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How successful are some existing vaccinations in preventing COVID?

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Abstract. The COVID-19 pandemic has placed immense pressure on the global healthcare sector. The rapid development of vaccines has significantly alleviated the rampant spread of the COVID-19 virus. This research paper aims to determine the success rates of various types of vaccines in preventing COVID. It will first list the brand of the vaccine, then identify the type of vaccine, and describe how the vaccine functions in providing the body immunity from the coronavirus, and finally it will compare the vaccines' success rates in preventing the patient from being infected with COVID. Coronavirus vaccine types include recombinant subunit vaccines, which injects a part of the virus into the body; viral vector vaccines, which gene vaccines and whole virus vaccines. This comprehensive review will assist us in gaining a deeper understanding of COVID-19 vaccines and provide a foundation for subsequent efforts to further optimize vaccine development.

Keywords: COVID-19; COVID-19 vaccines; COVID-19 vaccine success rates; WHO Emergency Use Listing.

1. Introduction

Since the global outbreak of COVID-19 at the beginning of 2020, the coronavirus has left a profound impact on societies worldwide, infecting an astonishing 586 million individuals and tragically claiming the lives of 6.42 million people. This pandemic has prompted an urgent and unprecedented global response, with countries racing against time to develop and distribute vaccines. Notable examples include the Oxford/AstraZeneca vaccine, proudly made in the UK; the Pfizer-BioNTech vaccine, a product of collaboration between the United States, Germany, Belgium, Ireland, and Croatia; and the Sinovac-CoronaVac, developed in China. As a result, a significant portion of the world's population has received vaccines, with an estimated 4.88 billion people, or 62.6% of the global population, having received at least one dose. However, the key question that looms over these achievements is the effectiveness and efficacy of these vaccines, which remain subjects of ongoing research and debate.

Vaccine effectiveness is a complex metric that assesses how well a vaccine performs in real-world conditions, considering factors like the type of vaccine, the prevalence of the virus in the community, and the emergence of new variants. To comprehend vaccine effectiveness, it is essential to distinguish between two key concepts: vaccine efficacy and vaccine effectiveness. Vaccine efficacy refers to how well a vaccine works in controlled clinical trials under ideal conditions, while vaccine effectiveness measures its real-world performance.

The Oxford/AstraZeneca, Pfizer-BioNTech, and Sinovac-CoronaVac vaccines have demonstrated varying levels of efficacy in clinical trials. For example, clinical trials for the Oxford/AstraZeneca vaccine showed an efficacy rate of around 70%, while the Pfizer-BioNTech vaccine exhibited an efficacy rate of approximately 95%. Sinovac-CoronaVac, on the other hand, reported an efficacy rate of around 50% in clinical trials. However, these figures may not fully represent real-world effectiveness, where vaccine performance can be influenced by factors such as the timing of vaccine administration, the prevalence of virus variants, and individual health conditions.

Given the critical importance of understanding vaccine effectiveness, this paper aims to provide a comprehensive evaluation of the vaccines currently approved by the World Health Organization

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(WHO) for Emergency Use Listing (EUL). The WHO plays a pivotal role in assessing vaccines' safety and efficacy, offering guidance to countries and facilitating global vaccination efforts.

The Oxford/AstraZeneca vaccine, for instance, has shown promise in protecting individuals against severe COVID-19 outcomes, reducing hospitalizations and deaths. However, concerns have arisen about its efficacy against certain variants of the virus. Similarly, the Pfizer-BioNTech vaccine has demonstrated remarkable efficacy in clinical trials but may face challenges related to cold storage requirements and global distribution. The Sinovac-CoronaVac vaccine has been utilized extensively in many countries, especially in Asia and South America, but questions linger about its overall effectiveness, particularly in the face of emerging variants.

This paper will delve into the latest data and research findings to assess how these vaccines are performing in real-world scenarios. By examining factors such as vaccine breakthrough infections, variant-specific protection, and population-level impact, we aim to provide a comprehensive overview of the current state of vaccine effectiveness. It is essential to acknowledge that the landscape of COVID-19 is continually evolving, with new variants and scientific discoveries shaping our understanding of vaccine performance. This evaluation will contribute valuable insights to the ongoing global efforts to combat the pandemic and guide vaccination strategies for the future.

