



What Are The Odds Of A New Major Global Health Emergency Over The Next 5 Years?

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It is likely impossible to accurately and quantitatively estimate the risk of a new major global health emergency occurring in the next 5 years. However, as the period considered expands beyond 5 years, it is nearly certain that the risk bounds narrow and creep closer to the upper limit of 100%. Indeed, the last century or so has seen a multitude of spillover events, in which pathogens from animal populations have posed substantial threats to human populations. Examples include the 1918 influenza virus, HIV, MERS-CoV, and, of course, SARS-CoV-2. Global health emergencies are certainly not confined to zoonotic viruses, however. In this same period, anthropogenic factors have accelerated the emergence of antimicrobial resistance, threatening the effectiveness of critical global health technologies such as antibiotics. Climate change also poses a critical threat to global health by changing the suitable geographical range and timing of numerous diseases, as well as direct morbidity and mortality arising from extreme weather events (as starkly highlighted in the most recent IPCC report¹).

In light of this, it may be useful to consider not only the likelihood of a new major global health emergency occurring, but what we can do to mitigate its impact when it does occur. In this piece, we will address this question by focusing on medical research and technology relevant to infectious diseases. It is important to note though that technological advances are far from the only domain that will allow for future emergency mitigation from this

threat. For instance, policy changes such as increasing the wages of long-term care (LTC) workers to prevent their need for multiple jobs and limiting these workers to a single facility have been identified as strategies to reduce resident mortality in LTC facilities, which were found to be 13-fold higher due to Covid-19 than in residents over 69 years of age in the Canadian province of Ontario². Additionally, the extent to which the world is presently interconnected differentiates modern day global health emergencies from historic ones. SARS-CoV-2 had spread to all six continents other than Antarctica by February 26, 2020, only 57 days after a cluster of pneumonia cases were reported in Wuhan, China on December 31 2019³. Strongly international patterns of disease transmission mean that future health emergencies will likely only be effectively managed using coordinated methods with global outlooks that are readily adaptable as the scientific understanding of the threat evolves.

The first SARS-CoV-2 genome was published on January 11 2020. Staggeringly, Moderna had completed a first clinical batch of its mRNA-1273 vaccine 27 days later⁴, and the UK approved Pfizer's Covid-19 vaccine on December 2 2020, less than one year after the earliest case reports. The impact of these vaccines has been tremendous, with high clinical protection resulting in substantial reductions in cases and hospitalizations in regions with high vaccine coverage. Both the Moderna and Pfizer vaccines rely on a novel messenger ribonucleic acid (mRNA)

platform for delivery, highlighting the importance of continued innovation in this field. Trials are ongoing to extend this mRNA platform for the development of vaccines against other diseases including respiratory syncytial virus (a leading cause of lower respiratory tract infections in infants with no current preventative vaccine) and Zika⁵. While most vaccines in use today are pathogen-specific, a long-standing scientific challenge has been to develop universal vaccines against an entire family of viruses, say coronaviruses or influenza viruses. These vaccines would theoretically target more conserved structural regions within a virus family, making them less sensitive to viral evolution⁶. The need for ongoing investment in this technology is more apparent than ever.

The development of safe and effective vaccines alone is not enough to mitigate the effects of a pandemic, as we have recently learned. The question of how to distribute them proved just as challenging. In the end, wealthy countries rapidly acquired the lion's share of available vaccines, while developing countries, even those with severe Covid-19 outbreaks, received few vaccines. This poses not only a moral issue, but a global health one as well. Sustained elevated Covid-19 cases present a high potential scenario for viral evolution⁷, and SARS-CoV-2 variants, largely characterized by increased transmissibility and reduced vaccine efficacy, quickly emerged. This issue will likely be aggravated by plans to administer "booster" vaccine doses in wealthy countries, largely before citizens of low-income countries have received a single shot. In the future, establishing binding international frameworks for enforcing equitable vaccine allocation will be critical

for mitigating the burden of emerging pathogens. Additionally, investing in vaccine development infrastructure (free of patent restrictions) for producing vaccines around the world, particularly in low-income settings, should be a high priority science funding objective.

Technological advances for mitigating the threat of emerging infectious diseases do not only extend to vaccines. An effective antiviral treatment for SARS-CoV-2 remains elusive, and the need for methodological improvements in identifying drug candidates has been noted.⁸ Effective rapid antigen tests for SARS-CoV-2 were quickly developed, and both modeling⁹ and real-world implementation¹⁰ validated the utility of their use, yet puzzlingly these tools were never seriously incorporated into government responses. This decision should be seriously reconsidered for future outbreaks. Real-time tracking of biological markers from viral genomes to antibodies occurred to an unprecedented degree during the Covid-19 pandemic, yet efficiently using these data to guide public health responses remains an area for improvement. Indeed, though this may be more prophylactic than responsive, calls for global immunological observatories to monitor population-level immunity against pathogens are gaining traction.¹¹

On the engineering side where my experimental work lies, the Covid-19 pandemic brought to light large knowledge gaps in the biophysical mechanisms governing disease transmission¹², such as the role of mucus in trapping viruses within hosts and controlling droplet dynamics during transmission events. These knowledge gaps contributed to the problematically protracted debate over whether Covid-19 transmission is airborne

and ventilation systems should be improved (it is, they should be), and broadly complicate the development of predictive, mechanistic models for disease spread. Other promising technological directions may include research into novel materials or nanoparticles for sequestering pathogens within hosts or on external surfaces.

Following the Covid-19 pandemic, many institutes ranging from academia to governments have formed groups focusing on pandemic preparedness. Ultimately, our ability to mitigate the impact of future global health emergencies may be strongly dependent on the longevity of these efforts and the continued funding of research in this domain. An engineering metaphor is instructive here. Scientists like me interested in soft squishy materials use the concept of a relaxation time to categorize materials based on the time it takes them to return to their equilibrium state after a deformation. For instance, water is a pure liquid with no memory of past deformations and “relaxes” nearly instantaneously: if you pour it from one vessel to another there is no remaining signature of what it looked like before. On the other hand, many biological gels like my personal favorite, mucus, that contain complex molecules like proteins return to their equilibrium state more slowly after a disturbance. It remains to be seen what our society’s collective relaxation time after this pandemic will be.

All of this said, in engineering risk management we learn that the most effective risk mitigation strategy is simply to eliminate inherently risky elements from the systems we design in the first place. If the same job can be done using a chemical that doesn’t pose substantial health threats, it probably makes sense to

move away from the toxic one. In the same way, the payoffs from investing in strategies to eliminate or mitigate factors that inherently threaten global health would almost certainly be enormous. These strategies could include prioritizing green technologies to slow the effects of anthropogenic climate change, dietary modifications to slow the need for agricultural expansion (which increases interactions between human and animal reservoirs), and improved medical practices in antimicrobial administration to suppress the emergence of resistant bacterial strains. The coordination and effort required to carry out even one of these suggested strategies are admittedly Herculean, but in the end, using toxic chemicals when benign ones are available will poison us all.

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Endnotes

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