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Digital technology and COVID-19

The past decade has allowed the development of a multitude of digital tools. Now they can be used to remediate the COVID-19 outbreak.

Daniel Shu Wei Ting, Lawrence Carin, Victor Dzau and Tien Y. Wong

The year 2020 should have been the start of an exciting decade in medicine and science, with the development and maturation of several digital technologies that can be applied to tackle major clinical problems and diseases. These digital technologies include the internet of things (IoT) with next-generation telecommunication networks (e.g., 5G)[1,2]; big-data analytics[3]; artificial intelligence (AI) that uses deep learning[4,5]; and blockchain technology[6]. They are highly inter-related: the proliferation of the IoT (e.g., devices and instruments) in hospitals and clinics facilitates the establishment of a highly interconnected digital ecosystem, enabling real-time data collection at scale, which could then be used by AI and deep learning systems to understand healthcare trends, model risk associations and predict outcomes. This is enhanced by blockchain technology, a back-linked database with cryptographic protocols and a network of distributed computers in different organizations, integrating peer-to-peer networks to ensure that data are copied in multiple physical locations, with modified algorithms to ensure data are secured but traceable[6].

However, 3 months into 2020, the world is facing an existential global health crisis: the outbreak of a novel coronavirus–caused respiratory disease (COVID-19)[7]. As the knowledge of COVID-19 evolves, increasing evidence suggests that it seems to be less deadly than initially thought (with a mortality rate of approximately 2%), although more contagious (89,779 cases in 70 countries, with over 3,069 deaths as of 2 March 2020) (https://www.worldometers.info/coronavirus/). The impact of COVID-19 will probably be greater than that of severe acute respiratory syndrome (SARS) in 2003, given globalization and the relative importance of China in 2020 in terms of world trade and travel.

How can this new crisis in 2020 be tackled? How does it differ from the SARS epidemic in 2003? Many countries have relied on an extrapolation of classic infection-control and public-health measures to contain the COVID-19 pandemic, similar to those used for SARS in 2003. These range from extreme quarantine measures in China (e.g., locking down over 60 million people in Hubei province) to painstaking detailed contact tracing with hundreds of contact tracers (e.g., Singapore, Hong Kong, South Korea). However, these measures may not be effective in 2020 for tackling the scale of COVID-19. Could new digital technology be used for COVID-19? In this Comment, we explore the potential application of four inter-related digital technologies (the IoT, big-data analytics, AI and blockchain) to augmenting two traditional public-health strategies for tackling COVID-19: (1) monitoring, surveillance, detection and prevention of COVID-19; and (2) mitigation of the impact to healthcare indirectly related to COVID-19 (Table 1).

Monitoring, surveillance, detection and prevention of COVID-19

First, the IoT provides a platform that allows public-health agencies access to data for monitoring the COVID-19 pandemic. For example, the 'Worldometer' provides a real-time update on the actual number of people known to have COVID-19 worldwide, including daily new cases of the disease, disease distribution by countries and severity of disease (recovered, critical condition or death) (https://www.worldometers.info/coronavirus/). Johns Hopkins University's Center for Systems Science and Engineering has also developed a real-time tracking map for following cases of COVID-19 across the world, using the data collected from US Centers for Disease Control and Prevention (CDC), the World Health Organization (WHO), the European Center for Disease Prevention and Control, the Chinese Center for Disease Control and Prevention (China CDC) and the Chinese website DXY, which aggregates data from China's National Health Commission and the China CDC (https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6).

Second, big data also provides opportunities for performing modeling studies of viral activity and for guiding individual country healthcare policymakers to enhance preparation for the outbreak. Using three global databases——the Official Aviation Guide, the location-based services of the Tencent (Shenzhen, China), and the Wuhan Municipal Transportation Management Bureau——Wu et al. performed a modeled study of 'nowcasting' and forecasting COVID-19 disease activity within and outside China that could be used by the health authorities for public-health planning and control worldwide[8]. Similarly, using the WHO International Health Regulations, the State Parties Self-Assessment Annual Reporting Tool, Joint External Evaluation reports and the Infectious Disease Vulnerability Index, Gilbert et al. assessed the preparedness and vulnerability of African countries in battling against COVID-19; this would help raise awareness of the respective health authorities in Africa to better prepare for the viral outbreak[9].