2. Various Vaccines

2.1 How Vaccines Function

Coronavirus disease 2019 (COVID-19) is the official name given by the World Health Organization (WHO) to the disease caused by SARS-CoV-2, the new coronavirus that surfaced in Wuhan, China in 2019 and spread around the globe. It was determined by the WHO to be a global pandemic early the next year[1]. COVID-19 can cause pneumonia, which is when the virus affects the pneumocytes in the lungs' alveoli, causing inflammation and filling the alveolus with fluid; bronchitis, inflammation of cells lining the bronchus, causing coughing and chest pain; and sepsis, where the infection invades other organs and kills tissue cells by spreading through the bloodstream. The patient may also develop acute respiratory distress syndrome, ARDS, if pneumonia progresses to a fatal state, which will result in organ failure due to the lack of oxygen provided by the lungs.[2] Additionally, there is a chance that the patient will get superinfection, which is when the body is more susceptible to other disease resulting from an immune system weakened by COVID infection.[3]

Vaccines aim to prevent these symptoms by delivering support to the bodies' immune system. The immune system consists of three types of white blood cells: T-cells, B-cells, and macrophages. The virus is considered an antigen upon entering the body.[4] Each B cell can only recognise only one individual type of antigen, and the cell activates when it encounters that specific antigen. When activated, the B cell divides rapidly into numerous copies. These "clone" cells become either plasma cells or memory B cells. The memory B cells remain inactive at this point, until another later encounter with the antigen, caused by a reinfection by the same bacteria or virus, results in them dividing into a new population of plasma cells to carry out the memory phase of the B cell response. This is how immunity to a certain disease is gained. The plasma cells produce colossal sums of antibodies, which is a protein that is produced by plasma cells after stimulation by an antigen. Antibodies can be found in a person's bodily fluids, including a mother's breast milk, which means these antibodies can be passed to infants so that they can gain some immunity.[5]

Vaccines vary in content, but all contain weakened or otherwise harmless molecules that helps the body produce memory T-cells and B-cells, which will memorize the virus and provide the body with temporary immunity. However, there is a time gap between taking a vaccine and acquiring immunity, which typically lasts several days to a fortnight. This time gap leaves the vaccine taker vulnerable to the virus. Sometimes vaccine takers may develop symptoms of a fever in correspondence to the body developing immunity.

If the person is infected with and survives the coronavirus, he or she will develop a more long-lasting immunity to that virus mutation.[6]

2.2 Review of Various Vaccines

The World Health Organisation (WHO) has an Emergency Use Listing Procedure (EUL), a "tragedy procedural" which resolves the issue of using a vaccine in an emergency scenario, based on all obtainable data on how effective and safe the vaccine is and its production cost. Vaccines are put through various examinations to ensure they meet acceptable standards. These trials ultimately determine whether the magnitude and urgency of the emergency in question justifies the usage of a risky vaccine. However, in emergencies countries are allowed to use non-WHO approved medicine.[7]

Table 1. As of 12 January 2022, the following vaccines have obtained EUL and other potential vaccines that are in the process of development and approval all belong to 4 platforms as shown below.[8]

Platforms	WHO Approved Vaccines (as above)
• Recombinant Subunit Vaccines	• Novavax (NVX-CoV2373)
• Viral Vector Vaccines	• Janssen/Ad26.COV 2.S • AstraZeneca AZD1222
• Gene Vaccines	• Moderna (mRNA 1273) • Pfizer/BioNTech (BNT162b2)
• Whole Virus Vaccine	• Sinopharm (BBIBP-CorV) • Sinovac-CoronaVac • Bharat Biotech BBV152 COVAXIN

3. Vaccine success rate

3.1 Subunit Vaccines

3.1.1 Mechanism

Subunit vaccines inject a partial pathogen into the body, which the immune system kills to gain immunity.

Polysaccharide vaccines, a subcategory of the subunit vaccine, provides immunity for bacteria, which is encased in a "coating" prior to entering the body. The "coating" is what the immune system responds to. Protein-based vaccines allow you to make a protective response against a protein on the surface of a virus, against a protein on the surface of a bacteria, or against a secreted toxin. Many coronavirus subunit vaccines are protein-based. In this case, it is the protein components of the bacteria or virus, such as the spike protein on the surface of the coronavirus, that activates the immune system response.

After injection, antigens trigger the production of antigen-specific antibodies, which are responsible for recognising and neutralising foreign substances. Basic components of recombinant subunit vaccines include recombinant subunits, adjuvants and carriers. Additionally, recombinant subunit vaccines are popular candidates for the development of vaccines against infectious diseases (e.g. tuberculosis and dengue)

3.1.2 Manufacture

Subunit vaccines can be made one of two ways: from the original pathogen or recombinantly.

