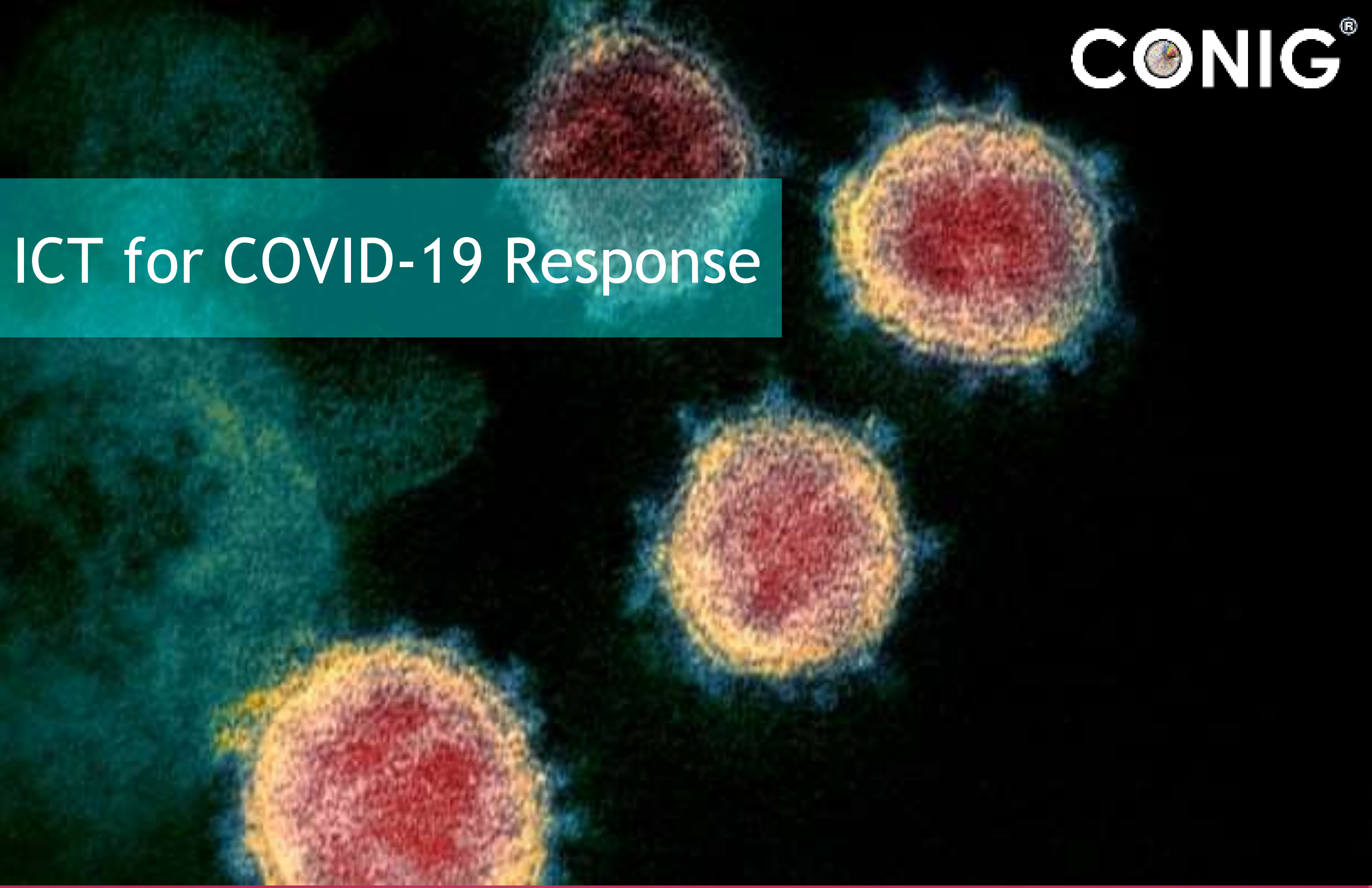

ICT for COVID-19 Response

ICT (Information Communication Technologies) for Covid-19 (Novel Coronavirus) Risk Response

KA. Knowledge Article

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About

He has more than twenty years of experience in Enterprise GRC, ITGRC, ITSM and DevOps. He specializes in the delivery of complex GRC and IT Governance transformation programs for clients in Turkey, UK, GCC Countries, Ukraine and Belarus. Currently he is providing advisory and consultancy services at CxO level for several organizations, and actively contributes to the creation and improvement of industry best practices. He is also a certified as CISA, CRISC, CGEIT, CDPSE, COBIT 5 Trainer, ITIL Expert, DASA Devops Coach, Resilia Practioner, ISO 27000LA, ISO2000C; and, a skilled reviewer of RiskIT and COBIT 5, COBIT 2019, ITIL4 DSV; and, the main author and task force chair for CONIG® (Consilient Information Governance).

He has conducted IT audits as well as the delivery of big and complex IT transformation projects. He successfully lead 50+ assessments and/or audits in his career with TAC for clients throughout Turkey and Middle East. Moreover, he has outstanding track record of projects in IT Governance mainly for big telcos, banks and other financial institutions.

