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How epidemiology has shaped the COVID pandemic

Nature's third progress report, coming at the end of the pandemic's first year, highlights key findings from epidemiology.

Epidemiology is essential to the fight against any disease. The study of how diseases spread, and why, has loomed large in the struggle to understand, contain and respond to COVID-19. Analyses of data on infections and deaths, and projections from studies that model the virus's spread, have driven policy decisions all over the world. Many of these, such as locking down countries, imposing quarantines, and mandating social distancing and mask-wearing, are now commonplace.

This editorial – the third instalment in *Nature*'s series of pandemic progress reports – explores some of the key research developments that have helped to illuminate the nature of the infection and the scale of the pandemic.

We also highlight how epidemiology will be important as the pandemic progresses – for example, in understanding the potential impact of the new variants that are currently wreaking havoc around the world. Epidemiology is changing the course of the pandemic, but the coronavirus has stress-tested epidemiology, too, and this report briefly explores how the field is changing as a result.

Epidemiology's early role

It is now more than a year since reports began to emerge of a previously unknown coronavirus causing pneumonia-like symptoms. By 5 January 2020, the virus was reported to have infected 59 people in the city of Wuhan in China's Hubei province; 7 were in a critical condition. By 20 January, the Chinese authorities had reported more than 200 infections and 3 deaths.

Initially, little was known about the virus's transmissibility, but that quickly changed. By about the middle of January, epidemiologists began reporting the results of modelling studies, which indicated that case numbers were likely to be much higher[1] than had initially been documented.

These studies found, for example, that the 'R_0' rate – which describes the number of people an infected person will pass the virus on to, on average, if the virus is allowed to spread uncontrolled – to be between 2 and 4 (refs 2, 3). Studies also estimated crucial parameters for understanding the virus's epidemic potential. This included its mean incubation period[4] – the time between a person getting infected and the onset of symptoms – and the proportion of people for whom the infection will be fatal[5]. Even early on, it was evident that the risk to people aged over 60 was substantially higher than that for younger age groups. Some estimates suggested that more than 1 in 10 of those over the age of 80 who became infected would not survive[5].

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In these first weeks, researchers were working with limited patient data. However, as more data became available, epidemiologists were able to confirm that the virus could be transmitted by people showing no symptoms[6] and that it had high pandemic potential[1].

Taken together, these studies helped to alert many governments to the fact that the situation might be much more severe than they had anticipated. The findings suggested that hospitals worldwide needed to prepare for a high number of admissions to intensive care.

At the end of January, the World Health Organization declared a Public Health Emergency of International Concern, which included advice for countries on implementing public-health measures, including testing and isolating infected people, and tracing and quarantining their contacts. These moves were based, in part, on research done by epidemiologists after previous infectious-disease outbreaks[7]. But, as *Nature* reports on page 499, few countries followed this advice.

At the same time, the epidemiological community also began turning its attention to evaluating measures that might help to contain the virus.

Lockdowns and masks

As case numbers started to soar, countries' options for reducing infections and deaths were very limited. It was hard to know what drug regimes might help to combat the disease, and there were no vaccines. In the absence of such tools, researchers began modelling the effectiveness of what are called non-pharmaceutical interventions.

Their models suggested that infections and deaths could be reduced if people wore face masks and maintained a degree of distance from one another, and if more people stayed at home[8,9].

Wuhan went into lockdown on 23 January, and by the middle of February movement was being restricted in about 80 other cities in China. Some months later, researchers would confirm that a range of public-health measures, including closing schools, restricting travel and reducing mixing to within households, brought transmission rates in Wuhan down[3].

Studies from outside China also later affirmed that transmission dropped considerably after educational institutions were closed, gatherings limited and essential businesses closed[10,11]. Moreover, researchers predicted that cities that delayed enacting restrictions would have to keep restrictions in place for longer periods before the virus could be controlled[12].