Recombinant vaccines combine different organisms and pathogens to make an antigen. These vaccines are biological preparations that are composed of multiple microbial organic material combined using DNA technology in vitro. The target antigen gene infects a cell's nucleic acid so that the cell produces the target protein in large quantity, then the protein is decontaminated, and substances that supplement the body's immune response to the vaccine are added to make vaccines

preparations.[9] Receivers of recombinant vaccines gain active acquired immunity to infectious diseases, as opposed to passive acquired immunity typically gained from vaccine, meaning that this type of vaccine gives better immune protection Subunit vaccines contain only specific antigenic parts such as the proteins on the surface of the virus, different from containing the whole pathogen in whole virus vaccines. [10]

3.1.3 Features

Because the pathogens in the vaccine are not active, there is no risk of introducing the disease into the host, guaranteeing a safe and steady gain of immunity than the whole-pathogen vaccines. This makes them ideal for children, the elderly, and those with a faulty immune system, who should not receive vaccines with more severe side effects. The development procedures for this vaccine also has a well-established technological basis.

The disadvantages include being relatively complex to manufacture compared to some vaccines, such as the mRNA vaccines. People who take this vaccine also require more booster shots and adjuvants to help the immune system.

One representative product of a subunit vaccine is the Novavax vaccine, made by the American pharmaceutical company Novavax.

A large number of COVID-19 vaccines have taken the recombinant subunit route. The overall protection by subunit vaccines in clinical trials is higher than that of inactivated vaccines. At present, more than 50 protein subunit vaccines are under development.

3.2 Viral Vector Vaccines

3.2.1 Mechanism

A viral vector vaccine is a vaccine that injects a modified and harmless virus—not the COVID-19 virus— into the upper arm. It is unique in that it uses the body's own mechanisms to produce its own antigens, instead of introducing a foreign antigen directly.[11] The harmless virus is used as a transmitter to deliver genetic material coding to the cells. With the virus, the cells now develop spike proteins, the same proteins found on the surface of the COVID-19 virus. The immune system then targets the cells for destruction and in the process gain temporary immunity from Coronavirus.[12]

These vaccines are safer, but less effective for people with damaged immune systems. Therefore the patient might need to take more than one dose to ensure full protection against the virus, especially if that patient has a weakened immune system to start with.[13]

3.2.2 Manufacture

Viral vector vaccines production requires modifying a virus to contain the target antigen gene. Most viral vectors are stripped of the genes that allow normal viruses to duplicate, but some have these genes included to ensure a wider immune response.

Viral vector vaccines are difficult to manufacture in large quantities since the virus strains are typically grown on underlying substances that are difficult to procure and expensive to use. However, scientific advances are opening the possibility of viruses being grown individually in large bioreactors. The viruses also risk escaping containment during the various stages of the vaccine development process. This risk, coupled with the exponential growth of the development cost of the vaccine with every stage, makes viral vector vaccines very arduous to manufacture.[14]

3.2.3 Features

Viral vector vaccines induce a very strong immune response from the receiver, and the time-honored technology in this vaccine field is highly recognized. The most often used viral vector is the adenovirus vector, which has the advantage of a high transduction efficiency, transgene expression, broad viral tropism. This vaccine can also infect both dividing and non-dividing cells. However,

people who have been exposed to and therefore already have immunity to adenoviruses or other viruses used in these vaccines would have a less effective response when taking the vaccine.

Notable viral vector vaccines include Janssen COVID-19 vaccine, aka the Johnson & Johnson vaccine, from the Belgium pharmaceutical company Janssen which is owned by the Johnson & Johnson company; and the AstraZeneca vaccine, manufactured by the British / Swedish company AstraZeneca.

The World Health Organization reports that the Janssen COVID-19 vaccine has an efficacy rate of 72% during the initial two months in the United States if only one dose is given to the patient. This rises to 94% if they get a second dose two months after the first dose. If they do not get a second dose the chance of getting COVID will rise to 50%.[15]

The AstraZeneca vaccine has an 82% efficacy rate if the two vaccine doses are given more than 12 weeks apart. If the doses are given within 12 weeks the efficacy rate drops to 63%. One single dose of AstraZeneca vaccine also has an efficacy rate of around 63%.[16] Clinical trials of more than 30 viral vector vaccines are still underway around the world.

3.3 Gene Vaccines

3.3.1 Mechanism

Gene vaccines, including the DNA vaccines and mRNA vaccines, introduce a specific DNA or mRNA sequence into the recipient's cells. This gene instructs the cells to create proteins that are identified as antigens, in a method very similar to viral vector vaccines. However, instead of a harmless virus, a mRNA or a DNA string is injected and brought into the cells.[17]

3.3.2 Manufacture

mRNA vaccines are growing popular as a substitute for conventional vaccines for their accuracy, safety, and cost-efficiency, which is why many companies chose to develop mRNA vaccines during the Covid-19 pandemic. The increased demand for mRNA vaccines results in large scale production of mRNA vaccines, which involve multiple convoluted steps, including an in vitro transcription of the antigen-coding genes from a DNA into the mRNA. The mRNA has to relay a gene code to the cell's DNA for it to create the antigens. It is a simple matter of transporting the mRNA into the cell, as it only needs to be designed to infiltrating the cell's membrane. The cell's biological processes will take care of the gene coding and antigen assembly from that point on.[18]

