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Herd Immunity: A Major Advantage or A Major Challenge to Achieve for the COVID-19 Pandemic

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Abstract

COVID-19 caused by the novel SARS-COV2 has been causing worldwide panic in recent times. Global epidemiological findings have shown numerous new cases being reported daily as well as drastic mortality rates. It is the need of the hour to plan out strategies to cope with this ongoing pandemic. Herd immunity has been used as an effective approach for years during epidemics and can prove to be a major advantage in controlling the spread of the disease. Various models have been studied using mathematical estimates to find out how herd immunity can be achieved as well as to predict risks involved in doing so. The current scenario where there are no efficient vaccines available has also been taken into consideration. It is important to take all these facts into consideration to come to a valid conclusion of whether achieving herd immunity can be beneficial or impractical.

Key Words: *COVID-19, SARS-COV2, herd immunity, vaccination, pandemic*

Introduction

The recently emerged COVID-19 or the so called coronavirus disease is caused by Severe Acute Respiratory Syndrome- Coronavirus 2 (SARS-COV2) and is a deadly disease of recent times that is of major health concern throughout the world.(1) Globally, as of September 2020, there have been approximately 31,370,000 cases that are confirmed of COVID-19, including 966,000 deaths, reported to WHO.(2) The rising number of new cases and the level of mortality across nations makes it a major concern to find suitable means to flatten the curve of the disease and reduce mortality significantly. Various methods to deal with this pandemic are under development, including finding new treatment measures to improve symptoms, isolation of infected individuals to prevent spread, promoting disinfection measures, promoting social distancing and vigorous research to create an effective vaccine.

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“Herd immunity or community immunity is a type of immunity that occurs when a portion of the population is immune to a certain disease and provides protection to non-immune individuals in that population.”(3) Herd immunity can be achieved by vaccination or by natural immunity being generated after being infected by the pathogen. It can play a significant role in preventing further spread of the disease in the society, which has also been achieved successfully in the past decades, especially during epidemics. But it is important to understand that achieving herd immunity without an effective vaccine against SARS-COV2 is a challenging task. Moreover, anticipating for target herd immunity to be achieved in a population naturally involves number of people being infected by the disease and may lead to unethical fatality rates. Hence, it is important to understand how herd immunity works to understand whether it is effective to aim at achieving target herd immunity threshold or if the idea itself has too many adverse effects to achieve in real life situations.

Material and Methods

Over the span of a few months the novel corona virus spread to several countries transforming an epidemic quickly into the form of a pandemic. Various researches were done to find an effective way to control the pandemic. Many measures were implemented in all countries all over the world to prevent the spread of the disease. This included shutting down of schools, offices, public places, etc. Lockdowns were implemented which ranged from minor restrictions to locking down of entire countries. "However, while these harsh measures may have been extremely successful in averting catastrophic epidemic rise, they inflict major social and economic expenses on the society at the same time."[4] Hence, all countries have been trying to find an effective and responsible way to waive off the lockdown gradually. It is possible to achieve this if there is adequate herd immunity being set up in the society. Herd immunity can prevent sudden rebound of new cases during the relaxation period of the lockdown. "The concept of herd immunity is based on the fact that direct effect of immunity in decreasing infectiousness in some individuals can reduce the risk of infection among those who still remain vulnerable in the given population."[5]

There are two known effective methods to reach herd immunity. The most effective method is to successfully vaccinate individuals. The other method is to let natural immunity generate in individuals naturally infected with the said pathogen. Various mathematical models have been created using statistics of new cases, their recovery rate, overall case fatality rate, data obtained by screening tests, antibody testing in affected individuals, etc. which have helped to learn about the novel corona virus. Mathematical estimates are available which have been used to calculate how we can achieve herd immunity as well as to calculate the risk factors involved in achieving the goal. Studying the mathematical model has been helpful to weigh the pros and cons and to understand whether achieving herd immunity can turn out to be an advantage in this pandemic or prove to be just another unachievable challenge in an already critical situation.

Study Design:

Various mathematical models were studied to understand herd immunity and its significant effect in the COVID-19 pandemic and further observations were hence made. "Herd immunity refers to the indirect protection from a certain pathogen inherited by susceptible individuals when a adequately huge fraction of immune individuals exists in a population."[6] The concept of classical herd immunity arose from mathematical models that were developed according to the impact of vaccination in a population. Depending on the amount of pre-existing immunity to a certain pathogen in the population at hand, probably due to successful vaccination, addition of a single infected individual to the same population will have varied outcomes. In an entirely susceptible population, the said pathogen will spread through non-immune hosts in a completely reckless manner after exposure of susceptible and infected individuals. However, if a large proportion of the given population is immune to the said pathogen, the odds of effective exposure of susceptible and infected individuals are greatly reduced. If the proportion of vulnerable or non-immune individuals in a population in comparison to infected individuals is too less, then the pathogen cannot spread effectively as the immune individuals prevent its spread and thus the prevalence of the disease will eventually decline. "The point at which the fraction of non-immune individuals falls below the threshold needed for transmission is known as the herd immunity threshold."[6] It is important to calculate this herd immunity threshold to reach effective herd immunity. The herd immunity threshold, h_C is calculated as $h_C = 1 - 1/R_0$.[7] "R_0 is the basic reproduction number, defined as the average number of secondary infections caused by a single infectious individual during the early stage of an outbreak in a fully susceptible population."[6,7] Let's take a pathogen whose value of R_0 is 5, this suggests that a single infected individual will further infect five other individuals following exposure, assuming a completely susceptible population at hand. The more transmissible the pathogen the greater is the value of R_0. "*R*t is defined as the number of secondary infections caused by a single infectious individual during the infectious period in a partially immune population."[6] *R*t is considered a more practical form of R_0, which uses re alistic figures to assess the reproductive number.[8] "The value of *R*t can be estimated by using the exponential growth method, using data gathered on a daily basis of new COVID-19 cases, or by multiplying R_0 with the fraction of non-immune population. We can use these estimated values of *R*t to calculate the herd immunity threshold h_C, to cease the spread of infection in the given population. For example, since $h_C = 1 - 1/Rt$, if the value of $Rt = 3$ then, $h_C = 0.67$, i.e. at least two-thirds of the population needs to be immune."[8] It has been assumed that the value of *R*t should be brought down below 1. This can only happen when the immune fraction of the population surpasses the calculated herd immunity threshold level. When this point is reached, the transmission of the pathogen cannot be maintained effectively and there is a significant deterioration seen in the overall cases of infected individuals in the same population.

Although these mathematical models are helpful in making estimates, they majorly rely on assumptions made during creating the models. The model assumes the population to be homogenous in nature, which is far from reality. There are many heterogeneities in a real life population that influence the virulence and transmissibility of the virus. It is also assumed that all individuals in a society will develop absolute immunity to the pathogen and that the immunity developed will have lifelong protection against the pathogen.[6] "A possibility of partial immunity to SARS-COV2, even when it is a new coronavirus, may be present due to some antibody cross-reactivity and a form of partial immunity derived from former infections with the seasonal coronaviruses (OC43, 229E, NL63, HKU1) that have been present in the population for decades, which has already been seen for SARS-COV. A similar case could also be seen for SARS-CoV-2 and might explain the reason why some individuals have milder symptoms or even asymptomatic infections."[8] This also proves that the virus that affects the population doesn't have the same effect on all individuals, striking out the possibility of homogenous mixing of the population. A single pathogen will have not a single but numerous values of R_0 depending on the communicability dynamics of the virus and the population. To eliminate the assumption of homogeneity, we will have to consider different parameters like age, social activity level, population density, population structure, etc. Some models have been created wherein the population has been divided into different cohorts depending on these parameters to get more accurate values of herd immunity threshold.

Another problem that has emerged depends on the accuracy of screening tests for SARS-COV2 done across countries. If testing is done randomly and assuming that the test has very high sensitivity as well as specificity, we can obtain reasonably accurate estimates of the infected, the population attack rate, and the infection fatality rate. But the current worldwide situation does not bear a resemblance to this ideal condition.[9] If the estimates obtained by testing are low on accuracy, the calculated herd immunity threshold will also ultimately be less accurate. Therefore, it is important to get accurate statistics before making future policies and planning strategies in the ongoing pandemic.

There are various pathways that can be followed to achieve effective herd immunity levels. These pathways are made according to the value of *R*t in the given population. If the value of *R*t is more than 2, it indicates an uncontrolled epidemic spread of the disease. In this case the best solution would be to limit mortality rates and prevent an epidemic overshoot. A targeted lockdown implemented for a shorter duration once it is observed that we are on the verge of reaching threshold levels, could reduce mortality, and at the same time prevent socioeconomic losses caused by prolonged lockdown measures. If the value of *R*t is between 1 to 2, it indicates a controlled epidemic spread of the disease. In these situations, the population can be divided into two groups depending on the risk factors. A lesser degree of social distancing would be implemented to the group with less risk factors while strict measures of social distancing would be implemented to the group with high risk factors to make certain that only the groups with the least risk and least fatality become infected. If the value of *R*t is less than 1, it indicates that a local elimination of the disease can be carried out. With values less than 1, pathogen spread cannot be maintained effectively and the epidemic cannot sustain itself. Therefore, the epidemic and be controlled locally. This can be accomplished by early detection of active cases with extensive screening tests, along with strict isolation of primary cases and quarantine of all close contacts to inhibit further spread which will safeguard rapid elimination of the disease.[4]