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Expertise Areas

GRC - Governance Risk Compliance
ITGov - IT Governance
IRM - Information Risk Management
ICM - Internal Control Management
RCM - Regulative Compliance Management
ORM - Operational Risk Management
BRM - Business Resilience Management
ISM - Information Security Management
ITSM - IT Service Management
ICTCM - ICT Internal Control Management
Devops
Agile Service Transition
BPMN - Business Process Management
PPM - Project Portfolio Management

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Introduction

Abstract

The globe is currently gripped by the deadliest and most widespread pandemic it has faced in over a century. Confronted by accelerating death tolls and widespread fear, societies around the world have also been forced to acknowledge points of stress in their economic and social fabrics that had long gone overlooked. In the midst of this turmoil, Information and Communications Technology (ICT) has played an essential role in facilitating the safe relief and treatment of affected populations. ICT has also shown itself to be essential both to bolstering long-term resiliency against future pandemics and to resolving the secondary challenges that emerge within a socially distanced environment. However, involving ICT in in pandemic relief and prevention carries with it its own set of challenges involving transparency, accountability, and privacy. Governments which apply ICT must ensure that far-reaching crisis measures do not become permanently entrenched in society, and that measures which are taken are deemed fair, proportional and just. [1]

What is COVID-19 ?

Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus.

Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness and recover without requiring special treatment. Older people, and those with underlying medical problems like cardiovascular disease, diabetes, chronic respiratory disease, and cancer are more likely to develop serious illness.

The best way to prevent and slow down transmission is be well informed about the COVID-19 virus, the disease it causes and how it spreads. Protect yourself and others from infection by washing your hands or using an alcohol based rub frequently and not touching your face.

The COVID-19 virus spreads primarily through droplets of saliva or discharge from the nose when an infected person coughs or sneezes, so it's important that you also practice respiratory etiquette (for example, by coughing into a flexed elbow).

At this time, there are no specific vaccines or treatments for COVID-19. However, there are many ongoing clinical trials evaluating potential treatments. WHO will continue to provide updated information as soon as clinical findings become available. [2]

COVID-19 Pandemic

The COVID-19 pandemic is now a major global health threat Since theinitial identificationof the virusin China, global spread has been rapid, with 182 of 202 countries having reported at least one case. The experience in countriesto date has emphasised the intense pressure that a COVID-19 epidemic places on national health systems, with demand for intensive care beds and mechanical ventilators rapidly outstripping their availability in evenrelatively highly resourced settings. This has potentially profound consequences for resource-poor settings, where the quality and availability of healthcare and related resources (such as oxygen) is typicallypoorer.

There remain large uncertainties in the underlying determinants of the severity of COVID-19 infectionand how these translate across settings. However, clear risk factors includeage, with older people more likely to require hospitalisation and to subsequently die as a result of infection, and underlying co-morbidities including hypertension, diabetes and coronary heart diseaseserving to exacerbate symptoms. Both the age-profile and the distribution of relevant co-morbidities are likely to vary substantially by country, region and economic status, as will age-specific contact patterns and social mixing. Variation in these factors between countries will have material consequences for transmission and the associatedburden of disease by modifying the extent to which infection spreads to the older, more vulnerable members of society.

To help inform country strategies in the coming weeks, we provide here summary statistics of the potential impact of mitigation and suppression strategiesin all countries across the world. These illustrate the need to act early, and the impact that failure to do so is likely to have on local health systems. It is important to note that these are not predictions of what is likely to happen;

this will be determined by the action that governments and countries take in the coming weeksand the behaviour changes that occur as a result of those actions.[3]

ICTs in the Context of COVID-19

The COVID-19 pandemic represents a combined global economic, social and health crisis more acute than any such event so far this century. As of May2020, over 5.5million cases had been confirmed around the world, leaving at least 330,000 dead so far. These figures almost certainly underestimate the true toll, given the mass testing shortages which have hamstrung the worldwide response so far. Developing countries have fortunately not experienced the same toll as developed countries so far, but absent immediate measures to assemble a comprehensive pandemic management framework, they risk a similar or even greater magnitude of disaster given the existing stress on their medical systems.

Pandemics present challenges of an entirely different typethan other disease outbreaks or the vast majority of other natural disasters. Because these diseases strike global populations which have no immunological experience with them, their spread is far more rapid, and frequently, more deadly than any comparable disease outbreaks. Essentially by definition, pandemics impact virtually every corner of society almost simultaneously, in contrast with the comparatively contained damage of other events. This leaves little room for the resiliency and flexible reapplication of resources which aids recovery from more localized types of disasters. Furthermore, unlike other types of disasters, pandemics target not physical infrastructure, but the very human infrastructure which is most necessary to combat them. The longer a disease rages on, and the more it kills and incapacitates vital personnel on the front lines of the response, the weaker the defenses societies can mount against an inferno which burns hotter the more fuel it consumes. These crippled medical systems must somehow find a way to hold the line over the months or even years it can take to develop treatments and vaccines from scratch, even assuming the pathogen does not mutate in a way which renders these efforts moot. And finally, as the disease causes fear to spread among the general public, it undermines institutional and societal trust, especially within the rapidly evolving and unreliable information environment which such an event creates. This trust is the most important ingredient for countries which hope to mount a cohesive, national response which halts the spread of the disease before it has the chance to rage through the entire population. The socialcontagion which a pandemic creates may not kill in the same way as a virus, but it is indirectly just as deadly.