3.3.3 Features

The advantages of gene vaccines over traditional vaccines are ease of design, fast speed and low cost of production. Moreover, gene vaccine can induce both cellular and humoral immunity. Some mRNA vaccines have the disadvantage of requiring ultracold storage before distribution, while others are making improvements to lift the restriction. The WHO has approved of two mRNA vaccines, the Moderna vaccine made by the American biotechnical company Moderna Inc, and the Pfizer-BioNTech COVID-19 vaccine, which was a collaboration between the pharmaceutical companies Pfizer, from Germany, and BioNTech, from America.

3.4 Whole Virus Vaccine

3.4.1 Mechanism

Whole virus vaccines are categorized as inactivated vaccines and live-attenuated vaccines. An inactivated vaccine is a vaccine with of dead lab-grown virus particles that, being dead, pose no danger to the body. Live-attenuated vaccines use weakened COVID-19 viruses that are still alive, making actual infection with the disease highly unlikely. The immunogenic content of whole virus vaccines induces an immune response dominated by humoral immunity or antibody-mediated immunity that neutralizes and removes the pathogen.

3.4.2 Manufacture

Pathogens for whole virus vaccines are grown under controlled conditions and are killed using chemical or physical methods such as formaldehyde or heat, then purified and added adjuvants to make vaccine preparations. This measure increased the safety of the killed vaccines while maintaining their antigenicity due to the preserved structure of the antigens.

3.4.3 Features

Whole virus vaccines, especially inactivated vaccines, have a high safety profile and are easy to produce and transport on a large scale. It is a mature technology that has been used for hundreds of years. Therefore, it is usually a prioritized route of vaccine development in immediate response to the outbreak of a pandemic. The drawbacks of inactivated vaccines include the relatively low level of induced immunity and the large dosage required for each immunization. To generate enough protection, multiple inoculations may be required. Some of the more widely-used whole virus vaccines are the Sinopharm vaccine, manufactured by the Chinese National Pharmaceutical Group Corporation; Coronavac or Sinovac, manufactured by the Chinese company Sinovac Biotech; and Covaxin, manufactured by Indian pharmaceutical company Bharat Biotech.

The above two vaccines have been officially approved for use by the WHO, and large-scale vaccination has been carried out in Asia, Africa, South America, and Europe. Russia, India, Kazakhstan, and Iran have also successfully developed their own inactivated vaccines for COVID-19 that are approved by at least one governmental health sector for use in the general population. There are also more than 20 inactivated vaccines under development at clinical trial stage.

3.5 Table for success rates

Table 2. Efficacies of COVID-19 vaccines based on clinical trial results[19]

Vaccine	Protection against all symptomatic disease after 1st dose in the USA	Protection against all symptomatic disease after 2nd dose in the USA
AstraZeneca	63% (At least 2 weeks after vaccination)	63% (if there is less than 12 weeks between the two doses) 82% (if more than two weeks)
Moderna	85% (66%-93%)	95% (90%-97%)
Pfizer-BioNTech	82% (76%-87%)	94% (90%-97%)
Sinopharm	n/a	78% (65%-86%)
Sinovac	n/a	51% (36%-62%)
Janssen/Johnson& Johnson	72%	94%

4. Conclusion

The COVID-19 pandemic has placed immense pressure on the global healthcare sector. The rapid development of vaccines has significantly alleviated the rampant spread of the COVID-19 virus. These vaccines, including the Oxford/AstraZeneca, Pfizer-BioNTech, and Sinovac-CoronaVac, represent vital tools in our fight against the pandemic.

This research paper aims to determine the success rates of various types of vaccines in preventing COVID. It will first list the brand of the vaccine, then identify the type of vaccine, and describe how the vaccine functions in providing the body immunity from the coronavirus, and finally, it will compare the vaccines' success rates in preventing the patient from being infected with COVID. These

vaccines employ different mechanisms to stimulate an immune response, ranging from recombinant subunit vaccines that introduce a part of the virus into the body to viral vector vaccines and whole virus vaccines.

By examining real-world effectiveness, we seek to bridge the gap between clinical trial data and vaccine performance in the field. This comprehensive review assists us in gaining a deeper understanding of COVID-19 vaccines and their role in controlling the pandemic. It underscores the importance of monitoring and adapting vaccination strategies as new variants emerge and scientific knowledge evolves. Ultimately, this research provides a foundation for subsequent efforts to further optimize vaccine development, distribution, and administration, ensuring a more effective response to current and future global health threats.

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