CME

Herd Immunity and Reproduction Number

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Immunity is a concept applicable to individuals, but the concept of herd immunity applies to the populations. Soon after Corona pandemic has risen on horizon, this term has taken prominence, not just with health professionals, but also with the public at large. Social media, electronic media and print media played a major role in arousing the inquisitiveness and, in some cases, even took initiative to explain this concept. The concept acquired importance, as everybody was curious to know when the pandemic will subside. People were able to relate secular decline in incidence to herd immunity and appreciated that a certain percentage of population has to acquire immunity to deny the opportunity for infection to spread and thereby impede the progress of the epidemic. Herd immunity is the indirect protection to the susceptible individuals.

In the face of all the hype built around it, the professionals started discussing the actual meaning of the term. I observed that the term herd immunity is used by different people to mean three very different concepts:

1. The proportion of persons immune to the infection at a particular point in time. If 62% of people are immune today in an area either because of exposure or because of vaccination, the herd immunity in that area is 62% at that point in time. This pertains to the level of immunity in the population and expressed in terms of percentage.
2. The minimum threshold of immune population required to stifle the transmission of infection such that not many susceptibles are available around an infectious person for passing it to the others. It is generally believed that heard immunity for polio is 80% and for measles is 95%1. This, in a way, describes the desired extent of immunization to control the transmission of the disease. This implies that new infections may continue to occur but they will gradually decline. This requires consideration of the reproduction number as discussed in this note.
3. The level at which the population is protected from invasion of new infections. For example, if 96% of population is immune for an infection, no new infection can occur and only those who are already infected need treatment for complete elimination of the disease.

In view of such widely varying interpretations, I thought of approaching a group of specialists who can enlighten me. For this purpose, there was nothing better than the Google group of the Epidemiology Foundation of India (EFI) with nearly 1500 members. I posted my concern to this group and several experts responded. I am grateful to these experts. A careful study of these responses revealed that there is a wide variation in understanding of the concept of herd immunity and there is no consensus. This underscored the need to explore the concept in depth. The President of EFI and the Editor of this Bulletin approached me to prepare a document for the benefit of our members. For this, I discussed the concept of herd immunity with some other experts and looked at the literature. The following is what I could understand regarding herd immunity. This note may be helpful in developing a consensus amongst ourselves.

The concept of herd immunity cannot be fully understood without an explanation of the reproduction numbers.

Reproduction Numbers

The reproduction number is the average number of persons infected by one index case during the entire infectious period. This number depends on the number of susceptible persons who came in contact, the duration of the contact, the infectivity of the pathogen, and the infectious period. Infectivity (or infectiousness) of a pathogen depends on how quickly and how far it can travel and what quantity is required to infect a contact. The contact rate depends on the density of the population around the index case and how much do they mingle with one-another. The level of susceptibility of the

contacts depends on the level of innate immunity in different segments of the population such as in different age groups. For example, in the case of SARS-CoV-2 viruses, the present evidence suggests that it is a droplet infection that can travel up to 2 meters, can stay on hands and other surfaces for up to several hours (perhaps days), and possibly a small dose of pathogen is enough to infect others. Thus, this virus is highly infectious, and will have a high reproduction number in a vulnerable population. The infectious period is how long an infected person can shed the virus to infect others. This is generally surmised 5 to 14 days for Coronavirus. Important consideration that some of us tend to ignore is the percentage of susceptibles around the index case. At the beginning of the epidemic of a new pathogen such as Coronavirus, everybody is considered susceptible. This gives rise to basic reproduction number denoted by Ro. According to Al Raeei 2, the basic reproduction number of Coronavirus is between 1.0 and 2.8. Many believe that it is higher. R0 is difficult to estimate with precision because of data limitation. Basic reproduction number varies from population to population because of the difference in the factors just cited. In addition, it is generally believed for Corona, especially in the Indian context, that some of us have innate immunity due to genetics, our constant exposure to other viruses, or due to healthy diet constituents. Our population structure with nearly 40% of age less than 18 years, who are not as susceptible, may also be a contributor. Thus, everybody is not necessarily susceptible even at the beginning of the new infection and our basic reproduction number for Coronavirus is lower than some other populations.

As the pandemic progresses, people become aware and non-pharmacological interventions such as sanitization; facemasks, social distancing, and hand washing in the case of Coronavirus are adopted on a large scale. Some people become immune due to prior infection and some get vaccinated as the vaccine becomes available and a vaccination programme is rolled. Thus, the number of susceptibles around an infected person declines and the reproduction number reduces. The reproduction number at time t is denoted by Rt and it is necessarily less than Ro. Some people call it effective reproduction number and denote by Re but this name does not highlight that it varies from time to time because of the interventions. Thus, there are at least two kinds of reproduction number and that is the reason that the title of this section uses it in plural.