A pandemic, at its heart, createsa monumental information and communications challenge. During the initial stages of an outbreak, novel diseases often spread rapidly before they can be widely recognized and contained by authorities. When such diseases are new and highly contagious, standard diagnostic techniques are frequently insufficient to highlight the new threat, while treatments for new diseases are developed too slowly to outpace the unchecked spread of the contagion among an immunologically naïve population. Once a new disease has been identified, its potential for danger must be communicated to officials at all levels of government in order to choreograph a containment response as rapidly as possible through contact mapping and tracingandstrict enforcement of quarantines. If these measures fail and community spread begins to accelerate, authorities must shift gears from containment to mitigation by informing the population of the threat, communicating what steps people must take to minimize their risk. In the socially distanced environment that is necessitated during the mitigation phase of a pandemic, systems for distance communication and interaction must be instituted in order to replace the daily, normally face to face interactions that ordinarily keep a society running, but under such conditions represent unacceptable health risks. Similarly, systems must be put in place for individuals in isolation to communicate urgent needs and for society to meet these needs under conditions where in-person communication is extremely discouraged. Finally, once treatment has been developed which can be deployed to the population at large, the population must be informed how delivery will take place in a way which ensures the highest possible compliance. Most importantly, each of these steps must take place in a fashion which upholds institutional trust to the greatest possible degreeso that the misinformation and conspiracies which flourish during times of uncertainty and fear do not undermine efforts to put the outbreak to an end as rapidly as possible.

Given the myriad of information and communications challenges which are presented by a pandemic, Information and Communications Technology (ICT)is particularly well-equipped to offer solutions to the problems that emerge over the course of these catastrophic events. Before a novel pathogen is even identified, ICT-based techniques such as search result correlation and mapping can flag the emergence of potentially deadly diseases before more traditional methods could alert disease control specialists to their presence, offering hope for immediate containment and near-total avoidance of an outbreak. Should containment need to take place at a more ambitious scale, mobile technology can aid these efforts by tracking and notifying individuals who have come in close proximity to suspected carriers, as Singapore has carried out to great effect, and GPS tracking can be used to enforce the quarantine of these individuals, as South Korea has successfully modeled.Throughout the treatment process, cognitive computing techniques can be applied to identify promising experimental treatments, risk factors and comorbidities in a way which helps society protect those who are most at risk. If an outbreak progresses to the point where containment must be abandoned in favor of mitigation, ICT can likewise play a key role by providing means for e-health checkups which relieve the pressure felt by overburdened hospitals and medical personnel. Adequate communications infrastructure also facilitates interpersonal connections at a stage when much of the population is likely to have been forced into isolation. This not only helps alleviate the personal stress which can negatively impact mental health during such times, but can also serve as a decentralized diagnostic network to flag potential new cases which would otherwise not be placed in contact with the relevant medical personnel. Finally, technology can facilitate economic resiliency by allowing employees in certain sectors to work from home, facilitating direct payments to workers in more vulnerable industriesto stave off mass unemployment, and helping deliver essential services while minimizing the required labor presence.

In section one of this paper, we surveythe ways in which ICTs can strengthen the short-run medical and institutional response to COVID-19, including improving the testing and diagnosis regime, streamlining patient tracking, recordkeeping and case management, and ensuring thecontinuation of routine, yet still necessary medical procedures. Section two explores howICTs can contribute to the long-term resiliency of society to pandemics and other similar disastersby making labor markets and supply chains more resilient, aiding the spread ofaccurate and quality information, and providing channels fordirect economic support for the population.Third, we discuss the weaknesses and blind spots which ICT initiativestend to fallvictim to, and what this may mean for a public health response predicated on the use of ICT. Finally, we investigatewhat thecountries which have most successfully contained the spread of COVID-19 have done, particularly regarding the use of ICT, and assess the best practices emerging from these experiences. [1]

Impact and Risk Response

In the face of the growing spread of COVID-19, many businesses are formulating action plans to mitigate the potential impact on business operations, while at the same time meeting the needs of their customers and other stakeholders.

It is too early to assess the ultimate consequences on businesses, as the situation is still evolving. We are seeing volatility in the stock markets, travel restrictions, cancellation of events, school closings, constant news coverage and social media obsession with COVID-19.

And while there's still much uncertainty, prudent leaders should be well-prepared.

Impact on Health and Safety

COVID-19 is an infectious disease.

