].

Side Effects

Serious reactions from the Moderna inoculationremain uncommon still may include severe allergic reactions, myocarditis, and pericarditis. In children, signs to watch for include difficulty breathing, chest pain, rapid or irregular heartbeat, fainting, and persistent symptoms like fever or headache, which require medical attention [31].

Effectiveness

The updated 2024–2025 Moderna vaccination hadrevealedcapable outcomes in laboratory trials against current virus strains. While it may not completely prevent infection, it offers strong defencein contradiction of serious disorder, rehabilitation, and fatal. As of November 2024, the CDC expected it to be effective against the dominant and emerging variants [32].

Protein-Based Vaccines

Protein-based vaccines are a well-established method for preventing viral infections and have contributed to major public health achievements, such as eradicating smallpox. These vaccines use viral proteins-produced through various techniques like recombinant technology or virus-like particles-to trigger an immune response. Peptide-based versions are considered particularly safe, as they avoid components that could lead to antibody-dependent enhancement (ADE), though they often require adjuvants to strengthen their effectiveness. For SARrS-CoV-2, the spike protein of SARrS-CoV-2 has been identified as the key target, and 2 amino acid-based vaccines-Novavax's NVX-CoV2373 and EpiVacCorona—has been approved for use [33].

Mechanism

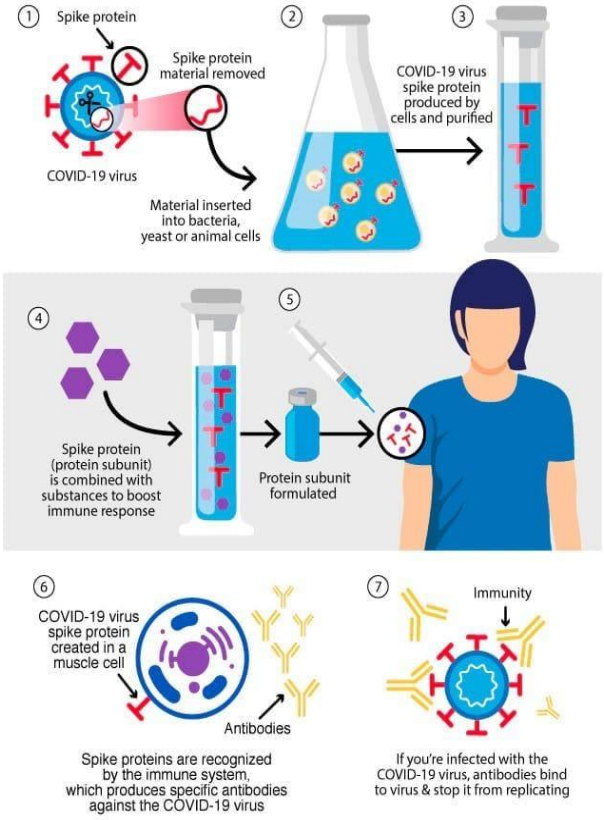

Figure: 05 Mechanism of protein-based vaccines

(a) NovavaxCorona Vaccine (Nuvaxovid)

Nuvaxovid, established by Novavax, became the fourth corona vaccine availablethroughout the United States, following now-discontinued Johnson & Johnson vaccine. It is currently the only authorized non-mRNA COVID-19 vaccine in the country. As a protein-based vaccine, it includes an adjuvant to boost immune response and showed around 90% effectiveness in clinical trials, similar to early mRNA vaccine results. Its simpler production process and ability to be stored in regular refrigerators make it easier to manufacture and distribute [34].

Figure: 06 Novaxovid Corona Vaccines

For the 2K24–2K25 vaccination period, the NOVAXOVI Dcoronavaccine is approved for individuals aged 12 and older, with dosing varying by vaccination history:

Unvaccinated individuals receive two doses, spaced three weeks apart.

Those with one prior Novavax dose get a second dose at least three weeks later.

Those previously vaccinated with two or more COVID-19 doses have a single proponent at the minimum8 weekslater than their last dose [35].

Immunocompromised individuals may get an additional dose after two months, with further dosing guided by a healthcare provider's recommendation.

Composition

The Novavax vaccine contains a lab-produced spike protein that targets both the original COVID-19 strain and the Omicron XBB.1.5 variant. It includes Matrix-M, an adjuvant made from plant-derived saponin particles to enhance the immune response. Other components include various buffering agents and stabilizers such as phosphates, polysorbate 80, cholesterol, phosphatidylcholine, salts, and water for injection, with some ingredients used to maintain the vaccine's pH balance [36].

Side Effects

The Novavax vaccine may cause common adverse effects like tiredness, fever, headaches, arthralgia, nausea,&soreness at the injection site. In some cases, more serious reactions have been reported, including severe allergic responses, nerve-related symptoms like tingling or numbness, heart inflammation (myocarditis and pericarditis), and ringing in the ears (tinnitus) [37].

