Step 3.5 How can modelling help?

Professor Mark Jit discusses how modelling can be used to understand how an outbreak may progress, informing the interventions needed (recorded 10th March 2020). He explains the limitations of mathematical and statistical models and the level of uncertainty in cases and deaths. Together with colleagues including Amy Gimma, Research Fellow at LSHTM, and those in the Centre for the Mathematical Modelling of Infectious Diseases (CMMID) COVID-19 working group at LSHTM*, he updates us below on the continued role of modelling in the pandemic. As you watch and read the material consider the range of ways modelling informs response, and the limitations in terms of the assumptions in models.

Mathematical modelling has played a key role in informing interventions that are being deployed around the world to control the spread and mitigate the impact of COVID-19. Modelling is used to describe the characteristics of transmission, such as the reproduction number (number of secondary infections arising from one infected person) 1, incubation period (time between infection and symptom onset) 2, serial interval (time interval between symptoms in a primary case and in someone infected by the primary case), and other important parameters for use in estimating the potential number of cases and deaths. Models were developed immediately after investigators confirmed that the coronavirus was able to spread from person to person. Early models showed that the coronavirus was able to spread between people very quickly 1, and that there were many more cases in Wuhan and other Chinese cities than were being reported 3. These analyses convinced authorities to take rapid action to try to contain the epidemic. Subsequent models examined the impact of those interventions. These found that imposing travel restrictions on Hubei province 4, 5 and China as a whole 6 only had a small effect on the spread of the coronavirus globally. However, restricting movement outside of homes for people in Wuhan and many other cities was helping to slow down and eventually reverse its spread 7 - 9.

Since then, countries around the world have used findings from models to develop strategies to contain COVID-19 outbreaks within their borders, or at least to mitigate the effects. They have helped to understand the effect that different interventions could have. For instance, screening at ports of entry into a country was found to be unlikely to delay local outbreaks by long 10, while isolating cases and monitoring their contacts is effective in slowing transmission, but would have to be very comprehensive in the absence of other public health interventions to control such an outbreak 11. Additionally, the timing of implementing physical distancing measures, such as closing schools, workplaces and places of entertainment, is crucial in planning long-term strategies 12. The results of modelling studies have been used to inform the public of the status of the pandemic and to reinforce the importance of adhering to public health measures and other behavioural recommendations. Current modelling efforts are focused on investigating whether extensive testing and contact tracing could provide an avenue to allow countries to exit physical distancing measures, as well as developing interventions that would work in low- and middle-income settings.

The COVID-19 pandemic is also disrupting the delivery of other health services, health care systems, and the economy along with travel restrictions and border closings. This is impacting the delivery of essential health services, including childhood immunisation in low and middle income countries 13. Modelling studies assess the health benefits of sustaining immunisation delivery against the risk of COVID-19 infections and are useful in guiding vaccination policy and practice in these uncertain times 14.

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Video transcript:

MARK JIT: Today I'm going to be talking about one of the essential tools that has been used to understand the spread of infectious disease outbreaks, such as the current outbreak of COVID-19 that we're seeing in the world today. I'm going to be talking to you about models - mathematical, statistical, and economic models.

Models are simply a simplification of a very complex object. In this case, the complex object is the real world-- 8 billion people in the world all interacting with each other, getting infected, interacting with the pathogen-- the COVID-19 virus-- and interacting with their environment. This is far too complicated for us to understand just with our unaided minds so mathematical, statistical, and economic models help to simplify this by setting up relationships between different aspects of the world.

Models have been an essential part of understanding and responding to the outbreak of COVID-19. At the beginning, models were used to understand what was happening in Wuhan, where the outbreak first started, and how infections spread from Wuhan to other parts of China and other parts of the world. Now that we're having outbreaks in many parts of the world and epidemics in many parts of the world, the models have been used to understand some of the key features of the virus that we need to know in order to know how to respond to it.

For instance, how long are people infected? How many people might they infect when they get infected? Can people infect other people even before they show symptoms? That's essential to understand to know whether we can stop people from transmitting to other people by actually finding them quickly and making sure that they are isolated before they spread to other people. We're also using models to understand how large the epidemics will be in different parts of the world and whether we have the health care resources that we need in order to make sure that people have enough space in hospitals, enough space in intensive care units to make sure they get the treatment that they need.

The rate at which the disease spread is influenced by how often people come in contact with one another. And, obviously, within very closed environments, such as on a cruise ship or in prison, there's a lot more close contact between individuals and these are some of the places where we've seen big outbreaks of COVID-19. So the spread of the virus can also be influenced by what's happening in the country or in the location. So, for instance, if schools are closed or if workplaces are shut and people start working from home or if people stop travelling or stop going out, then this will reduce the number of contacts people have with other people. And that will slow down infectious disease spread.

Countries with COVID 19 cases report the number of cases that they've detected but these numbers are probably much less than the actual number of cases that are in the country because many people who are sick have mild symptoms or maybe no symptoms at all and, therefore, they don't report themselves as being sick to be tested for COVID-19. As a result, modellers have to look for other hints about the true number of cases. For instance, they look at the speed at which these reported cases are increasing in order to understand how fast the virus is spreading or they look at other outcomes which might be better recorded like the number of deaths due to COVID-19 or the number of cases that are picked up because people leave the country and go to another country. So we put all these clues together to try to get a good understanding. And to do that one really important number we try to estimate is R0. And if we know this number R0 and we know the length of time that someone is infected, then we can have a good guess as to how fast the virus will spread.

We also want to know the number of deaths. And we have to be careful when we look at the number of deaths that is being reported because deaths are a lagging indicator. So you might be sick for a week or two weeks before you'll die and, therefore, the number of deaths we see today probably reflects what's happening with the epidemic about one or two weeks ago rather than what's happening now. So we have to be careful when we calculate the ratio between cases and deaths-- what we call the case fatality ratio-- to take into account the fact that actually there is this lag between the cases and deaths.

See Also

Mathematical Modeling of Infectious Disease Dynamics

https://collections.plos.org/collection/mathematical-disease-dynamics/

Mathematical-statistical modeling of COVID-19 on the restricted population

https://www.researchgate.net/publication/339566420_Mathematical-statistical_modeling_of_COVID-19_on_the_restricted_population

COVID-19 and Italy: what next?

https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30627-9/fulltext#seccestitle30

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

MRC Centre for Global Infectious Disease Analysis

https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/

Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts

https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(20)30074-7/fulltext

Using a delay-adjusted case fatality ratio to estimate under-reporting

https://cmmid.github.io/topics/covid19/global_cfr_estimates.html

The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study

https://www.thelancet.com/journals/lanpub/article/PIIS2468-2667(20)30073-6/fulltext