COUNCIL ON STRATEGIC RISKS

BRIEFER

No. 10 | September 9, 2020

Pathogen Detection, Mapping and Early Warning: *Opportunities & Obstacles on the Path Toward Preventing Future Pandemics*

Discussion Summary Compiled by Christine Parthemore

Introduction

The current pandemic from the novel coronavirus responsible for the disease labeled COVID-19 is showcasing in horrific detail the severity of biological threats and the need for systemic change in how we counter them. Since its founding, the Council on Strategic Risks (CSR), a nonpartisan, nonprofit organization dedicated to addressing some of the world's greatest threats, has been dedicated to a future in which natural disease outbreaks are found and addressed before reaching pandemic scales, alongside preparedness and rapid response systems that end the mass-effect potential of deliberate biological weapons.

Early warning when new pathogens and signs of disease emerge is critical to this vision. Such warnings must include national and international systems that receive and evaluate real-time data to trigger appropriate actions by policy-makers and frontline responders. It must also include systems to get data and meaningful information to the broader public in clear, widely-trusted ways.

On August 19, 2020, the CSR hosted a virtual discussion on this subject with leaders from the public and private sectors. The event highlighted the strategic need for real-time data sharing and early warning as soon as new disease threats emerge, and the technical possibilities that could enable such a vision to become a reality. It was held under the Chatham House Rule. As such, this briefer highlights several important themes from the conversation, though any ideas expressed here should not be attributed to any individual participant.

1. We are closer than ever to the capabilities needed for real-time pathogen early warning, greatly improved modeling and prediction, and weather map-type applications to inform policy decisions, pandemic responses, and individual actions.

Leading experts have for decades envisioned an advanced suite of technologies that could make real-time disease detection and reporting a reality. This would enable applications like advanced early warning systems for outbreaks and tools designed for easily informing the public, akin to the ubiquitous and intuitive use of weather maps.

Today, we are closer than ever to this becoming technically possible due to several interrelated trends, including dramatically reduced costs for DNA sequencing, multiplexing (pooling and sequencing large numbers of samples together) driving fundamental changes since the early 2000s, and others. The required industrial bases and public and private sector expertise also exists today.

Indeed, the United States and many countries have the capabilities today to ingest and utilize vast sources of data in cost-effective ways---especially when compared to the economic costs of uncontrolled pandemics. Broad spectrum metagenomics (direct genetic analysis of genomes in samples, avoiding the need for culturing) can play a pivotal role, as can next generation sequencing (NGS), which allows parallel sequencing of millions or more DNA segments. Leveraging these tools and putting to use the sequencers already deployed across the country, there is a possibility of it becoming cost effective to use samples already taken in clinical settings, interrogate them for the presence of a much wider range of pathogens or indicators of disease, and more cost-effectively test other sources (e.g., widespread sampling from sewage streams). Other data can still be used, including from individual hospital records, public health records, Google searches, and more, though the need to clean up such data, review quality, and find useful missing information is contributing to the disease reporting issues hindering the current U.S. response to COVID-19.

These tools could help form a semi-centralized approach that would focus mostly on gathering significantly more data at sites where samples are taken, by pooling barcoded DNA samples where they reside for highly multiplexed cost-effective sequencing, and sending resulting data for daily reporting. A more decentralized approach is also possible, in which individuals essentially become sensors. The use of nanopores or molecular transistors could enable widely distributed, individual-level collection tools tied to applications that share resulting data into a common system in real time. Both approaches were envisioned in the more distant past but just in the past few years tech developments have come far enough to enable their deployment.

All of these and other inputs could create an unprecedented ecosystem of passive and active pathogen data collection. Passive collection could be low-cost, coming from sources such as smart thermometers, sewage streams, airports, and health clinics, as well as the currently-installed base of sequencers---data from which can constantly be compared to existing libraries in order to spot anomalies.

