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Vaccines, the Only Way to Herd Immunity: Challenges and Solutions

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Abstract: The novel coronavirus is still spreading around the world. Vaccines play an important role in curbing the spread of novel coronavirus. Herd immunity through vaccines is the only way to eliminate new peaks. However, herd immunity has not yet been achieved. Therefore, in this article, we summarize and analyze the factors that affect the implementation of vaccines and the realization of herd immunity and then put forward relevant suggestions to contribute to the completion of herd immunity.

1. Introduction

Coronavirus disease 2019 (COVID-2019) has spread rapidly worldwide, and SARS-CoV-2 can be transmitted from infected people who are asymptomatic and may cause a pandemic within a week. It is well known that the most effective way to eliminate the disease is vaccination, which is the most effective and economical way to prevent and control infectious diseases[1-2]. Although the traditional vaccine development process is quite long, more than a dozen COVID-19 vaccines, based on mRNA, viral vector, inactive, and protein, have been approved for use in about a year.

For any licensed vaccine, efficacy and duration of protection are key issues. Many vaccines prevent disease by preventing the person receiving the vaccine from being infected and preventing the spread of infection from one person to another.

The COVID-19 vaccine that has been vaccinated is very effective, but herd immunity needs to be achieved to end the pandemic. Herd immunity and community immunity refer to the indirect protection of unvaccinated people by increasing the universality of immunity in the population. Herd immunity is the ultimate goal of all countries in fighting the novel coronavirus epidemic, and vaccines are the best plan to achieve herd immunity.

Therefore, in this article, we summarized and analyzed the factors that affect herd immunity in implementing vaccines and other measures assisting vaccine implementation in achieving herd immunity to provide some valuable suggestions for vaccine implementation and herd immunity.

2. Current status of vaccination in various countries

The distribution of COVID-19 vaccines and vaccination coverage rates vary from country to country. See Table 1 [2] for the situation in all parts of the world, including the problem in developed and developing countries with large populations. From the three factors of vaccination rate, strict index, and confirmed cases, the current situation of the novel coronavirus epidemic in various places can be seen. China has a relatively small number of confirmed cases due to its high vaccination rate and strict restrictions. Russia is currently experiencing increased epidemics due to its low vaccination rate and less stringent limits.

Although a vaccine with an acceptable duration of effectiveness is the only possible long-term pandemic withdrawal strategy, immunization must be swiftly absorbed and reach a high level of coverage in a short amount of time to have an early influence on the epidemic's growth [3]. Most portions of the United States followed Israel's rapid vaccination plan. Eight months later, in August 2021, over 66 percent of New York State's population had been properly vaccinated [4].

Table 1. Vaccine status table around the world.

country	Vaccination rate1	Stringency Index2	Confirmed cases3
China	77.6% [5]	76.39	0.03
Japan	77.1% (70.45,6.65)	47.22	2.24
Brazil	74.17% (54.3,19.87)	40.28	57.20
United States	65.61% (56.73,8.88)	56.02	207.29
India	51.76% (22.23,29.53)	50.46	9.04
Russia	36.23% (32.83,3.4)	54.17	245.76
Philippines	25.06% (19.23,5.83)	74.54	43.07
Bangladesh	24.22% (12.38,11.84)	46.30	2.67
Egypt	16.06% (8.00,8.06)	43.52	8.50
Nigeria	2.61% (1.36,1.25)	50.93	1.21

1: Total (Share of people fully vaccinated against COVID-19, Share of people only partly vaccinated against COVID-19)

2: Stringency Index: school closures, workplace closures, and travel bans

3: A 7-day rolling average

3. Vaccine implementation factors affecting herd immunity

The vaccination rate and effectiveness of the vaccine, the immune efficacy produced by the vaccine, and the cost of vaccine implementation all directly affect the realization of herd immunity. Governments need to pay attention to the problems caused by related factors. Propose some solutions to the problems that arise.

3.1 Vaccination rate and effectiveness

Only after the cumulative vaccination rate reaches a certain level, the local protection of herd immunity can play a role and reduce the incidence. Shen et al. [6] found that 80% of effective vaccines require 48-78% vaccination coverage, while 100% of effective vaccines require 33-58% vaccination coverage to curb the spread of COVID-19, indicating a low vaccination rate. Low-efficiency and low-efficiency vaccines cannot contain the spread of the COVID-19 pandemic. When the vaccination rate reaches the turning point level, all vaccines currently vaccinated in each country can effectively prevent the spread of COVID-19, even if the vaccination rate is below the herd immunity threshold. To avoid the recurrence of COVID-19 infection, the vaccination plan should follow an intensive strategy to ensure that the turning point reached quickly.

