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Superspreaders, asymptomatics and COVID-19 elimination

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Abstract

There is pessimism regarding the ability of a nation to eliminate COVID. It has been suggested that COVID might always be able to re-emerge because of the ongoing presence of unrecognised asymptomatic cases. However, calculations described here show that, despite asymptomatic cases, elimination may be easier than anticipated. The example of New Zealand, some Australian states and some East Asian nations, support this conclusion. The reason at first glance seems paradoxical - the presence of superspreaders. It is known that there are occasional superspreaders who pass the disease on to many others, so there must be many more who pass the disease on to nobody given that the average number of secondary cases, R_0, is just 2.5. When towards the end of an elimination program, there is only a small number of infected people, symptomatic or not, that small number may well not include any superspreaders. As a result, chance effects may make elimination likely. However, if towards the end of an epidemic, lockdown is lifted with numbers low, but not zero, the situation is brittle. Whilst there is the possibility that chance effects could lead to elimination, it is also possible that one or two superspreaders could remain, and infect more superspreaders resulting in a major "second wave". This paper estimates the risk of lifting lockdown at various times near the end of the epidemic. It is hard to navigate a course of adequate suppression between the two extremes of elimination and a major epidemic. Moreover there is no need to, as national elimination on an island continent could be achieved with a relatively short additional period of restrictions.

Introduction

Superspreaders are a well known feature of some infectious diseases [1, 2]. Clearly, differing social roles will mean some infected people are more likely than others to spread a disease. However, biological factors are also important. In the case of COVID-19 there is a million fold variation in the viral load in secretions [3] Direct measurement of the number of secondary cases from a given primary, has shown superspreading is more important in COVID-19 than in many other infections [4, 5, 6, 7, 8].

To take an extreme example, if superspreaders were all important, so that the average R_0 of 2.5 was made up of 1% of infected people, who each spread the disease to 250 others and 99% who spread the disease to no-one, then there is at least a 99% chance that any randomly chosen infected person will not generate ongoing transmission. Even if, as would happen 1% of the time, the initial infected person was a superspreader, all the secondary cases generated may be in non-spreaders, or even if a superspreader or two were included, the following generation of infected people may include no superspreaders and so on. Fortunately, there is an area of mathematics, branching processes, that allows us to calculate algebraically, the probability that the disease will eventually die out without chasing down the endless possible permutations here [9, 10].

In reality, superspreading will not be quite such an all or nothing phenomenon. Direct measurement suggests the distribution of secondary cases reasonably matches a mathematical construct known as a negative binomial distribution with an average value, or R_0, of 2.5 and an overdispersion parameter in the range 0.10 to 0.17 [4, 5, 6]. As the overdispersion parameter gets smaller, the superspreaders get more rare but also more extreme in the number they infect. To be conservative about the importance of superspreaders, the results in this paper assume the upper value of 0.17 for the overdispersion parameter.

This paper gives the risk of disease re-emergence with three scenarios – release from lockdown once there is just a single symptomatic case; release from lockdown one incubation period (assumed to be 2 weeks) after diagnosis of the last case, and release from lockdown two incubation periods after diagnosis of the last case. The calculations assume there is no appreciable herd immunity, there is no quarantine free cross border human travel and when lockdown is lifted, transmission immediately goes back to an average transmission rate of $R_0 = 2.5$. It is assumed that 50% of cases are asymptomatic and they are as infectious as the symptomatic.

Methods and Results

Using the negative binomial distribution described above for the number of secondary COVID cases and the theory of branching processes, we find that with restrictions lifted immediately, when we are down to a single symptomatic case and with R_0 then back to 2.5, there is a probability of 78% that a single case will not generate any ongoing chain of cases. If we then also take into account the asymptomatic cases, we can calculate algebraically, that the chance that the disease will die out, is 64%. It is not feasible to use algebra alone to calculate the probabilities of disease re-emergence when lockdown restrictions are continued past the time of the single case, so computer simulation is used. The probabilities that there will be no re-emergence of disease if release from lockdown is delayed by one incubation period or by two incubation periods are 96% and 99.6% respectively [11].

The simulation part of the model does not simulate cases on a day by day basis. Instead, cases are simulated in fixed units of non-overlapping generations of the disease. These generations may be taken to represent a duration of a fortnight, the duration of the longest likely incubation period. Ideally, the calulations here would involve construction of a model calibrated in days and in which the generations would randomly overlap. It seems likely that the results given by the current discrete generation model would approximately correspond to such a more sophisticated model. However, a statement based on the current model that there is just “a single case”, needs to be re-interpreted as “a single newly diagnosed case during the fortnight centred somewhere about the day of diagnosis.” Whilst more sophisticated modelling would be desirable, the general conclusion that without reintroduction of cases from outside the region, the disease will likely be eliminated within a few fortnights of no diagnosis of a new case, would seem almost certainly valid.

Discussion

Australia’s initial COVID policy was to “flatten the curve”, that is reduce the rate of exponential growth so that numbers rose slowly, giving us time to prepare and giving a lower peak that would be within the capacity of our ICU bed numbers. Australia’s lockdown proved to be more successful than anticipated and instead of slow exponential growth we have had exponential decline bringing the prospect of national elimination tantalisingly close. It should be noted that there are some important but fine lines here. If lockdown had reduced our initial estimated R_0 from 2.5 to say, only 1.5, we would still have had an unmanageably large epidemic and catastrophe. Even with an R_0 of say 1.2 that reduced the epidemic to a manageable level, there would still have been tens of thousands of deaths and a need to maintain some social restrictions for many more months. However, the exponential decline shows that Australia’s lockdown reduced R_0 to less than 1.0. We didn’t flatten the curve, we stopped it. The disease has probably been eliminated from some Australian states and territories. Unfortunately, lockdown may have been released just a little too soon, or the virus may have been reintroduced to the community due to lapses in infection control relating to overseas arrivals in hotel quarantine. Chance effects are now resulting in a re-emergence of the epidemic in Victoria. There is political reluctance to reintroduce widespread lockdowns.

According to media reports, Singapore and South Korea have emphasised a strategy of contact tracing and isolation of detected cases rather than rigorous lockdowns, but international COVID monitoring sites indicate that transmission is continuing, albeit at lower levels [12]. It seems likely that contact tracing and testing are not sufficiently effective to achieve elimination without some degree of lockdown. With lockdowns, it seems likely that a few weeks of additional effort would likely eliminate the disease from Australia, barring reintroductions. Whilst some community transmission remains, the possibility remains that there could be a superspreader who passes the disease on to several other superspreaders and control will be lost. If effective measures are not reintroduced in Victoria and borders are not secure, we could yet have a COVID catastrophe throughout Australia.

Of course governments must factor in economic and ideological concerns along with epidemiological advice. The immediate economic cost of lockdown must be balanced against the economic risk of a "second wave". The cost to individual freedom must be balanced against community protection. A world dichotomised into nations that have eliminated COVID and those that haven't, will be a world with severely restricted international travel. It will be a less globalised world, at least until an effective vaccine is available. Unfortunately, these non-health concerns may be counted twice. Epidemiological advice varies. Personal discussion indicates this may sometimes reflect distortion of the epidemiological advice by the advisors libertarian views.

The simple model here, indicates that despite asymptomatic cases, we can be almost certain that COVID will have been eliminated once adequate restrictions have resulted in a few incubation periods passing without a case. Provided there is secure quarantine on our external borders, the internal economy could then be fully reopened and internally, society could regain normality.

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