Additional, active data collection could then come from deliberate targeting for sample collection and analysis, though this may come at higher costs and require more resources to scale significantly. Leaders of such work will have to decide where to allocate resources for collecting samples. Even before getting to specifics, which types of diseases are most important to prioritize (human vs. animal, those with strong potential for specific health impacts in humans, etc.) is an open question for detecting and curtailing outbreaks. If some of these basic questions can be addressed, one model for moving forward could be a system of hubs with robust sampling in key locations, with spokes into other areas, perhaps supported by portable, individual-level sequencers.

Many experts who joined CSR's conversation are thinking creatively on how to make active collection more cost effective. Considering such vast pathogen data collection systems as part of the broad "Internet of Things" may help, as there are layers of information that could be leveraged in countless ways. Day to day uses that don't directly relate to pathogen early warning and weather mapping systems may therefore subsidize the data collection required for meeting public health needs.

Industry, philanthropic, and government efforts today are already working to apply numerous approaches to the COVID-19 pandemic. The IDseq initiative, for example, identifies pathogens through metagenomic sequencing from specific locations where sequencers are deployed and reports them into a common system that facilitates free, open real-time detection.

Additionally, our capabilities for merging disease and climatological data are growing, and along with it the world's understanding of the interplay between unprecedented changes to the global environment and disease trends. Appropriately-leveraged artificial intelligence and machine learning systems are quickly improving our understanding of these converging risks, and making that knowledge more useful for policy leaders and decision-makers.

Such initiatives should be supported and examined for the lessons applicable for widespread deployment and scaling. Yet significant obstacles remain in the United States and beyond.

2. Despite this incredible potential, the United States is devastatingly far from putting it to full use.

Capabilities like those outlined above are bringing us closer than ever to real-time disease detection and tracking, and innovation in how results are conveyed to medical workers, policy decision-makers, and the general public. However, the current U.S. experience is devastatingly far from effectively putting these tools to use at scale.

The experts CSR convened shared incredibly troubling stories of the status of data collection, sharing, and use for informing the U.S. response to the COVID-19 crisis. As is reported frequently in the media, fax machines are still required for many information-sharing functions---a perfect illustration of the need for change. Test results for too many Americans are transmitted by paper records, too slowly to inform medical or behavioral efforts to stop transmission or to optimally inform public policy. In many states different systems exist for health records and billing vs. public health information systems. The potential of electronic medical records that can facilitate better care as well as faster, anonymized data-sharing has not been met in the United States despite billions of dollars of investment.

All of these issues are also confounding modeling and prediction. The nation's COVID-19 responses are hindered by these data challenges, making statistical inference less useful in stopping the disease's spread. In the current pandemic, this means predictive tools that could indicate trends in the disease, and inform both health and economic reopening policies, are not nearly as useful as they could be.

Even for pockets where the types of tools noted above are being used and are proving useful in addressing the current pandemic, numerous challenges will need to be addressed moving forward. For the real-time detection and early warning systems we need, computing and data storage costs will be high, and it is unclear who should bear that cost. Some of the capabilities highlighted above require significant training and expert support, highlighting new human resource needs that we will have to meet. Shipping and using sequencing tools in some types of environments may require development of special, ruggedized gear. Bottlenecks may still come in the production and distribution of materials (e.g., paper strips used for testing) and sample gathering and preparation if not properly accounted for.

Significant public education and behavioral instincts will need to be addressed as well. Fiefdoms and silos persist. Today, experts and companies are offering to assist with the COVID-19 crisis, yet are often turned away by public health centers and medical facilities. While there are certainly liability and other issues involved in this, much comes down to bandwidth: in some locations there is not a single individual who is comfortable using the cutting-edge tools, techniques, and methods that could be used to inform decision making.

3. It is unclear what trusted entity exists or should be created to address these issues.

The sense of the group was that “we can do this.” However, though there was rich conversation, there was no resolution on the question of who could be the neutral, trusted actor or actors we need. As several participants cast this question: who is Switzerland in this case? Many of the participants were taking actions to pilot and build up test systems but hoped a trusted entity would emerge to maximally use their data.

There is significant need here, given the vast sources from which data would need to be ingested and assimilated. Data will need to be properly anonymized, managed, and secured for both proper function and public trust. Some of the inputs mentioned in this paper and beyond are slow and incomplete, and do not meet the pandemic-response need for analytically-ready data. And who then owns this data, if anyone?