The virus is thought to spread mainly from person-to-person through respiratory droplets when an infected person coughs or sneezes. It is also possible that a person may catch coronavirus by touching something that has the virus on it and then touching their own mouth, nose or their eyes. Gathering employees together at the workplace or large corporate events may put them at risk of exposure to the virus. The nature of the virus makes it challenging for companies to strike a balance between maintaining productivity and efficiency and providing a safe working environment for their employees. Early adoption of adequate preventive measures and maintaining an effective communicable illness policy can help ensure a safe work environment for employees, customers and clients. [4]

Risk Response

To protect employee and customer safety while minimizing adverse economic impacts on the business, companies should consider the following actions, among others:

- Remind employees about the importance of maintaining personal hygiene and thoroughly washing hands and/or using hand sanitizer. Refer to guidance provided by the WHO and local authorities.
- Encourage employees to stay home at the first onset of any cold or flu-like symptoms.
- Disseminate information on precautions to help stop the spread of the virus.
- Continually update records of travel and monitor employees' potential exposure to COVID-19.
- Reconsider any non-essential travel plans, especially to events with large groups of people. Social distancing is encouraged at this time.
- Review and evaluate remote work policies and capabilities.
- Provide sufficient and accessible infection control supplies (e.g. hand sanitizer) and ensure cleaning services are properly cleaning and disinfecting frequently-touched objects and surfaces.
- Coordinate with Human Resources to establish procedures for how to respond to any symptoms displayed by employees.

Impact on Governance

The organization's management is responsible for identifying, assessing and responding to risks. These include emerging and atypical risks, as well as risks which are newly developing and difficult to fully assess but could affect the viability of an organization's strategy.

The board of directors has a fiduciary duty to ensure the organization acts in the best interest of its stakeholders. Board members should oversee the organization's ability to successfully identify and respond to emerging risks, as well as provide timely and transparent information to internal and external stakeholders. [4]

Risk Response

During times of crisis, people look to their leaders for strength and stability. Leaders do not wish to be caught off guard, especially when a situation escalates and thrusts the organization into chaos. Management and the board must work together to ensure a strong culture and effective communication is maintained throughout the process. Consider the following steps:

- Review the operational risk management capabilities, such as crisis management, business continuity, third-party risk and insurance. Verify that all key members of the team have been identified and fully understand their duties and are confident in their ability to carry out the responsibilities. If the operational risk management capabilities do not exist or are insufficient, consider involving risk management and internal audit professionals to assist in rapid development.

- Encourage collaboration across the organization to develop a strategy for adjustments to business continuity plans that adapt to evolving conditions.
- Center your focus on key business outcomes. This may require a different cadence, specific measurements for remote teams, and empathy during difficult situations. Focusing on your communications plan and your work culture will allow you to manage through distractions.
- Establish clear responsibilities between the board, audit and risk committees, and management team. Assess whether management has adequate resources internally or externally to help in assessing and mitigating risk.
- Ensure timely and relevant information is being received by the board.
- Develop centralized, timely messaging from leaders disseminated to employees to instill confidence and calm, and counter fear and misinformation.
- Require transparency in communications and set expectations for the frequency of communications.
- Ensure there is a platform or communication channel (e.g. hotline or website) to timely communicate information about COVID-19 inside and outside the organization.

Impact on Financial Reporting

Operations for some organizations will be negatively impacted by the COVID-19 situation. Companies should onsider the additional risks involved and the impact on the company. In some cases, the impact may ecessitate adjustmnents to accurately reflect the financial situation of the organization. [4]

Risk Response

- Evaluate potential disclosure of subsequent events in the notes to the financial statements, as well as how the organization plans to respond to the events as they unfold, which can be material to an investment decision.
- Due to COVID-19, the SEC has granted relief related to financial reporting and has established a protocol. Contact the SEC staff regarding guidance.
- Reassess the reasonableness of allowance and/or reserve balances, as these may be impacted. For instance, the company could have large accounts receivable amounts from a certain customer who may have incurred severe impact on their business due to COVID-19, causing an inability to pay and thus necessitating an increase in the allowance for doubtful accounts.

- Examine all actions taken by the organization in response to COVID-19. Consider the impact to the financial statement, and ensure appropriate entries are recorded in the general ledger to accurately capture the impact.
- Assess deferred tax assets – the need for a valuation allowance (or the magnitude of an existing valuation allowance) may need to be re-evaluated.
- Assess derivatives and hedging – forecasted purchases and sales and hedging of these activities may be impacted. These factors should be taken into consideration in the valuation of the contracts, and may cause problems from a hedge accounting standpoint as forecasted transactions are no longer probable of occurring. There may be legal questions on whether force majeure clauses are tripped.
- Public companies should consider whether updates are needed to Risk Factors, MD&A (known trends and uncertainties, potential impacts to guidance, capital expenditures, collectability issues, any impacts to cash flows, etc.), and other parts of filings.

Impact on Economic Sustainability

As the number of COVID-19 cases continues to climb across the globe, businesses of all sizes and across all industries are feeling a significant impact.

Mass cancellations and travel restrictions are having a big impact on the airline industry. Hospitality businesses have seen a sharp decline in their customer numbers. Supply chain disruption is pervasive and only getting more difficult to navigate.

Organizations may be faced with tough decisions to alter operations temporarily, modify business hours, or operate below capacity due to the impact on their workforce, customers or suppliers. We recommend you consider contingency planning and “what if” scenarios to establish back-up plans.