According to stochastic computational simulation, the peak epidemic magnitude in the population is heavily influenced by the network topology. Regardless of the network topology, assuming vaccine efficiency is at least 80% in the mass vaccination plan, at least 70% of the specific population needs to be immunized to achieve herd immunity. Higher vaccination coverage is required if vaccine efficacy is reported at a lower level in practice. The simulation shows that the "vaccination loop" strategy of vaccinating susceptible contacts and contacts will prevent a new wave of COVID-19, and a high proportion of the population is vaccinated [7].

However, the mutation of the virus affects the effectiveness of the vaccine. The state of emergency announced by Japan failed to change the growth rate trend, and mutations in the country caused the three epidemic peaks. The chaos in Japan will continue for some time, partly because there is no effort to identify asymptomatic carriers, and the details of the vaccination plan have not yet been determined [8].

The mutation of SARS-CoV-2 will reduce the transmission ability and increase the infectivity[9] and reduce the protective effect of antibodies, which exist after infection, vaccination, or antibody treatment. The alpha variant causes an increase in the R-value, so the infectivity increases by 75%; the beta variant (B.1.351) reduces the ability of the antibody to neutralize SARS-CoV-2; the AstraZeneca vaccine almost has no protection; the transmissible strains of gamma variants (P.1 or B.1.1.28.1) maybe 1.7 to 2.6 times more than the strains previously circulating in Brazil; the risk of death of gamma variants also seems to increase adult 1.2 to 1.9 times, the risk of death for young patients increased by 5 to 8 times. Delta variants (B.1.617) are dominant in most countries today. Vaccination is more likely to spread disease through Delta variants than unvaccinated, but the fatal consequences are less common. The increased virulence of SARS-CoV-2 VOCs will result in a more significant and more deadly pandemic [10].

The effectiveness of the mRNA-1273 (Moderna) vaccine against any serious, critical, or fatal COVID-19 disease caused by any SARS-CoV-2 infection (mainly B.1.1.7 and B.1.351) was 81.6 % for the first dose and 95.7 % for the second dose, the mRNA-1273 vaccine was effective against B.1.1.7 and B.1.351 infections (regardless of whether they are symptomatic or asymptomatic) and any COVID-19 hospitalization [11].

3.2 Immunity produced by the vaccine

Herd immunity isn't a set number. Herd immunity cannot be immediately translated from the fraction of persons who have been vaccinated. In theory, it is unaffected by the main reproduction number (R0), but it can be influenced by the appropriate regeneration number (Re) at a specific time and location. Herd immunity is not required to suppress the epidemic if rigorous social distancing measures are applied and re falls below 1 because the pandemic will decline on its own. In contrast, if the modified R0 is higher than the original virus, herd immunity is unlikely.

Immunized and vaccinated individuals have similar endowments in plasma anti-RBD IgGs. Still, the different ways the virus enters may be the possible reason for not combining immunization and vaccinated individuals to achieve immunity to the target group [12]. However, the only reliable window for evaluating COVID-19 disease is serum IgG for people who have been vaccinated and immunized. Paper by Callegaro et al. also shows that among subjects who have experienced asymptomatic SARS-CoV2 infection or COVID-19 disease, even if a single dose of the vaccine improves IgG immunity, it will also lead to the production of large amounts of antibodies, which is significantly higher. In the naive population of SARS-CoV2 [13].

Achieving herd immunity means that considering that the range of asymptomatic people infected with SARS-CoV2 is the widest, and their anti-RBD IgG can solve COVID-19 immunologically, the vaccination campaign may be more cost-effective, more straightforward, and more effective. More time-saving. In addition, it can also solve people's worries about vaccines so that everyone has the opportunity to enjoy their rights [14].

An age-stratified exposure model should be considered to calculate the population immunity level. South Korea has explored solutions to achieve theoretical herd immunity under different age immunization scenarios and found that the risk of COVID-19 infection among young people is lower than that of the elderly. It is recommended that vulnerable groups (especially the elderly) be vaccinated to restore normalcy [15]. The immunity of the population is obtained through natural infection and vaccination. Because of the uncertainty of unreported cases (including asymptomatic infections), the actual number of conditions throughout the pandemic and the population immunity level achieved so far in the United States are still there are doubts. A study estimated the overall and age-specific immunity levels to COVID-19, highlighting the need to speed up vaccination to prevent the evolution of other waves and new variants of COVID-19 and shorten the U.S. pandemic control schedule. At least until the population's immunity is high enough to control the pandemic, adherence to non-pharmacological interventions, such as masks and functional testing, should be encouraged [16]. Indeed, on June 1, 2021, the United Kingdom (U.K.) stated that there had been no coronavirus deaths since the outbreak began. The United Kingdom has one of the highest immunization rates globally, and it continues to prioritize vaccination for the elderly [17].

3.3 Cost and implementation difficulties

Production, logistics, the cold chain, and actual vaccine management are all huge vaccine issues [18]. According to the World Health Organization, nearly half of all vaccines will be discarded owing to supply chain temperature control [19]. As a result, vaccination delivery in many low- and middle-income nations, particularly in rural and isolated populations, necessitates international national and robust supply chains.