Effectiveness

The 2024–2025 Novavax vaccine is designed to target the JN.1 variant. While it isn't specifically matched to the KP.2 strain like the Moderna and Pfizer vaccines, Novavax reports that it generates a strong antibody response in contradict to several variants, with JN.1, KP.2, and KP.3. According to the CDC, the updated vaccines are expected to offer solid protection against the most common and emerging strains [38].

3) Inactivated Vaccines

Inactivated, or "killed," vaccines are formulated using viruses or bacteria that have been rendered non-infectious, meaning they cannot reproduce or cause illness. This is achieved by growing the pathogen in laboratory conditions and then inactivating it through physical or chemical methods to ensure it cannot cause disease.

Unlike live vaccines, which use weakened but still active forms of the pathogen, inactivated vaccines rely on the body's reaction to the non-living version of the microorganism. While modified live vaccines always trigger a stronger, longer-lasting body's reaction with fewer doses, inactivated vaccines usually produce a milder immune response. As a result, they often require additional doses or booster shots, along with adjuvants—materials that boost the body's reaction—for achieving optimal protection.Live vaccines are typically more effective in healthy individuals due to their strong and lasting resistance.Though, that aren'tapt for everyone. Persons including compromised resistance systems and elderly may be at increased risk from live vaccines and are often better protected with inactivated vaccines, which offer a safer alternative while still providing immune defence [39].

MECHANISM

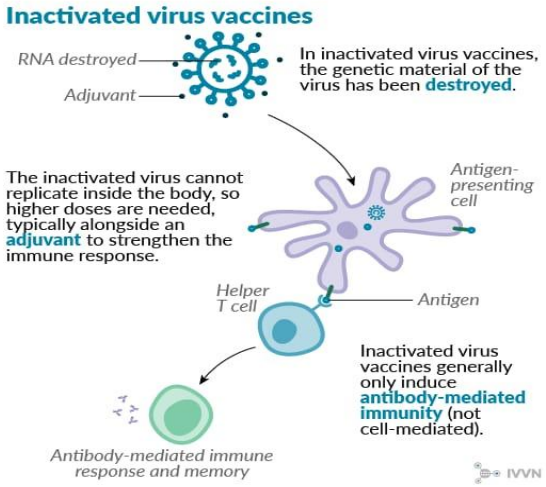

Figure: 07-Mechanism of inactivated vaccines

(a) Sinopharm Vaccine (BBIBP-CorV):

The Sinopharm COVID-19 inoculation, called BBIBP-CorV, was established by the Beijing Institute of Biological Products. It is one ofthe company's inactivated virus vaccines and was tested in Phase III clinical trials across multiple countries with participation from over 60,000 individuals.

Figure: 8: Sinopharm Covid Vaccine

Composition

The Sinopharm vaccine is produced by growing the WIV04 strain of SARrS-CoV-2 in Vero 81 cells. After inactivation,virus is purified and combined with aluminium hydroxide to boost the body's reaction. The inoculation doesn't contain preservatives or antibiotics and includes excipients like sodium chloride and disodium hydrogen phosphate [40].

(b) Sinovac Vaccine (CoronaVac)

Sinovac, established in China, is akilled COVID-19 inoculation similar in outline Sinopharm's BBIBP-CorV and Covaxin from India. It underwent 3rd phase researchprotocol in several nations, likeIndonesia, Turkey, Brazil, Chile, and the Philippines.

Figure: 09 Sinovaccovid Vaccine

Composition

CoronaVac is made using the CZ02 strain of the coronavirus, cultivated in Vero cells and then inactivated to ensure it cannot replicate. The virus is purified using specialized chromatography methods like IEC and SEC. An aluminium hydroxide adjunct is added to enhance the body's reaction. CN2 strain, chosen from clinical samples, was used during the vaccine's development [41].

(c) Bharat Biotech Vaccine (COVAXIN®)

COVAXIN is Bharat's 1st homegrown coronavirus inoculation, advanced by Bharat Biotech in the firm of the IndianCouncil of Medical Research and National Institute of Virology. It is based on an inactivated whole-virus platform using Vero cell technology.

Figure: 10 COVAXIN Vaccines

Composition

COVAXIN is formulated with 6 micrograms of inactivated SARrS-CoV-2. To boost immune response, it includes Al(OH)3 and imidazoquinolinone. A stabilizer, C8H10O2, is also part of the formulation. Although the virus is inactivated and cannot reproduce, it still prompts the body to develop immunity.

Side Effects

Common side effectslike redness, pain, itching, swelling at the site of administered. Some people may also experience fever, fatigue, headaches, muscle or joint pain, digestive problems like diarrhea or appetite loss, and respiratory symptoms such as a sore throat or nasal congestion. Other effects might include dizziness, skin rashes, weakness, allergic reactions, or swelling in the limbs [42].