Third, digital technology can enhance public-health education and communication. In Singapore, the government has partnered with WhatsApp (owned by Facebook) to allow the public to receive accurate information about COVID-19 and government initiatives (https://www.form.gov.sg/#!/5e33fa3709f80b00113b6891). Multiple social-media platforms (e.g., Facebook and Twitter) are currently used by healthcare agencies to provide 'real-time' updates and clarify uncertainties with the public. Additionally, some facial-recognition companies (e.g., SenseTime and Sunell) have adopted the thermal imaging–enabled facial recognition to identify people with an elevated temperature at various screening points in China (https://apnews.com/PR%20Newswire/354aae0738073bc95331ee72a458cb50).

Fourth, AI and deep learning can enhance the detection and diagnosis of COVID-19. The need to provide access to accurate and low-cost tests for the diagnosis of COVID-19 is a challenge. Many peripheral hospitals in China and other developing countries in Asia, the Middle-East and Africa do not have the tests or resources to accurately distinguish COVID-19 from the 'common flu'. In Indonesia, which has only two reported case thus far, despite substantial exposure to Chinese tourists (Bali had 1.2 million Chinese tourists in 2019), health authorities decided against testing the 243 returning

Table 1 | Digital technologies and their impact on public-health strategies

	Digital technology			
Public-health measures	**IoT**	**Big data**	**AI**	**Blockchain**
1. Monitoring, surveillance, detection and prevention of COVID-19 (directly related to COVID-19)	+++	+++	++	+
Examples	1. Real-time tracking and live updates in various online databases in the USA, UK and China	1. Modeling of disease activity, potential growth and areas of spread	1. Detection of COVID-19 from chest imaging (X-ray) (Beijing Hospital)	1. Manufacturing and distribution of COVID-19 vaccines once they are available
	2. Live tracking of the at-risk vicinity in Korea (Coronamap.live; Wuhanvirus.kr)	2. Modeling of the preparedness and vulnerability of countries in fighting a disease outbreak	2. Prognostication of disease progression via clinical data, imaging and AI	2. Insurance claims from COVID-related illness and death
2. Mitigation of impact (indirectly related to COVID-19)	+++	++	+++	++
Examples	1. Virtual clinics (PingAn, China)	1. Business modeling on pharmaceutical supplies for various medications	1. AI to automatically diagnose medical conditions unrelated to COVID-19 (Zhongshan Ophthalmic Eye Center, China)	1. Distribution of patients' regular medication to the local pharmacy or patients' doorstep
	2. Public information dissemination via WhatsApp in Singapore[a]	2. Modeling of the utility of operating theaters and clinics with manpower projections	2. Medical 'chat bots' to address public inquiries on COVID-19	

The likely impact of digital technologies on (1) disease monitoring, surveillance, detection and diagnosis, and (2) mitigation of impact: +, low (no clear example yet in either official government website); ++, moderate (one clear example); +++, high (two or more examples). Gray shading indicates potential applications that are not described in the literature thus far but should be considered by technology companies or research groups worldwide to help battle against COVID-19. Additional examples beyond those mentioned in the text are included in this table. [a]https://www.form.gov.sg/#!/5e33fa3709f80b00113b6891.

but asymptomatic citizens from Wuhan because of cost of the test (the reagent was quoted as costing nearly US$75,000). Alternative diagnostic and screening tests for COVID-19 will be extremely useful. In this context, China has large datasets of cases positive for COVID-19 (>70,000 cases). These are ideal datasets for deep AI and deep learning (https://www.wired.com/story/chinese-hospitals-deploy-ai-help-diagnose-covid-19/). Such AI algorithms can then be used as an initial screening tool for suspected cases (e.g., travel history to China, Iran or South Korea, or exposure to confirmed cases) so that patients at higher risk could have confirmatory laboratory-based tests or be isolated.

Although most patients have mild cases of COVID-19, physicians have to apply the same level of intensive methods to isolate, treat and monitor all patients. AI algorithms could be developed to help physicians triage patients with COVID-19 into potentially three groups: the 80% who have mild disease; the 15% who have moderate disease; and the 5% who have severe disease, including those at high risk of mortality. Finally, AI can also facilitate the discovery of novel drugs with which to treat COVID-19.

Mitigation of COVID-19's impact

Although the focus of tackling the direct impact of COVID-19 is important, in many healthcare settings, it is important to maintain core and critical clinical service. The initial reaction in many countries is for healthcare facilities to reduce or even cease many clinical services, including closure of clinics and postponement of medical appointments or elective surgeries. However, such strategies cannot be sustained indefinitely if the COVID-19 pandemic extends beyond 6 months.