These issues may lead to falling revenue, reduced financial liquidity and the going concerns of key business partners, negatively impacting companies' sustainability. [4]

Risk Response

It is difficult to assess how long the novel coronavirus will cause significant disruption. In the meantime, cash is king: The critical element in any time of uncertainty is to ensure that the company's liquidity position can be maintained and to buy time for the company to recover.

We recommend that company management establish a task force to monitor the level of impact on the business and periodically report to the board on the status of the key performance indicators for critical business units. Companies may also consider the following actions, among others:

- Conduct a thorough risk assessment of business operations, taking a holistic approach across the globe rather than focusing on certain regions, to assess the level of possible interruption and formulate measures to mitigate potential impacts.
- Perform financial scenario, sensitivity and ratio analysis, examining the overall threat to the organization should sales and/or production decrease at various percentage rates. Determine what actions may need to be taken at certain stages to reduce further losses.
- Plan for voluntary/involuntary employee absenteeism and reduction in workforce, which will impact production and service levels. Consider alternative work arrangements such as relocation (working from home or other locations), reassignment of workflow (altering shifts), or reallocation of production.
- Review the pace of expenditure in relation to the company's expansion plans and existing development projects (if any) and slow down the cash burn rate.
- Re-prioritize the allocation of resources to unaffected business lines.
- Assess any impact relative to customer behaviors or sales over the past month(s) to determine if adjustments should be made to the level of staff needed or business hours.
- Explore and identify business transformation opportunities and models to reduce over-reliance on existing business segments.
- Identify measures for controlling budgets and increasing cost savings, such as assessing the possibility of outsourcing or reduction of non-critical business activities.
- Explore opportunities for collaboration with new strategic business partners for new market development and to meet customers' needs.
- Identify alternative solutions if forced to suspend operations at the business premises.

Impact on Contract Compliance

Companies are experiencing an impact on sales, production and supply chain, among others, as a result of COVID-19-related issues from business interruptions. These impacts have a cascading effect on the ability to meet contractual obligations. [4]

Risk Response

We recommend that companies consult their legal advisors and review their contracts to determine what, if any, contractual obligations may be impacted and the rights and remedies they have as a result of the delayed performance of contracts.

Companies should also take (and document) reasonable steps to mitigate the impact of COVID-19. If companies cannot fulfill their contractual obligations, they may need to quantify the amount of financial damage and the impact on their long-term business relationships.

Companies should review their existing insurance policies to find out whether any losses they incur relating to COVID-19 can be covered under existing terms or whether they need to adjust their coverage for additional protection.

Impact on Supply Chain

China is well known as the largest supplier of goods all over the world. Governments around the world have begun to take measures that limit the movement of goods and people across borders. Restrictions imposed by the Chinese government, for example, have included quarantine mandates and factory shutdowns across the country. As China is the factory of the world, supply chains are deeply affected. [4]

Risk Response

If management believes there is a risk of disruption to their supply chains, they should take the following steps, among others, to mitigate the potential consequences:

- Understand the behavior of disruptive models applied to the supply chain and establish the point in time at which such disruption is located.
- Consider re-prioritizing the production line to respond to market impacts associated with the threat, increasing safety stock levels, and stockpiling essential supplies and resources.
- Determine which vendors may be most severely impacted and if alternative vendors can provide a solution to meet business needs.
- Pre-qualify alternative domestic or international suppliers and outsourced vendors in case primary suppliers can no longer provide support.
- Assess if suppliers have documented plans for business unit continuity and information technology disaster recovery, including for critical business.
- Formulate contingency measures, give first response and anticipate possible failures in the supply chain. For example, examine the capacity of other suppliers in other geographical areas, change the production mix and plan for new delivery methods to reach customers.
- Take into consideration the absence of a large number of critical staff over an extended period.
- Estimate the recovery time for the supplier's "mission-critical" business processes.
- Develop actions for business recovery. For example, find and approve new suppliers and alternative modes of transport, then identify which of those options are available, and sell products on that basis.

Impact on Technology

Many organizations will activate contingency and business continuity measures to allow employees to work from home to limit the spread of the virus. A significant number of remotely-connected employees, for an extended period, may put a strain on the company's network.

Furthermore, as businesses and employees are determining the potential impacts of COVID-19 on their operations, some cybercriminals are exploiting the hysteria. There are reports of phishing emails masquerading as guidance about COVID-19, as hackers disguise malware in email attachments purporting to contain information to protect against its spread. [4]

Risk Response

- Assess whether security settings for remote connections and secured individual access mechanisms are in place and operating effectively.
- Determine sufficiency of network capabilities if a large number of employees are expected to be working remotely for an extended period.
- Enable staff to utilize equipment and tools to maximize their productivity while working remotely, such as video calling, cloud-based collaboration software, and online document authoring.
- Consider moving appropriate applications and decision support systems to the cloud to enhance your ability to not only manage through difficult times, but also harness the innovation,

compliance and security features provided by global public cloud vendors.