Viralbased Vaccines

Viral based vaccines utilize altered viruses that transport congenital substance inside human nucleus, warningit to construct amino acid chain that activates body reaction. This technique involves delivering DNA that is converted into mRNA, leading to antigen production. By April 2021, six such vaccines had been approved—four for COVID-19 and two for Ebola. The strategy of using viruses as carriers began in 1972, with early developments including the insertion of hepatitis B antigen genes into the vaccinia virus.

Over the years, various viruses such as adenoviruses, retroviruses, and vaccinia viruses have been adapted as vectors for vaccines, with adenoviruses and vaccinia being the most widely used due to their strong immune-stimulating capabilities. Since the 1980s-especially after the vaccinia virus was first used as a vector in 1984-these platforms have been tested in clinical trials for vaccines against diseases like HIV, Zika, RSV, influenza, and malaria. This foundational research helped pave the way for viral vector-based COVID-19 vaccines [43].

Mechanism

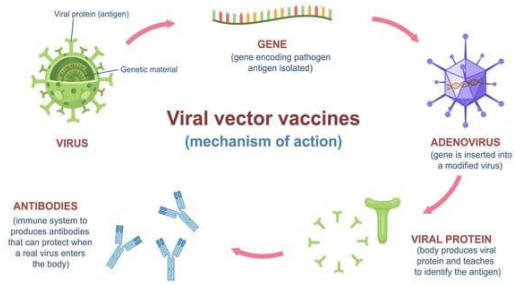

Figure: 11-Mechanism of Viral Vector Vaccines

(a) Oxford–AstraZeneca COVID-19 Vaccine: The Oxford–AstraZeneca corona vaccine, marketed as Covishield and Vaxzevria, is a viral based vaccine. Alteredfrom chimpanzee adenovirus (ChAdOx1) to distribute instructions for producing the coronavirus peplomer protein, triggering an immune response. Given through an intramuscular injection, the vaccine has shown about 76% effectiveness after the first dose and approximately 81.3% following the second [44].

Figure: 12-AstraZeneca covid-19 vaccine

(B) Janssen Corona Vaccine

The Janssen Corona vaccine, known as Jcovden, established by Johnson and Johnson Vaccines and its holding entity, Johnson & Johnson. This single-dose viral based vaccine utilises a defined virus called adeno virus (Ad26) to transport congenital instructions to coronavirus

peplomer protein, warning the body to produce protective antibodies. Its ability to be stored without ultra-cold temperatures makes it easier to transport and distribute [45].

Figure: 13 Johnson and Johnson corona vaccine

(b) CanSino Biologics corona vaccine

The corona vaccine progressedby CanSino Biologics in China a virus-based vaccine that utilise avirus called adenovirus to transport the gene of corona virus peplomer protein, triggering immunity. Intended for adults, it has demonstrated good safety and effectiveness in people aged 18 and above. The World Health Organization recommends its use particularly for vulnerable populations, including the aged people, medical staff, and immunosuppressed persons[46].

Figure 14: CanSinoBio COVID-19 VACCINE

Distribution of Corona Vaccine

12th of august, 2024, greater than 13.53 billion corona vaccine doses had been given globally, with about 70.6% of the world community receiving as a minimumsingle dose. Despite this progress, distribution remained unequal. By September 2022, just 22.3% of individuals in poor countries had undergo their initial dosage. Data from national health sources and "Our World in Data" provide insights into global vaccination trends, including full vaccination rates, first-dose coverage, and dosages given for hundred persons.

In 2020, at the onset of the COVID-19 pandemic, global organizations such as WHO and CEPI worked with governments, scientists, and pharmaceutical companies to coordinate vaccine distribution. A major concern was that countries producing vaccines might favor their own citizens or wealthier nations. To address this, experts pushed for fair access, stressing the need to prioritize healthcare workers and high-risk groups. In April 2020, the United Kingdom committed to partnering with over 20 nations and international bodies-Italy, France, Germany-to support inoculation development and ensure shared access to discoveries. The UK government stated that its citizens would not receive priority access to vaccines created at publicly funded British institutions.

Some pharmaceutical companies initially pledged to supply vaccines at reduced or break-even prices to meet urgent demand but signaled plans to adjust pricing later. This would help maintain profitability if routine or seasonal COVID-19 vaccinations became necessary and as governments began stockpiling for future use [47].

Developers of Covid-19 Vaccine: A number of pharmaceutical companies and research institutions played major roles in creating vaccines to combat COVID-19. These include:

Pfizer and BioNTech collaboratively produced the mRNA-based vaccine known as Comirnaty.

Moderna createdan mRNA vaccine called Spikevax.