Herd Immunity

Out of the three alternatives I proposed in the beginning, keep focus on the second and consider the other two as distractors. Herd immunity is not the percentage of immune persons in a population but is a binary status (yes or no) that says that the herd immunity has reached or not reached. A population is considered to have reached the herd immunity level when the reproduction number starts to become less than 1. This really means that one infected person is able to infect less than one person on average – the pathogen spread fails to maintain and thus the number of infected persons declines in the course of time. Note that here we are concerned with Rt and not Ro. However, at the beginning of the epidemic, when everybody is susceptible, herd immunity will reach when the proportion immune exceeds (1 – 1/ Ro) 3. As per this formula, in the case of Coronavirus, if the basic reproduction number is 2.5, the herd immunity will reach when at least 60% of the erstwhile susceptibles become immune. This immunity can be reached either by prior infection or by vaccination.

If the vaccinations are evenly distributed across all susceptibles and the population is homogeneously mixed, a coverage of 60% will be enough to generate herd immunity in this case. This assumes that there is no innate immunity and no acquired immunity due to exposure. More importantly, this assumes that the vaccine efficacy is 100%. (This efficacy is against infection and different from the efficacy against disease, severe disease, or death.) A vaccine with efficacy of 100% is rarely possible and serious questions are raised when this is less, particularly when it is nearly 70%. Coverage of 60% population with 70% efficacy vaccine will imply a protection of 42% population. When the efficacy is low, the vaccine coverage should be at least V = (1 – 1/ Ro)/E where E is the efficacy3. For our Corona example, with Ro = 2.5 and E = 0.70, this gives V = 0.86. This says that 86% of the susceptibles

should be vaccinated to reach the herd immunity. If R0 = 4 and E = 0.70, V becomes 1.07 and then even the complete vaccination of the entire population of susceptibles with this vaccine will not be enough to generate herd immunity. The transmission will continue even with 100% coverage by this vaccine unless many have innate immunity, have developed immunity due to prior exposure, or use non-pharmacological interventions.

For a vaccination programme, it is important to distinguish between those infected and those who manifest the disease. In the case of Coronavirus, the disease has been named COViD-19 (Corona Virus Disease 2019). (I am using a slightly different acronym than what is used by WHO and others.) It is generally observed that the infection can occur in people of any age and gender but the disease (and deaths) occurs more frequently in those who are of old age and have some comorbidity. Thus, the first target for Corona vaccination is this group that would control the disease and deaths. Note that the target in this case is disease and not the infection.

As more and more are vaccinated, the reproduction number Rt will progressively decline with time and the disease will be in control. Innate immunity or acquired immunity can also provide substantial help.

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Communicable Diseases:

COVID19 Vaccination Program – a Public Health Challenge

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Abstract:

In an unprecedented effort by the global community, scientists developed the COVID-19 vaccine in one year's record time. There are many operation hurdles to bring the vaccine from the laboratory to the community. However, with scientists and public health experts' combined efforts and the National Regulatory Authority (CDSCO) prompt authorization, the Ministry of Health launched the COVID-19 vaccination program in India on the 16th. January 20121. Initially, there were glitches, but gradually it is easing up. Future success will depend on the public health expert's ingenuity to devise a strategy like "Ring Immunization", which can cut short the transmission chain and vaccine wastage instead of aiming to achieve the elusive "Herd Immunity" by vaccination.

Keywords:

"Covishield"- gene-based and "Covaxin"- a protein-based vaccine Central Drugs Standard Control Organization (CDSCO) Drug and cosmetic Rules 1940 and the Drugs and clinical Trial Rules of India. "COVISHIELD", "COVAXIN" and "Restricted use in Emergency Situation". Vaccine Intelligence Network (Co-WIN), "Vaccinee"; Adverse Event Following Immunization "Ring Vaccination."

Introduction:

To combat the COVID 19 pandemic, the World Health Organization, European Commission, "Global Alliance for Vaccine and Immunization (GAVI)" and the "Coalition for Epidemic Preparedness Innovation (CEPI) and different countries, including India, jointly launched the international platform "COVAX" to develop a vaccine. It coordinated with the world's leading research and pharmaceutical companies and developed several safe and effective vaccines