Isolation Control and Its Challenges

Dah Ming Chiu, March 8, 2020

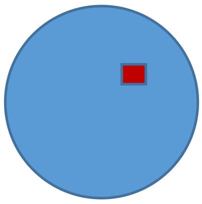
Just about all measures to deal with an epidemic when virus is passed from person to person are some form of *isolation control*, trying to isolate infectious virus carriers from healthy people. Yet, any isolation control brings at best some inconvenience, but at worse serious social and economic costs, and health risks to some people, for the welfare of other people. That is why these isolation control policies are always complicated and controversial. Nonetheless, governments often have to make these decisions in very short time, without the benefit of accurate information. In this article, we try to systematically group different isolation mechanisms under (a) Carrier isolation, (b) Border control, and (c) Isolate everyone. We will use some scenarios arising from the recent fight against the COVID-19 virus as examples. In the process, we point out the benefits and limitations of these isolation measures, and discuss how they can be wisely applied together, under different situations, and improved using information technology.

1. Carrier isolation

A carrier is someone who carries the virus and is contagious (someone infected but not contagious yet is not considered a carrier for our discussion). If all carriers can be identified and isolated from the public (usually by the government), then virus spreading can be stopped. This kind of isolation is also referred to as quarantine, a word originated from Italy when they tried to deal with the Great Plague in 1348-1359 [1]. However, identifying the carriers, and keeping them isolated is not always easy. There are basically two main scenarios:

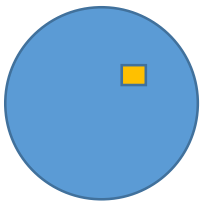
a) All carriers are known

If a virus carrier always has symptoms that requires medical attention, e.g. hospitalization, then it is possible to test the patient to ascertain he carries the virus and isolate him. Pictorially, we represent the quarantined carriers using red color in a square; and the rest of public is represented by the blue circle. This scenario is much more straightforward; but most of the time we have the second scenario below



b) Some carriers are unknown

Much more likely is that we do not know all the carriers. This could be due to the fact that some carriers do not have strong enough symptoms and they do not seek medical service. Even if the carrier eventually has symptoms, it may occur several days after he got infected and became contagious himself. The period during which the patient is contagious but symptomless is known as the incubation period. This is the case with the current Covid-19 virus, for which the incubation period is usually less than 14 days. Although we don't know all the carriers at any given time, we try our best to find all the suspected carriers from the known



carriers, by tracing all the people who have been in close enough contact with the known carriers, so that they could be infected. To be sure not to miss any carriers, the suspicion criteria are conservative; so many suspected carriers never turn out to be a carrier. To safeguard the public, we quarantine all the suspected cases for the maximum incubation period (e.g. 14 days). Pictorially, we represent the quarantine population by an orange square, consisting a mixture of true carriers and suspected but non-carriers. If the maximum incubation period is short, say 1-2 days (which is the case with SARS), then the number of suspected cases resulting from each known carrier is not that high and manageable. If the maximum incubation period is long, e.g. 14 days, which is the case with Covid-19, the number of suspected case may be much larger.

Discussion:

- Carrier isolation is very effective if it is done at the early stage of an epidemic, by isolating a small number of carriers (and suspected carriers), avoiding any harm to the rest of the public. In this case, the scale of the quarantine is small; though it may inconvenience those quarantined, it is miniscule compared to the social benefit.
- If the incubation period is long, then finding out all the people that need to be quarantined is tedious, almost like detective work. In Hong Kong, there is a few new cases of confirmed Covid-19 carriers every day, and the Center for Health Protection (equivalent to CDC in a country) would chase down all the suspected carriers they can identify, and brief the public about the new cases and seek the public's help to find out all the suspected carriers.
- If the number of suspected carriers is large, it may not be easy to find a suitable place to quarantine all the suspected cases in a way that they don't infect each other. The vivid example of this for Covid-19 is the Diamond Princess cruise debacle. The cruise had 3700+ passengers plus crew. A passenger who had left the ship earlier was found to be a carrier, so all these 3700+ on the cruise suddenly all become suspected cases. Without more suitable quarantine facility, the government (Japan) that allowed the cruise to dock decided to let the ship be the place of quarantine, for 14 days. Sick people were taken off the ship. But after the quarantine period, over 700 people become carriers.
- The effectiveness of carrier control varies (inverse) exponentially with timeliness. If you try to apply quarantine after there is already an outbreak (i.e. many people are carriers and suspected carriers), then drastic action is required. For the Covid-19 case, the mainland Chinese government decided to lock-up the entire Wuhan city, and later the entire Hubei province. This is equivalent to quarantining the entire city (and entire province) from the rest of the country. The effectiveness of this is much (exponentially) lower than the case had the government started quarantining the suspected carriers at an earlier time. Nonetheless, the action of quarantining the entire Wuhan is quite helpful for the rest of the country and the world in controlling the epidemic.