AstraZeneca and Oxford University co-developed a viral vector vaccine distributed under the name Covishield in some regions.

Johnson & Johnson (Janssen Pharmaceuticals) developed the single-dose Janssen COVID-19 vaccine.

Bharat Biotech: An Indian company that produced Covaxin, an inactivated virus vaccine.

CoronaVac is a Chinese pharmaceutical establishment that advanced the inactivated coronavirus inoculation known as CoronaVac.

Sinopharm: The Beijing Institute, part of BIBP vaccine development, developed the BBIBP-CorV inactivated coronavirus vaccine in China.

Novavax: Novavax developed the protein-based coronavirusinoculation NVX-CoV2373, which is recognized as Covovax when produced by the Serum Institute of India [48].

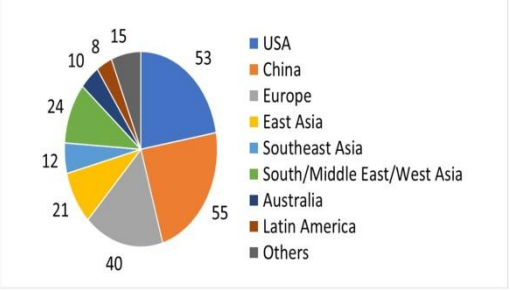

Figure: 15-COVID-19 VACCINE DEVELOPERS BY COUNTRY

Vaccine Cost

The pricing of corona virus inoculations varied significantly, liable to the manufacturer and agreements in place with each country.

Covishield (Oxford–AstraZeneca): Priced between ₹200 and ₹250 per dose in India.

Covaxin (Bharat Biotech): Cost the Indian government approximately ₹206 per dose.

Pfizer–BioNTech: In the United States, the cost per dose ranged from $110 to $130.

Moderna: Similarly priced in the U.S., with doses costing between $110 and $130.

Country/Region	Doses Purchased	Global Share (%)
European Union	1.585 billion	21.87%
India	1.5 billion	20.70%
United States	1.01 billion	13.93%
COVAX Initiative	700 million	9.66%
Canada	358 million	4.94%
United Kingdom	357 million	4.92%
Indonesia	338 million	4.66%
Japan	290 million	4.00%
Brazil	196 million	2.70%
Mexico	146.8 million	2.03%
Australia	114.8 million	1.58%
Chile	84.4 million	1.16%
South Korea	64 million	0.88%
Egypt	55 million	0.76%
Turkey	50 million	0.69%
Argentina	47 million	0.65%
Bangladesh	30.1 million	0.42%
Thailand	26 million	0.36%
Hong Kong	17.5 million	0.24%
Israel	14 million	0.19%
Malaysia	12.8 million	0.18%
Switzerland	10.5 million	0.14%
Venezuela	10 million	0.14%
Morocco	10 million	0.14%
Peru	9.9 million	0.14%
Ecuador	9 million	0.12%
Costa Rica	4 million	0.06%
New Zealand	3.5 million	0.05%
Panama	3 million	0.04%
Philippines	2.6 million	0.04%
Kazakhstan	2 million	0.03%
Lebanon	2 million	0.03%
Kuwait	1 million	0.01%

Janssen (Johnson & Johnson): Estimated at around $10 per single-dose shot.

CoronaVac (Sinovac): Approximately $30 per dose.

BBIBP-CorV (Sinopharm): Costed roughly $60 per dose [49].

Global Distribution:

As of August 2024, over 13.5 billion corona virus vaccine inoculation dosages had been distributed across the globe, with about 70.6% of the world'speoplehaving sustained at least one dose. Countries and alliances that acquired the largest quantities of vaccines were among the top in procurement efforts [50].

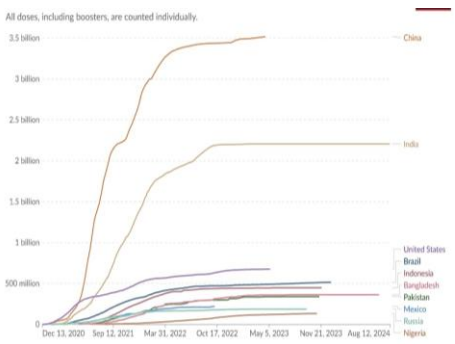

Figure: 16-Doses Administered Globally

Conclusion:

Corona vaccines have played a vital role in loweringeffect of the widespread by preventing severe illness, hospitalization, and death. Advanced preparations like messenger RNA vaccines based on mRNA technology, have shown strong effectiveness. Booster shots have further improved protection, especially against new variants. Although most side effects are minor, safety continues to be closely observed. Overall, vaccines remain essential in managing and curbing the spread of COVID-19 worldwide.

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Conflict OF Interest

Authors are declared that no conflict of interest.

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Informed Consent and Ethical Statement

Not Applicable

Author Contributions

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