The pandemic's fast finish is far from assured. The early delivery of vaccines is expected to modify the game's rules, yet vaccination promotion has long been a huge difficulty around the world. Many governments are willing to assure vaccination doses despite a restricted global supply, under pressure to prevent domestic diseases. Because the impact of the vaccine supply chain extends far beyond those who work directly with them, scientists and decision-makers in the vaccine industry must understand the impact of their work on the supply chain [20]. Few people can get enough supply for their population, while others have to deal with the surge of infections with little protection from vaccines. Because there is a lack of global coordination, new viral types may arise more easily and acquire the upper hand. A mid-term study of the COVID-19 pandemic's macroeconomic repercussions was done. The median output loss in 2020 is predicted to be around 6.5 percent, and by the end of 2021, this gap is expected to be decreased to around 4% of the pre-pandemic trend [21].

A new mixed-integer linear programming (MILP) model is proposed, which can simultaneously solve the best plan for the COVID-19 vaccine supply chain and the best project for daily vaccination in available vaccination centers, generate information about the number of transfers between locations and the central hub as well as the inventory profile of the vaccination center and the best decision of the daily vaccination plan of the vaccination center of the supply chain network. This model aims to minimize the total cost, and the efficiency of the distribution network is improved, thereby helping to combat COVID-19 Mass vaccination campaigns [22].

3.4 Suggested measures

High vaccination rates are crucial to ensuring the highest possible herd immunity is getting closer, and the pandemic is under control. Even with reduced protection against mild and moderate diseases, vaccination usually provides excellent protection against life-threatening diseases and fatal disease processes. Increasing the daily vaccination rate will accelerate the improvement of the population's immunity and reduce hospitalizations and deaths, even if the vaccine against immune-evading variants is less effective when an infection occurs [23].

Understanding the epidemiology and guiding public health responses required mathematical modeling, which included (1) calculating herd immunity thresholds and assessing their limitations; (2) confirming that nascent vaccines can prevent serious diseases, infections, and transmission; and (3) confirming that nascent vaccines can prevent serious diseases, infections, and transmission. (3) evaluating the best vaccine distribution strategy given supply and availability constraints; and (4) determining that VoC is more transmissible and lethal than previously transmitted strains, and that immune escape could impair vaccine-induced herd immunity. The models aided us in anticipating and planning for COVID-19 epidemiology's next stages (and other diseases). From the early stages of the pandemic, modeling could characterize key epidemiological features, help determine when and what kind of restrictive measures should be used to control epidemics [24-27], and clarify social interactions to predict the consequences of reopening schools [28-29].

4. Other measures assisting vaccine implementation

Perceived risk-inducing actions and preventive measures are the most significant ways to stop the disease from spreading further before distributing vaccinations. These include case testing and isolation, contact tracing and isolation, social distancing and masks, avoiding frequent touching of the eyes, nose, and mouth, cleaning surfaces that have been touched regularly, wearing masks, maintaining social distancing, and seeking medical advice for symptoms like a sore throat, fever, or shortness of breath [30-31]. However, when voluntary action is insufficient, most governments are forced to establish stringent regulations and steps to stop the disease from spreading further. Many governments around the world are still struggling to put these rules into effect. Healthcare professionals and government agencies have created strategies to raise awareness, improve knowledge, and reinforce preventive measures to reduce the spread of illness since the virus's debut [32].

New Zealand simulated the potential impact of the vaccination program on open borders. It found that vaccination of high-risk groups will reduce hospitalizations and deaths and open borders compared to reducing transmission. With highly effective vaccines and high total intake, opening borders will increase the number of cases, hospitalizations, and deaths. Other public health and social measures are still needed to respond to the pandemic [33] effectively.

The impact of masks on the epidemic is immediate, while vaccination has a delayed effect, especially in the case of long-term implementation. Preemptive early mandatory use of masks is more effective than delayed use of masks, but even delayed use of shows will reduce the number of cases and deaths by more than 20%. From the beginning of the outbreak, at least 50% of people wear masks, and the popularity curve is suppressed, but when the mask-wearing rate drops to 30% or less, the popularity curve will surge. As the vaccine is slowly introduced within five months at an absorption level of 20% to 70%, it is still necessary to use non-profit institutions and significantly impact epidemic control. Shen [6] shows that, without covers, 50% of effective vaccines will not suppress infection under low vaccination coverage. To avoid additional conditions from the COVID-19 pandemic, the government should require strict NPI (Non-pharmaceutical interventions) measures.

5. Conclusion

This paper summarized and analyzed the vaccination rate and effectiveness, the vaccine's immune effects, implementation cost, and the impact of other non-drug measures combined with the vaccine on herd immunity. We suggest that epidemiological models might be used to help humans fight the epidemic comprehensively. In the future, with the continuous deepening of vaccine development and the constant optimization of related measures, herd immunity will eventually be realized.

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