The costs of creating a real-time pathogen early warning system and apps to inform the public will also be significant---though must be considered against the even greater loss of life and economic productivity of uncontrolled biological threats. Today, despite incredible public and private sector investments, there are not yet models for scaling up to the systems we need in the United States---let alone ensuring the rest of the world is doing the same. Full costs, and how they are met or offset, will have to cover keeping systems running between pandemics, and how people will get use out of them on a regular basis.

One approach would be to create a new, independent data-focused institute devoted to the public good. Another would be for the U.S. federal government to create the system the nation needs.

Moving forward, we may see private sector (including philanthropic) leadership in addressing the public need, in addition to government systems developed to support specific policy-making and national leadership-level decisions. Decision support at the federal government level may be narrower than broader public needs; this requires that we think in terms of what decisions national leaders need to make, what information is essential to those decisions, what analytics are therefore useful, and what data is therefore required and how is it acquired.

Several participants also noted that we should not dismiss the potential for bottom up, grassroots progress (Wikipedia-style, as one expert described). Companies, academics, and individuals across the nation are starting to develop and deploy systems that can contribute to widespread, real-time pathogen early warning systems and important innovations for informing individual decisions.

Whatever the model, it is critical that all parties coordinate going forward so as not to waste significant time and resources, leave assets under-utilized, or confuse the public. Open data and platforms may be critical, though it is unclear what will convince reluctant parties to take an open approach. Some experts also noted the critical importance of bipartisanship in whatever policy work needs to advance in the United States, and the need for strong and transparent governance mechanisms given that so many stakeholders will need to coordinate. It is also critical to avoid nationalistic approaches, and keep a global view in mind even if systems begin within specific countries.

Conclusion: Adopt a wartime footing to response now, and think transformatively as we look ahead.

Real-time pathogen detection and information-sharing are within reach. This can enable the kind of disease early warning the world needs and facilitate the development of applications that could fundamentally change how individuals interact with pathogen data, akin to our ubiquitous use of weather maps and similar tools.

Many of the technologies and methods required are already in use. And as this discussion recap indicates, many hurdles to scaling them up to achieve this vision are known and fixable, from ending outdated laws requiring information travel by fax, to bringing down data silos and regulatory hurdles, to training a Peace Corps-like force of individuals who can be deployed during disease outbreaks to bring data in meaningful ways into decision-making and public policy at all levels.

We cannot wait for the COVID-19 crisis to abate before acting. The capabilities mentioned in this paper and many others can be advanced and deployed for use in addressing the current pandemic, saving lives and reducing physical and economic burdens on the living. We should be on a wartime footing now, and remain so for the many months, and potentially several years, before vaccination and other measures combine to end this pandemic and prevent its resurgence.

Getting the data-related element of pathogen detection and responses correct is critical and urgent. It is a stepping stone to preventing and mitigating future pandemics---and deterring nefarious actors from believing that deliberate biological weapons could be some of the most powerful in their arsenals.

The opportunity and obstacles are remarkable, and the time to act on both is now. CSR will continue to convene the public and private sector experts who are pursuing the vision of ending mass-effect biological events, and working through the policy solutions that vision requires.

This report was compiled by Christine Parthemore, Chief Executive Officer of the Council on Strategic Risks (CSR). It captures main themes and ideas shared by participants (listed below) in an August 2020 event CSR held under the Chatham House Rule.

ENDNOTES

1. This work is part of CSR's ongoing efforts to drive systemic change in preparedness and deployment of rapid response capabilities in order to prevent future outbreaks from reaching pandemic scale and effectively ending biological weapons as a strategic threat.

2. Indeed, a few countries such as South Korea already have near real-time disease surveillance systems, though many still rely on consistent human inputs to a common national system that may not be replicable in all countries.

3. See https://www.discoveridseq.com/

4. Prior initiatives such as GISAID---originated during the avian influenza outbreaks of the 2000s and recently adopted for depositing SARS-CoV-2 sequences to enable genomic epidemiology efforts---lack the necessary resourcing for widespread adoption (or vice versa).

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