The covid-19 epidemic – Herd immunity or herd protection?

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Abstract

In the absence of effective vaccine, isolation and protective measures (non-pharmaceutical interventions) are adopted worldwide to flatten the covid-19 epidemic. Differently to the permanent protection (herd immunity) provided by the vaccine, the non-pharmaceutical interventions provide temporary protection (herd protection). Therefore, once the release of the isolated individuals are initiated, the mitigated epidemic retakes the increasing trend.

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Short communication

Britton et al. [1] stated that "herd immunity is defined as a level of population immunity at which disease spreading will decline and stop even after all preventive measures have been relaxed. If all preventive measures are relaxed when the immunity level from infection is below the herd immunity level, then a second wave of infection may start once restrictions are lifted". They described SARS-CoV-2 transmission by a mathematical model by incorporating the heterogeneity and concluded that "the disease-induced herd immunity level can be 43%, which is substantially less than the classical herd immunity level of 60% obtained through homogeneous immunization of the population". We illustrate this misapplication of herd immunity taking into account three examples: Isolation in São Paulo and Amazon States (Brazil) and lockdown in Spain. From a mathematical model based on the natural history of covid-19 encompassing young (60 years old or less) and elder (60 years old or more) subpopulations, we estimated the model parameters (transmission rates, proportion in isolation, protection factor, decreased transmission rates by interiorization, and fatality rates) and retrieved both the basic (R_0) and effective (R_{ef}) reproduction numbers [2] [3]. Based on the estimated model parameters, we calculate R_{ef} during the four phases of the covid-19 epidemic: natural (without any interventions), isolation (lockdown), adoption of individual (face mask) and collective (social distancing) protective measures, and interiorization (contribution of small cities in the epidemic).

(A) São Paulo State has 44.6 million inhabitants (demographic density $177/km^2$) with 15.3% of the elder population. The basic reproduction number $R_0 = 9.24$ (February 26) decreases, successively, to $R_{ef} = 4.35$ (isolation, March 24), to $R_{ef} = 2.15$ (protective measures, April 4), and $R_{ef} = 1.78$ (interiorization, May 1). On June 15, at the beginning of the release, we had $R_{ef} = 1.022$, with the proportions of the immune and susceptible individuals being, respectively, 15% and 25% (77.4%, if summing up the isolated susceptible individuals) of the circulating population. (B) Amazonas State has 3.5 million inhabitants (demographic density $2.23/km^2$) with 4.22% of the elder population. The basic reproduction number $R_0 = 6.76$ (March 13) decreases, successively, to $R_{ef} = 4.22$ (isolation, March 21), to $R_{ef} = 1.85$ (protective measures, April 30), and $R_{ef} = 0.82$ (interiorization, May 26). On June 1, at the beginning of the release, we had $R_{ef} = 0.78$, with the proportions of the immune and susceptible individuals being, respectively, 10.3% and 43.4% (81.0%, if summing up the isolated susceptible individuals) of the circulating population. (C) Spain has 47.4 million inhabitants (demographic density

$92.3/km^2$) with 25.8% of the elder population. The basic reproduction number $R_0 = 8.0$ (February 26) decreases to $R_{ef} = 0.771$ and $R_{ef} = 5.14$, respectively, in circulating and locked-down populations on March 16, and on March 24, reduction to $R_{ef} = 0.382$ and $R_{ef} = 0.59$, respectively, after the transient period. On June 8 (phase 3 of release), we had $R_{ef} = 0.51$, with the proportions of the immune and susceptible individuals are, respectively, 23.6% and 74.8% of the circulating and locked-down populations. However, if the release is not permitted, the proportions of the immune individuals at the end of the first wave of the epidemic in São Paulo State, Amazonas State, and Spain are, respectively, 38%, 34%, and 26.4% of the entire population, while for the susceptible individuals, 62%, 66%, and 73.4%. These numbers of lower immune but higher susceptible individuals may allow the retaken of the suppressed epidemic by non-pharmaceutical interventions. Indeed, after the release of all isolated individuals, and at the end of the first wave of the epidemic, 95% of the population is composed of immune individuals [4] [5]. These findings are based on a deterministic model, for this reason when an epidemic approaches the ending phase, stochastic simulations or even stochastic modelings are more suitable.

The concept of herd immunity is associated with the protection provided by immunized (not by infection) susceptible individuals to a specific subpopulation under a higher risk of death caused by a syndrome or comorbidity. For instance, in the rubella infection, mass vaccination was planned to diminish the infection among pregnant women to reduce the number of congenital rubella syndrome [6]. The misunderstanding of the concept of herd immunity, and the rapid dissemination of underestimated R_0 lower than 2.5, may have led to misconducting public health policies. For instance, the United Kingdom (at the beginning of epidemic) and Sweden adopted the idea of immunization by natural infection, believing that this "herd immunity" would protect susceptible, especially elder subpopulation. However, the concept of herd immunity must not be understood as immunization by the circulating virus, especially in the case of SARS-CoV-2 having high lethality, but by the vaccine aiming at the protection of especially elder subpopulation under higher risk of infection and death. The decrease in the effective reproduction number R_{ef} by vaccine is permanent [5], however, the non-pharmaceutical interventions decrease R_{ef}, which is temporary and lasts whenever the population maintains adherence to lockdown/isolation and protective measures. As these interventions are removed, the dammed epidemic is released and follows quite its natural course, and practically all populations may have had contact with the virus (95% of immune individuals).

As we have pointed out, the isolation (lockdown) and protective measures flatten the epidemic resulting in the suppression of the epidemic, and the proportion of the immune individuals at the end of the first wave of the epidemic without release must not be assumed as having achieved the herd immunity. On the contrary, the epidemic retakes its course when interventions are removed. Indeed, currently, the daily number of deaths (this is the most reliable portrait of the epidemic of covid-19) in São Paulo State, after the beginning of the release, is maintained quite at the same level that occurred at the peak of the daily cases, instead of decreasing [7]. However, in Amazonas State [8], a lower number of deaths is persistently maintained after the beginning of the release. The release in São Paulo State begun in the ascending phase of the epidemic ($R_{ef} = 1.022$), while in Amazonas, at the descending phase ($R_{ef} = 0.78$). The number of elder population in Amazonas State is 0.15 million, which explains the lower number of deaths in Amazonas State in comparison with 6.82 million in São Paulo State. As Amazonas State, Spain initiated the release when $R_{ef} = 0.51$ and having a lower number of infectious individuals [9]. After the release, the not decreasing number of deaths in São Paulo and Amazonas States and the risk of an outbreak in Spain show that the covid-19 epidemic was not suppressed. Therefore, the non-pharmaceutical interventions must be understood as transitory herd protection, rather than permanent herd immunity.

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