2. Border control

Some regions/countries are more affected by the virus than others. Border control is used by a non-affected (or less affected) region/country to stop people from a more affected region/country entering. There may not exist a border between arbitrary regions, so border control may not be easily done; we mostly consider cases when there is a border. There are basically two kinds of controls: (a) refuse entry; and (b) allow entry but quarantine suspected.

a) Refuse entry

There are at least two types of borders: (i) land border separating two countries, and (ii) airport where people coming from can be determined by the flight they took. For both these cases, the goal for entry refusal is the same: stop all suspected carriers (from a particular region/country) and any others who cannot be separated out. This can be done by stopping all people coming from a place (inside a country, e.g. "Wuhan in China") where there is an epidemic outbreak. If you cannot separate out those exposed to the place (e.g. Wuhan), you may have to include all people from the same country (e.g. Chinese passport), and including all flights. Pictorially, what border control tries to achieve can be illustrated by the above picture: countries in the blue part of the circle try to stop the virus from the yellow part of the world, those countries already have the virus outbreak to different extents.

b) Allow entry but quarantine suspected

Border control (a) is often found too drastic. Between two countries, there are more or less different exchanges, such as tourism, educational exchanges (e.g. students), and business exchanges, that are sustained by people flow back and forth. Furthermore, a country has to seriously consider whether to disallow its own citizen from returning home temporarily. Because of these reasons, a relaxed form of border control (b) is often used. This policy can also be used to differentiate countries that have different degree of outbreak. For example, for countries with community outbreak (many infected cases with source unknown), (a) is applicable; but for countries where the outbreak is less severe, (b) is used instead. Due to the quarantine in border control, the rate of border crossing will naturally reduce. But if there is a large normal flow between two countries, then other form to discourage the flow may need to be put in place, such as restricting visa issuance, else there will not be enough space for quarantining the inflow.

Discussion:

- In comparison to carrier isolation control, border control is less effective, since the percentage of true cases is likely much lower than the percentage of true cases when quarantining the suspected carriers near the source. Earlier we discussed the quarantine of Wuhan, which could have been more effective had it been done earlier. But if Wuhan was not quarantined by the Chinese government, then more country would likely exercise harder form of border control, which would be less effective globally, in terms of number non-infected cases quarantined or stopped at border.
- Whether to apply border control, and what form of control to enforce, is something a government needs to carefully evaluate and decide. For the local population, usually the vast majority would ask for as forceful border control as

possible, to minimize their exposure to the virus. But the government will try to balance the health risks with the impact of border control to other normal activities. The result of border control can affect different stakeholders, including the neighbor country (where there is an epidemic) who may complain the border control is not friendly. In the case Covid-19, China complained about US, Korea complained about Japan, for example. It is ultimately the challenge for the local government, as it must be prepared to eventually answer for the consequences of its decision.

- As an example, consider the case of Hong Kong. It needed to decide what form of border control to enforce against people traveling from mainland China where there is a severe outbreak in Wuhan, and lesser outbreak in other provinces. As a part of China, Hong Kong has a heavy flow of daily cross-border traffic, a significant fraction of it by Hong Kong people themselves. Local demand for stronger border control led to a strike by health professionals (in the public sector). The government gradually tightened border control in several steps, eventually implementing a form of (b), insisting the decisions were based on scientific evidence rather than reacting to the strike. Since a significant of the incoming people are Hongkongers, and the number is too large for quarantine centrally, they are allowed to quarantine themselves at home (most of them have a home, relative's home, or rented space in Hong Kong). Government would use a sampling method to check on them, using location-tracking mobile applications as an assisting tool as well. Violators can be imprisoned. In contrast to this, many cities in the mainland China also quarantine people from outside, in particular from Wuhan and Hubei. But in China, city government can mobilize a street-level management committee to ensure the quarantined people from outside are staying at home, with higher assurance.
- Border control, especially (b), can hardly be full-proof. A country may not be able to accurately and timely assess the outbreak in another country; it may adopt a strong border control against some countries but overlook some other countries. The risk of letting the virus in would depend on effective border control with all neighboring countries. Even a few (or a single) carriers that went through the cracks can lead to local virus spreading.

