LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Step 1.9 How infectious is the virus?

In this mini-lecture Professor Judith Glynn talks about spread of infection, how this is measured and what we know about transmission (recorded 2nd March 2020).

This lecture focusses on R0, as well as explaining secondary attack rates and how we measure them, and describing the transmissibility of SARS-CoV-2. As you watch the lecture, consider whether transmissions per case are increasing or decreasing in your context. What is it about the context, or interventions, that are influencing this?

R0 is defined as the average number of successful transmissions per case when everyone in the population is susceptible. However in the course of an outbreak - once you have a population in which not everyone is susceptible (survivors with immunity, or after vaccination) you can no longer talk about R0. The reproduction number in that situation is known as R or Rt. It is related to R0:

R = R0 x the proportion susceptible

So as the proportion susceptible goes down (= the proportion immune goes up), R (the number of new cases per case) decreases. For example, if R0 is 2, and half the population is immune, so half is still susceptible, R would be 2 x 0.5 = 1. In this situation each case would on average give rise to one more case and the disease would become stable. The proportion of the population that needs to be immune to bring R down to 1 is known as the herd immunity threshold. When the proportion immune increases further, R will be less than 1 and the incidence of new cases will decrease.

The secondary attack rate is defined in particular situations as the proportion of those exposed to the primary case that develop disease as a result of that exposure. For example as the proportion of people in a household who get COVID-19 from exposure to the first person in the household to get it. A paper from China with frequent testing of contacts estimated that the secondary attack rate in households was 13% (90 infected from 699 household contacts). In that situation cases were isolated once diagnosed which may have reduced the transmission in the household.

You may find the FAQs for this Step helpful – they cover a lot of areas. For those looking for additional technical detail, there are also specific papers shared in the See Also section and a link to a global summary of countries with the latest reproduction number estimates, which show whether cases are expected to be increasing or decreasing at present.

Video transcript:

JUDITH GLYNN: People talk about the new coronavirus being more or less infectious than flu or than SARS, but what do they mean? In this step, we will look at how we measure infectiousness.

So imagine a population where one person gets a virus and they transmit it to two people. And each of those people transmits to two people. You can see that the numbers of people infected would increase quite quickly in the population. And if each person transmitted to three people, it would increase more quickly.

The basic case reproduction number, R0, is a measure of that spread. It's the average number of successful transmissions per case when everyone in the population is susceptible. While R0 is above one, case numbers would increase. If R0 equals one, case numbers are stable-- on average, each case gives rise to just one more case. And when R0 is less than one, case numbers decrease.

So it's clearly important to know what R0 is. For COVID-19, because it's caused by a new virus, SARS-CoV-2, we can assume everyone is susceptible. We can estimate R0 by looking at the average number of secondary cases per case-- if we can find chains of transmission- - or from looking at how cases increase in the population over time, which is known as the epidemic curve.

An epidemic curve is a bar chart of cases by time. This shows the epidemic curve of the outbreak up until travel restrictions were first imposed in Wuhan on 23rd of January. Cases are plotted by date of onset of symptoms. Most of these cases were not actually diagnosed till after the 23rd.

The rate of increase depends on R0, the number of successful transmissions per case, and on the time between one case and the next in the chain of transmission, which is known as the serial interval. Cases increase more quickly went R0 is large and when the average serial interval is short.

From chains of transmission, it was estimated that the average serial interval is about a week. For the virus causing COVID-19, various estimates of R0 have been made. These have been in the range of two to three. But what's this mean?

It means that in the early stage of the epidemic, using the available data, in Wuhan, on average, each case gave rise to between two to three further cases. These more extended epidemic curves show some of the difficulties in estimating R0 and interpreting trends in numbers.

First, who is a case? Do you include only confirmed cases or also suspected cases? And note that the case definition has changed over time. Then, who is investigated? If contacts is screened, denoted mild or no symptoms included if they test positive, then numbers found will depend on the screening activities.

Also, what time period can you use? Were numbers really decreasing at the time shown here? Or are there many people with more recent symptom onset who have not yet been diagnosed and reported? The orange bars show that the dates of diagnosis are much later than the dates of onset. These factors partly explain why estimates vary.

But also, importantly, R0 is not fixed. R0 depends on three factors-- how long people with COVID-19 are infectious, the probability of transmission per contact between susceptible and infected individuals, and the average rate of such contacts. How long people with COVID-19 are infectious and the probability of transmission per contact depend on characteristics of the virus and also of the people infected.

But the average rate of contact depends on the population. And this varies between populations. Reducing contact is a key target for interventions. So if interventions are successful in reducing contact, R0 can be decreased.

So how does COVID-19 compare to other infectious diseases? The R0 is much lower than for infections which are known to transmit particularly easily, such as measles and chicken pox. It's in a similar range to SARS, Ebola, and seasonal influenza.

Another way to measure infectiousness is a secondary attack rate. It's a measure of spread in specific situations-- for example, in households. It's defined as the proportion of those exposed to the primary case that develop disease as a result of that exposure.

Unfortunately, there is limited information on the secondary attack rate for the virus causing COVID-19. For the related coronavirus that caused SARS, the household attack rate was quite low, around 6%. It was calculated as the number of secondary cases arising out of household members exposed to primary cases.

Note that the secondary attack rate depends on context. For example, it depends on closeness of contact. For SARS, it was much higher for those caring for patients than for those living in the same residence. It also may depend on the stage of illness, as infectiousness varies.

Finally, note that R0 and the secondary attack rate are related. Remember that R0 is the average number of secondary cases per case, and that the secondary attack rate is a proportion of those exposed in particular situations who develop disease. So R0 is the sum of the secondary attack rate in each situation multiplied by the number of contacts in that situation.

See Also

Modelled estimates of changing r0 over time with physical distancing measures in place by country

https://epiforecasts.io/covid/posts/global/

Early dynamics of transmission and control of COVID-19: a mathematical modelling study

https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(20)30144-4/fulltext

Epidemiology and Transmission of COVID-19 in Shenzhen China: Analysis of 391 cases and 1,286 of their close contacts

https://www.medrxiv.org/content/10.1101/2020.03.03.20028423v3