- Adopt and/or verify enforcement of multi-factor uthentication for employees who are logging into the company network.
- Review communications and information technology infrastructures as needed to support employee telecommuting and remote customer access.
- Enhance user awareness of cyber-attacks and provide frequent alerts to employees to enhance cyber vigilance.
- Educate employees on red flags to look out for within phishing emails.
- Practice consistency in communication methods and protocols to heighten an employee's awareness of phishing attempts.
- Monitor the use of unauthorized computers (especially for companies that have adopted a Bring Your Own Device policy) and their access to the network.
- Review the data backup policy and the frequency. [4]

ICT Interventions in Covid-19 Pandemi

The review study explored the existing digital or ICT-based technologies that are being used for containment of pandemic spread of COVID-19 around the globe. Figure 3 presents the key ICT-based technologies along with three examples (for each technology). The results showed that websites and dashboards, mobile applications, robotics and drones, artificial intelligence (AI) or machine learning (ML), data analytic, wearable or sensor technology, social media and learning tools and interactive voice response (IVR) are primarily used around the world as ICT intervention to combat the pandemic spread of COVID-19 and to provide health services during this vulnerable period.

a) Websites and Dashboards - Most countries have created websites, dashboards, and national portals to fight within a local sphere mainly to provide updated Corona statistics, preventive and controlling information, government and medical declarations, awareness and mental health related information, emergency contact information, hospital map, and facilitate for self-assessment and symptom reporting for the risk of COVID-19. For example, WHO collaborated with WhatsApp and CDC collaborated with Apple Symptom Checker are striving to raise awareness and provide updated statistics of COVID-19. A dashboard developed and maintained by John Hopkins University has used data visualization technique to provide latest scenario of the pandemic.

b) Mobile Application - A number of mobile applications are being developed almost in every Corona affected country around the world. The main purpose of using mobile applications includes providing treatment information or services, remote monitoring and assistance to Corona infected patients, provide updated statistics on COVID-19, making people aware about Coronavirus, providing communication service including live video chatting and emergency calls, assisting to improve self-confidence and mental health during the pandemic situation, and providing preventative and controlling information. For example, ADiLife COVID-19, HealthLynked COVID-19 Tracker, COVID Live Tracker - Corona Virus Pocket Guide are providing remote assistance, health awareness and updated statistics about the spread of COVID-19. Again, China based apps like "Close contact" and "Ali pay Health Code" are using data analytic to provide color codes to every citizen which is actively helping to maintain the social distance and monitor public health.

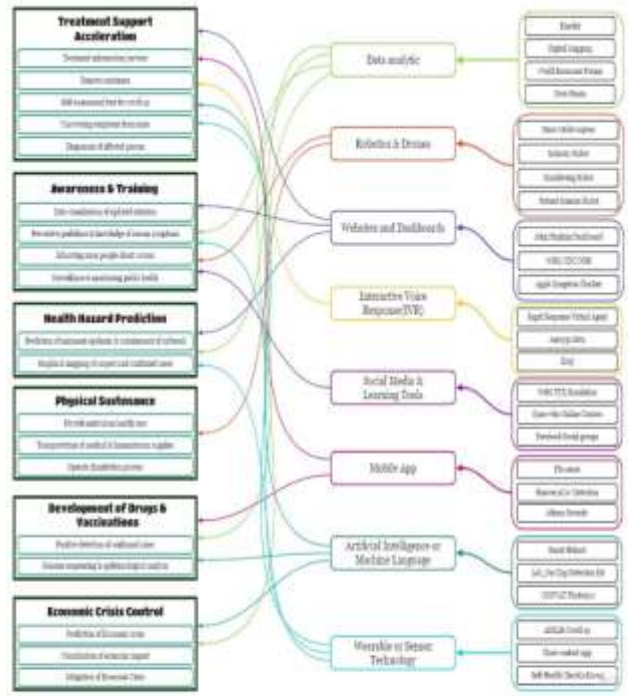
c) Robots and Drones - Several kind of robots and drones like disinfecting robot, agricultural robot, virtual human, micro-multicopter and industry robot are being used in several countries for multiple purposes that include transporting medical supplies, disinfection process, detection of symptoms, patient monitoring and in few cases providing physical medical support.

d) Artificial Intelligence - Artificial Intelligence (AI) is playing numerous roles to limit the human interaction and involvement to fight against the COVID-19 pandemic. Services like disease surveillance, early warnings and alerts, virtual healthcare assistance, diagnosis and prognosis, information verification over social media, controlling social distancing and measuring the lock-down, treatment and cures, processing and analyzing COVID-19 test samples, detecting and tracking individuals even when a person is wearing a face-mask and the likes are received from the AI-based technologies. For example, AI based system Flu-sense (US) is using machine learning and edge computing to predict the timing of the disease that to be launched within a small scale in university clinics. Another similar project was launched in Austria as Athena-Security using thermal imaging and AI. On a similar note, Huawei has created AI based swift diagnosis tool for COVID-19 patients and suspected cases.

e) Data Analytics - Big data, data analytic, predictive analytic or data science is used to provide data dashboard as well as to track, predict, control, respond to, and combat the pandemic spread of COVID-19. For example, the data analytic platform like Blue-dot is used to predict the upcoming epidemic using AI and data analysis. On a similar note Next-strain is an open dataset where the genome sequencing of novel corona virus was uploaded for data analysis purposes. Digital Mapping was also created in few countries using data mining. Like in Bangladesh, ICT Division and ROBI Axiata Ltd has developed a data analytic based digital solutions that allows to perform various innovative data visualization exercises to generate insights and as such, the Government can assess probability of exposure in a given area to determine the next course of action.