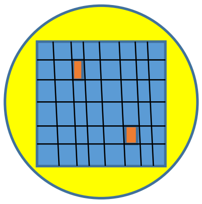
3. Isolate everyone

When it is hopeless to stop the virus by the above two measures, then the last resort is to isolate everyone. This means isolating the vulnerable from the carriers as well as isolating the carriers from the vulnerable at the same time, no longer trying to only target the carriers. In this category, we discuss three scenarios: (a) forced self-isolation, (b) government encouraged self-isolation, and (b) social distancing.

a) Mandatory self-isolation

Practically speaking, mandatory self-isolation means 24-hour curfew. If you force everyone to stay at home, and send those sick (from infection) to hospital or quarantine centers, then the infected would at most infect others in the same family. In order to deal with every day life, each family buys food and daily necessities online and receive delivery. Theoretically, this draconian measure can stop the virus after two incubation periods. This is what the government in Wuhan and surrounding cities in Hubei did for over a month. In a highly populated city like Wuhan, with hospital capacity seriously overwhelmed, such mandatory measures may be necessary, and the infection rate does come down quickly.

In other cities in China, they implemented a lessor form of forced self-isolation, with two measures: (i) ask all outside visitors self-quarantine at home, and use street level committees to monitor that; (ii) encourage all citizens to self-isolate, by canceling school and minimize going to office to work. This level of self-isolation is not as strict as the mandatory self-isolation in Wuhan, but virtually leave city streets empty. Pictorially, we represent this form of isolation mechanism by a yellow circle (those few people still going outside), and a blue grid (those majority of people isolated at home). Those self-isolated include carries, but also a huge number of the public just trying to protect themselves from getting infected.

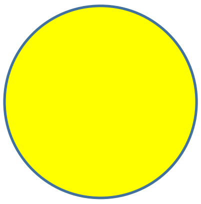


b) Government encouraged self-isolation

More relaxed form of government encouraged self-isolation is exemplified by what is implemented in Hong Kong. Government asks all schools to close; and ask all civil servants to work at home, and encourage all employers to let their employees work at home as well. Since all kids are at home, many workers have to stay at home to take care of their kids anyway. While people can still freely go out to shop for their needs, and carry out some business and social activities, the level of social interactions is drastically reduced. This can be considered a reduced form of (a). A big problem with (a), and even (b), is that its economic and social cost of stopping everything – we will discuss this point more later.

c) Social distancing

So far, all the isolation schemes we discussed are centralized controls, exercised by government to protect the public. In contrast, social distancing is decentralized, asking everyone to distance himself as much as possible with others, to protect himself. Here, distancing can mean isolating oneself at home, or simply wear certain protective gears such as face mask, washing hands, or staying several feet away from others and so on. All these distancing measures reduce the probability of infection.



This form of isolation control relies on self-discipline. Its effectiveness compared to (a) and (b) can vary a lot depending on how concerned the public is about the virus. But the advantage is that it allows us to carry on with normal life as much as possible, using our own best judgement on how rigorously to follow the social distancing practice. We represent the result of social distancing by a yellow circle, meaning there is a fair degree of outbreak of the virus, but the public has used social distancing to control its damage to within an acceptable level. For example, influenza is quite infectious. Although vaccine is often available, only about half of the population takes it in US [2]. The rest of the people only rely on social distancing at best as isolation control. This means in each flu season, there is a big fraction of the population infected. But since the fatality rate is relatively low (<0.1%), it is accepted by the public, without going for stronger form of isolation control.