Although once herd immunity threshold levels are reached by any of these measures, the actual efficiency of herd immunity is still greatly influenced by the strength and duration of the newly acquired immunity. "Recently shared research reports show that neutralizing antibodies were detected amongst patients with mild disease after roughly 10 days, but remarkably neutralizing antibodies were not detected in approximately 30% of patients."[10] Thus, it can be said that we still do not have enough research based evidence to find out the definite efficacy of the immunity induced by the pathogen. Herd immunity is extremely effective only when the pathogen induces lifelong immunity, for example measles vaccination. However, this is very rarely seen, as the immunity induced by many other pathogens is either less in strength or diminishes after a while. As a result, herd immunity is not adequately effective and sporadic outbreaks can possibly occur in the population. “Also, if immunity is distributed randomly and unevenly within a given population, masses of vulnerable individuals that habitually contact one another may remain. Even if the fraction of immune individuals in the population as a whole surpasses the threshold, these clusters of susceptible individuals still remain at risk for local spread of infection.”(6)

Most of the models that have been made over the years to learn about herd immunity have considered vaccination as the main source of achieving immunity. However in this case, SARS-COV2 being a new virus in the human population, enough studies have not been carried out yet to develop an effective vaccine. “Taking future research into development of a vaccine into mind, if we vaccinate a fraction v of the population at hand, assuming the vaccine giving 100% immunity, and individuals being vaccinated being selected uniformly, then the reproduction number would now be $R_v = (1 - v) R_0$. Using this, we can derive the critical vaccination coverage $v_c = 1 - 1/R$. So, at the least if this fraction of the community is vaccinated the population will reach herd immunity, as $R_v \leq 1$, and the epidemic cannot sustain itself. However, if the vaccine is less than perfect but only reduces susceptibility by a fraction E (so E = 1 corresponds to 100% efficacy), then the critical vaccination coverage is given by $v_c = E^{-1}(1 - 1/R_0)$, inferring that a larger proportion of the community needs to be vaccinated if the vaccine is not nearly perfect.”(7) These calculations may be helpful in testing the efficiency of a vaccine in the pandemic. However, since currently there are so such effective vaccines available for mass production, there is a huge gap that is too difficult to fill to achieve classical herd immunity. Merely naturally induced immunity cannot fulfill this adequately without having harmful consequences. If we rely only on natural immunity, for the herd immunity threshold that needs to be achieved, a large fraction of the population will have to be allowed to be infected by the virus. This can lead to severe rise in mortality rates.

While having the perspective of attaining herd immunity to SARS-COV2, it is mandatory to also keep in mind that there are only finite healthcare resources available throughout countries. As the approach of attaining herd immunity to limit the propagation of the disease has the major consequence of permitting a large portion of the community to be infected, if the healthcare resources are depleted, there would be an escalation in mortality rates not only due to coronavirus disease but also due to all other causes.(6) This would only make the current scenario worse and even more challenging to deal with.

Results and Discussion

After studying various models that have been made for achieving herd immunity in the COVID-19 pandemic, it can be said that we do not have enough data or sufficiently accurate data to estimate exactly how much duration it will take to establish adequate herd immunity in the society. It is also not practical to figure out exactly how effective herd immunity can be for this pathogen as we are still in the early phase of the pandemic where sufficient information is still not available to make a valid estimate. The development of a vaccine against the virus can drastically change the situation and may rapidly speed up the process of achieving target herd immunity threshold. But the idea of a 100% effective vaccine inducing 100% immunity in an individual seems too far-fetched. Also, the time taken to create a near perfect vaccine will take years and till then, waiting for herd immunity to be established based on only naturally induced immunity seems inadequate. Without an effective vaccine, there would be unnecessary mortality that accompanies reaching herd immunity which is an unethical compromise. “According to research, the case fatality rate of COVID-19 can be around 0.25–3.0% of the population, proving that the expected number of people who could possibly die from COVID-19, while the population reaches the herd immunity threshold, is too much to accept.”(8)

It is vital now to start planning policies and strategies guided with an end goal in mind. Until now individual countries have been driven by short term targets, such as flattening the curve. The longer term exit strategy should now be considered and should focus on better population health outcomes as well as the economic outcomes of any action taken.[4] While herd immunity is an approach that has helped in epidemics in previous years, it might not be the best method to follow in the ongoing COVID-19 pandemic considering the countless shortcomings that come along with it. Once we get acquainted better with this new virus and have better research results, as well as an effective vaccine at hand, there is a prospect that achieving herd immunity may perhaps become easier and more effective. But according to the current scenario, achieving herd immunity against the SARS-COV2 virus cannot be made the primary, global objective. Emphasis is given in primary prevention. So basic precautions like hand hygiene [11], avoiding undue public contact through movement and travel [12,13,14] can help a lot to prevent the spread of Covid-19. Also measures need to be taken to reduce depression, anxiety and stress among the general population[15]. In its place, making strategies to protect the most vulnerable group of the population should be highlighted, assuming that herd immunity will sooner or later be attained as a consequence of such strategies, instead of waiting in anticipation for the target herd immunity to be achieved.

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