f) Wearable Technology - Wearable computing or sensor technology like Smart Helmet (China) and portable Lab-on-chip detection kit (Singapore) are being used to detect COVID-19 cases in a mass crowd using thermal imaging, monitor and ensure quarantine of suspected patients, and measure/collect patient's health data remotely. In Spain, a scientist team named CONVAT (the Catalan Institute of Nanoscience and Nanotechnology) has built photonics system with ultra-sensitive laser sensor that detects Coronavirus at the earliest point of infection from a saliva or nasal swab in minutes.

g) Social Media and Learning Tools - Social Media platforms like Facebook, Twitter, Instagram, Telegram are playing a very effective role to raise awareness and spread preventive measures. Moreover, learning tools like simulation exercises and management presentation are being provided globally to raise resistance against the pandemic. Furthermore, online courses like Open-Who has been introduced to provide quality knowledge all over the world. h) Interactive Voice Responses - A wide use of Interactive Voice Responses (IVR) is introduced globally and locally to assist health system. Google launched Rapid Response virtual agent and Xaqt's Coronavirus IVR (US) as a service are conversational IVR that gives government agencies and NGOs the ability to provide relevant information to citizens in a responsive and proactive manner. Local use of IVR like Aaroyga Seba in India has been also observed effective for healthcare assistance, reporting and data collection on COVID-19. [5]



ICT for Risk Response

Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business. We are currently dealing with the challenges of a digital economy as well as a digital transformation. Furthermore, digital technologies are reshaping traditional business strategy and also transforming the structure of social relationships for both the consumer and the enterprise. However, we still do not have an in-depth discussion on what skills and abilities are required for the emerging digital economy that can help organizations to cope with these new challenges.

Furthermore, digital technologies are reshaping traditional business strategy as modular, distributed, cross-functional, and global business capabilities that enable work to be carried out across boundaries of time, distance, and function. These technologies are also transforming the structure of social relationships for both the consumer and the enterprise with social media and social networking. These transformations modify the processes and structures within and among businesses, increasing the relevant role of digital capabilities.

So, the objective of an organization for improving business capabilities shall be to increase digital capabilities as a driver related to digital business performance, particularly in competition. [2]

As the coronavirus pandemic (Covid-19) evolves, technological applications and initiatives are multiplying in an attempt to stop the spread of the disease, treat patients and take the pressure off overworked healthcare workers, while also developing new, effective vaccines. At a time when everyone needs better information, including epidemic disease modellers, state authorities, international organisations and people in quarantine or maintaining social distancing, digital information and surveillance technologies have been unleashed in an unprecedented manner to collect data and reliable evidence to support public health decision-making. Artificial intelligence, robots and drones are being deployed to help track the diseaseand enforce restrictive measures;while scientists are frantically applying gene editing, synthetic biology and nanotechnologies in a bid to prepare and test future vaccines, treatments and diagnostics. Blockchain applications can track contagion, manage insurance payments, and uphold medical supply chains. Furthermore, 3D printing and open-source technologies seem capable of sustaining the effort of governments and hospitals around the world to meet the increasing need for medical hardware (e.g. facemasks, ventilators and breathing filters) and optimise the supply of the necessary medical equipment. At the same time, telehealth technologies offer a cost-effective means to slow the spread of the virus and to maintain hospital capacity by operating as a possible filter, keeping those with moderate symptoms at home and routing more severe cases to hospitals.

Presenting a non-exhaustive overview of the technologies currently in use, this analysis highlights their main features andsignificance in the fight against thecoronavirus pandemic, focusing on the way they are being used to monitor and contain the rapid spread of thedisease, and to ensure that public health institutions maintain their capacity to meet theever-increasing needs causedby this pandemic disease. The analysis also illustrates the main legal and regulatory challenges and the key socio-ethical dilemmas that these technologies' manifold applications pose when used in a public-health emergency context such as the current one.

A scan of the technological horizon in the context of Covid-19 allows some preliminary remarks regarding the terms of technological engagement in the fight against this once-in-a-century pandemic. First, unlike previous public health crises, this one seems to be transforming citizens from objects of surveillance and epidemiological analysis into subjects of data generation through self-tracking, data-sharing and digital data flows. Secondly, although most of these technologies have not been applied in a medical emergency context before, their intensive use on a global scale triggers questions about the effects on civil liberties of mobilising mass surveillance tools as well as concerns about state authorities maintaining heightened levels of surveillance,even after the pandemic ends. In the context of the current pandemic, numerous data-collection and location-tracking technological applications have been launched on the basis of emergency laws that involve the temporary suspension of fundamental rights and authorisationof medical devices and vaccines via fast-tracked procedures.