Although mask-wearing is known to help combat the spread of many infectious respiratory diseases, the lack of controlled trials and direct data meant more time would be required before researchers were able to establish the effectiveness of the measure against the coronavirus. But by the summer of 2020, a number of studies had found that masks contribute to slowing the spread of coronavirus[13,14].

New unknowns

As the virus continues to surge across much of the world, new variants have emerged, and are prompting new questions for epidemiologists. Researchers say that these newer variants, such as B.1.1.7 (also known as VOC 202012/01), first identified in the United Kingdom, are more transmissible and potentially more severe than earlier lineages of the virus (go.nature.com/3a9i9p4). Such findings have implications for policy interventions that were based on earlier data on transmission. Epidemiologists will need to re-evaluate, on the basis of more recent data, whether guidelines on interventions such as social distancing need to be revised and made more stringent to account for the different ways the new variants behave.

Another new challenge for epidemiologists is measuring how the vaccines currently being rolled out around the world affect the virus's spread. Countries where roll-outs have already begun might soon be looking to relax restrictions, especially if cases and deaths fall to levels seen before the start of the second wave. But they should not do so before epidemiologists have established the extent to which vaccines are contributing to increased immunity and the extent to which a fall in cases is the result of the effects of restrictions.

Epidemiology is changing

The pandemic has changed epidemiology. As with many fields that are directly involved in the study of COVID-19, epidemiologists are collaborating across borders and time zones. They are sharing their data using online platforms – preprint servers are giving scientists early access to results – and journals are publishing at a faster rate.

Epidemiology itself is expanding, with the involvement of researchers from other fields, such as physics, mathematics, computer science and network science, who have been contributing their ideas and expertise. The US government has announced that it will establish a National Center for Epidemic Forecasting and Outbreak Analytics. We hope that this will be the epidemiological equivalent of a central meteorological office, an independent body that provides forecasts using advanced computational power, and the best available data. Other countries should consider doing the same.

With many more researchers joining the field from different disciplines – and more people using epidemiological data, including the public, policymakers and the media – researchers must find ways to make sure that their data and findings are communicated transparently, and to ensure the highest standards of research and data ethics.

> **"Researchers have had to learn how to communicate the inherent uncertainty in their models and predictions."**

Communication challenge

The pandemic has thrust epidemiologists and epidemiological models into the policy and media spotlight like never before, and they have faced many challenges. Epidemiology – in particular, epidemic modelling and forecasting – relies on statistical methods to make probabilistic predictions from real-time data. These initial predictions are often not accurate, in part because the underlying data can be incomplete and inconsistently categorized. Over time, as the data improve and more research groups become involved, results start to look more certain. But often, decisions such as whether to impose restrictions on movement need to be made before there is certainty. Epidemiologists need to communicate both the certainty and the uncertainty of their findings so that the best decisions can be reached.

This has meant that researchers have had to learn how to communicate the inherent uncertainty in their models and predictions in such a way that people can understand that an inaccurate prediction does not invalidate the model and that a general conclusion can still stand. It has also meant that people and policymakers have been exposed to new terminology – words and phrases that help to explain and visualize uncertainty – and models providing a range of probabilistic forecasts from best- to worst-case scenarios.

These challenges also represent an opportunity. They provide a chance to showcase science as it is happening, in real time – something that only researchers normally see. The pandemic has helped people to understand that science, by its very nature, needs to be continually corrected and refined, its conclusions changing as the balance of evidence changes. This contrasts with the way many may have previously viewed science – as a body of knowledge that is fixed and unchanging. The change in how science is perceived might give the impression that scientists are changing their minds, but to do so when the facts change can only be a good thing.

If the past year has taught us anything, it is that knowledge of public-health tools and access to data are not enough to control a pandemic. People have a natural desire for certainty in the face of something as alarming as a pandemic, yet the science informing the pandemic response, by its nature, operates through probabilities. This does not diminish the impact of epidemiology, but, rather, highlights the importance of maintaining a continuous and transparent conversation between researchers, policymakers and the public.

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