Discussion:

- Mandatory self-isolation, while effective in reducing virus spreading, also comes at tremendous social costs. For example, the tourism, retail, restaurant and other service industries will all be seriously affected. Furthermore, in the case of China, manufacturing is stopped for as much as one month (two incubation periods), which is quite serious; but somewhat fortunately, this work-stoppage overlapped with the Chinese New Year holidays.
- Compared to (a) and (b), (c) can potentially achieve a balance between isolation to stop/minimize the virus spreading, and social/economic activities. But to achieve the right balance, it is most important to let the public know the truth situation about the epidemic, and as much information about the virus (how it is transmitted, fatality rate etc) as possible [3].
- Comparing the three kinds of isolation controls we discussed so far, carrier isolation is the most effective and least costly, then border control, and isolating everyone is the last resort with huge economic costs. Social distancing can be effective if the public is reasonably responsible, and is given full information.

4. Smart isolation

We have tried to systematically summarize different isolation schemes used by governments, and discussed their effectiveness and costs. Can we do better? The answer is theoretically yes, but not easy. We discuss a couple of ideas below, which are very preliminary, just for brain-storming.

a) Risk-based isolation

The goal with any isolation scheme is to isolate the carriers from the vulnerable. But the challenge is how to isolate only those that need to be isolated, or at least with high probability of being a carrier, without unnecessarily isolating vast number of people from their normal activities. In today's information-based world, it is actually possible to collect all kinds of information about the potential risk of an individual. For example, through a location tracking app/service, it is possible know a person's daily trajectory and social interactions to some extent. Based on that, it is possible to compile some potentially useful information about a person's risk of acquiring the virus. Exactly how to do that is worth lots of exploration, and we will not get into that in this article.

But this idea is not so far-fetched, since there is already an implementation of it by Alibaba [4], based on the information collected for people using Alipay. It is too early to tell if it is effective (e.g. false positive and false negative rates), but that can always be improved. A big question is privacy. Once a centralized system can label people as risky, people also become worried whether such labeling will be misused, in the name of epidemic control. We speculate it is possible to create a distributed version of the risk-assessing function, by keeping the assessment and labeling at one's own mobile devise. When you interact with others, then you can exchange your risk information with the party you interact with.

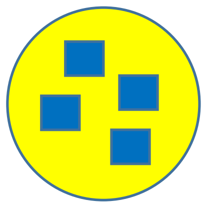
b) Vulnerability-based isolation

From statistics of fatality of Covid-19 so far [5], it is observed that the case fatality rate is not the same for all age groups, as shown in the following table:

Age	Fatality rate
80+	14.8%
70-79	8.0%
60-69	3.6%
50-59	1.3%
40-49	0.4%
30-39	0.2%
20-	0.2%

Besides age, vulnerability also depends on whether a person has a chronic disease, such diabetes or high blood pressure. Through experience in caring for Covid-19 patients, the fatality rate may improve somewhat (if health care service is abundant, and certain effective drug is found), to the extent that the fatality rate for young people may approach that of the flu.

In that case, the low fatality group can deal with the virus by using social distancing, as in the case of the flu; this would allow a large percentage of people to work, study and entertain normally. For the more vulnerable people, they can be subjected to a more stringent form of self-isolation. Note, many of the more vulnerable people will need the less vulnerable type to care for them; in that case, the carers will need to be subjected to the more stringent form of isolation as well.



And we can do better than isolate the vulnerable individually at home. What we can do is to create a *blue zone*, in which it is safe for the vulnerable people to live a more normal life. The blue zone can include some hospitals, restaurants, hotels, shopping malls and parks, various amenities to support normal life. This does require rigorously maintaining a *border* between the blue and yellow zones. Anyone who needs to move from the yellow zone into the blue zone would need to be quarantined for the length of the incubation period. Pictorially, the world under reverse isolation is represented by a yellow circle with a few blobs of blue squares.
To help implement a border between the blue and yellow zone, again some IT can be helpful. For example, one way to do it is to make all the people in the blue zone to be tracked via some electronic devise, that can vouch that the person has never left the blue zone in the past 14 days. There needs to be a map, showing the current territory of the blue zone, to help both people in the blue and yellow zone to navigate themselves. The cost of living in the blue zone may be higher, covering the cost of border control, and the higher cost of paying for service providers working in the blue zone.

Summary

In this article we try to abstract and systematically categorize the different isolation controls used to control epidemics, using some practices in the current Covid-19 epidemic as examples. We then discuss how to improve on the current isolation controls by using more information readily collected by smart devices, without getting into the details of their implementation. We call these "smart isolation". These ideas may be followed up by further research.

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