Healthcare systems should plan to use digital technology. For example, 'virtual clinics' could be set up through the use of tele-medicine consultations with imaging data (e.g., chest X-ray and/or CT of the thorax) uploaded from peripheral sites and interpreted remotely. This would ensure that patients continue to receive standard clinical care while reducing physical crowding of patients into hospital premises. For other key hospital activities (e.g., research and education), virtual e-learning platforms are increasingly being explored to eliminate physical meetings.

Second, the utilization of various AI-based triage systems could potentially alleviate the clinical load of physicians. An online medical 'chat bot' could help patients recognize early symptoms, educate people on the importance of hand hygiene and refer people for medical treatment should symptoms worsen. Additionally, phone-based software that detects and records patients' data (e.g., daily temperature and symptoms) may prevent unnecessary hospital consultations for patients with mild flu-like symptoms. These data could also be developed into AI algorithms for the detection of COVID-19.

Third, many hospitals in China are collaborating with blockchain companies and pharmacies to deliver patients' medication to their doorsteps. Through the use of blockchain, hospitals could ensure timely delivery of medications with accurate tracking.

In summary, while the world continues to rely on classic public-health measures for tackling the COVID-19 pandemic, in 2020, there is now a wide range of digital technology that can be used to augment and enhance these public-health strategies (https://www.vox.com/recode/2020/2/27/21156358/surveillance-tech-coronavirus-china-facial-recognition). There is also a longer-term goal. The immediate use and successful application of digital technology to tackle a major, global public-health challenge in 2020 will probably increase the public and governmental acceptance of such technologies for other areas of healthcare, including chronic disease in the future. As the saying goes, 'a crisis provides an opportunity'; this first great crisis of 2020 provides a great opportunity for digital technology. ❐

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Competing interests
D.S.W.T. and T.Y.W. hold a patent on a deep learning system for the detection of retinal diseases.

The physician-scientist, 75 years after Vannevar Bush–rethinking the 'bench' and 'bedside' dichotomy

Vannevar Bush enshrined the 'basic' and 'applied' research dichotomy on which much of science policy is still built 75 years later. However, it is time to assess whether this vision for science best serves the purposes of medical research and physician-scientists in the 21st century.

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Seventy-five years ago, Vannevar Bush, director of the US Office of Scientific Research and Development, submitted his landmark report "*Science, the Endless Frontier*"[1] to President Franklin D. Roosevelt. In addition to sweeping structural and operational recommendations, Bush's report elevated a key conceptual dichotomy that would have profound consequences for the future of American science: the distinction between 'basic' research and 'applied' research. His report set the tone for modern US science policy.

In the medical context, the concepts of 'basic' research and 'applied' research can loosely translate to the notions of 'bench' research and 'bedside' research. However, the road from fundamental biological insight to patient care (or vice versa) can be strewn with many obstacles that hamper the efforts of even the most qualified people. Overcoming these roadblocks requires that the many dimensions of the life sciences–medicine continuum be addressed.

Accordingly, in 1964, US National Institutes of Health Director James Augustine Shannon successfully lobbied the US Congress to fund the Medical Scientist Training Program (MSTP)[2]. The vision behind this new training program was precisely to bridge the gaps between the domains of 'basic' research and 'applied' research in the biomedical context, and it effectively created a new type of career: the dual-degree, MD/PhD physician-scientist.

In the nearly 60 years since the creation of the MSTP and the 75 years since Bush's seminal report, much has been learned about the complex terrain between bench and bedside and the institutional ingredients needed to realize this vision. As argued in 2016 by distinguished scientist, policymaker and administrator Venkatesh Narayanamurti and engineer–turned–scientific historian and policy expert Toluwalogo Odumosu, in the 21st century, research activities might be better understood in the context of 'discovery–invention cycles' rather than a basic/applied dichotomy[3]. Building on a wealth of historical knowledge, they argue that research exists in virtuous cycles in which some periods are dominated by knowledge creation (discovery) and others are dominated by the creation of new tools or processes (invention). They suggest drawing a boundary—and even then, a fluid one—between research and development, rather than between basic sciences and applied sciences. Research, they argue, should be thought of as an 'unscheduled activity' in the pursuit of new knowledge and inventions. Development, on the other hand, is a 'scheduled activity' directed at turning the fruits of research into new products and services.

Re-examining the foundations of physician-scientist training in the more fluid model of discovery–invention cycles would encourage not only deep engagement among physicians, scientists, engineers and other allied professions but also the development of institutional cultures that value all aspects of the knowledge creation and development process, whether scientific research, engineering, product development, entrepreneurship, journalism or management, among others[3]. Critical to realizing this vision is recognizing the scope of the undertaking beyond simply