Although the focus of this analysis is on technological applications presenting solutions to pressing pandemic-related problems, this piece of research does not aim to reinforce ideas of techno-solutionism. In other words, technological applications in their own right cannot solvecomplex societal challenges, such as those associated with the current pandemic. Rather, this work's main findings indicate that technology in itself cannot replace or make up for other public policy measures but it does have an increasingly critical role to play in emergency responses. Covid-19, as thefirst pandemic of the century, represents an excellent opportunity for policy-makers and regulators to reflect on the legal plausibility, ethical soundness and effectiveness of deploying emerging technologies under time pressure. Striking the right balance will be crucial for maintaining the public's trust in evidence-based public health interventions. [6]

1. Artificial intelligence

How Artificial Intelligence can help fight COVID-19

Artificial intelligence is contributing to fight the COVID-19 pandemic. Projects directly related to pharmacology, medical and hospital care, or mobility analysis to reduce contagion have found a crucial ally in data science to make progress and deliver results.

The pandemic caused by COVID-19 is the first global public health crisis of the 21st century. And today, multiple AI-powered projects based on data science, 'machine learning' or 'big data', are being used across a broad range of fields to predict, explain and manage the different scenarios caused by the health crisis.

AI is being used to support and help those making decisions. "No decisions, at any step, are fully and exclusive delegated on the algorithm," explains Nuria Oliver, data scientist, who holds a Ph.D. from the Media Lab at Massachusetts Institute of Technology (MIT) and is the Regional Government of Valencia's commissioner on AI matters.

Medicine, health management and public policies

In the context of the pandemic, AI is being applied and delivering results in three fields: in virus research and the development of drugs and vaccines; in the management of services and resources at healthcare centers; and in the analysis of data to support public policy decisions aimed at managing the crisis, such as the confinement measures.

As regards application of AI to research, work seems to be progressing at a modest pace. There are still many unanswered questions surrounding the virus. But scientific teams are not giving up and researchers break new ground every day. Scientists from Google-owned AI firm DeepMind are working to predict the protein structures of the novel coronavirus, which is essential to better understanding how it evolves and how to control it. Even to develop a vaccine in combination with the findings of other research projects.

Just a few weeks ago, the idea of widespread lockdown would have sounded preposterous. At one point during this crisis, over half of the world's population had been asked or ordered to stay at home. Cities have enforced mass closures of shops and schools. The reason? Reducing people's mobility and social interactions to slow virus spread and keep health systems from collapsing. In other words, to 'flatten the contagion curve', a sentence that has become one of the mantras of 2020.

These public decisions have been made based on data evidence. Data scientist Nuria Oliver is currently working on a pilot project that the Regional Community of Valencia is developing to analyze mobility during the COVID-19 pandemic based on the aggregated and anonymized datasets shared by the Spanish Statistical Institute and telecommunications service providers. "We've created a human mobility model to quantify and measure the impact of mobility during a lockdown situation and to understand what type of mobility has been reduced and to make decisions taking into account the data at our disposal," explains Oliver. In a second phase, both the mobility models and their findings will be assessed together with the SIR epidemiological models, which are used to trace how a pandemic evolves taking into account the number of individuals susceptible to the disease (i.e. not yet infected), the number of individuals infected and capable of spreading the disease, and the number of individuals who have recovered. This model allows quantifying mobility and forecasting how fast the epidemic can spread.

The third part of the project includes the conduction of a survey to better understand the situation of citizens, their social behavior, health condition and the economic impact of public decisions. "This project clearly illustrates how society and also Public Administrations can benefit from the use of AI. How they should transform to become more efficient by making data and evidence based decisions," Oliver explains.

"Machine learning and artificial intelligence algorithms allow us to diagnose and customize medical care and follow-up plans to get better results"

In field of primary healthcare, medical teams specializing in infections, epidemiologists and various experts have had to prepare for something new: a widespread health crisis triggered by an extremely contagious virus. In many cases, decisions on case detection, treatment prescription and ICU (Intensive Care Unit) procedures have been made without the required level of knowledge or evidence. Data science and big data are proving highly valuable for improving hospital management.

"Machine learning and artificial intelligence algorithms allow us to diagnose and customize medical care and follow-up plans to get better results," says Ángel Díez, CEO of Ubikare, a home healthcare application for the elderly. With the arrival of COVID-19, the company is focusing on understanding better how hospitals work and helping them deliver their services better. They have achieved this by adapting their software, data questionnaires, diagnoses and different algorithms.

"Once we get a database ready, we work with epidemiologists to, based on common patient variables, assess which management strategies do and don't work, to prescribe therapies." This is how Díez describes this initiative. He also underscores that having access to actual patient data boosts health professionals' ability to learn while reducing the threshold of uncertainty that affects decision making processes in a critical scenarios. [6]

Analytics have changed the way disease outbreaks are tracked and managed

Analytics have changed the way disease outbreaks are tracked and managed, thereby saving lives. The international community is currently focused on the 2019-2020 novel coronavirus (Covid-19) pandemic, first identified in Wuhan, China. As it spreads, raising fears of a worldwide lockdown, international organisations and scientists have been using artificial intelligence (AI) to track the epidemic in real-time, so as to be able to predict where the virus might appear next and develop an effective response.

On 31 December 2019, the World Health Organization (WHO) received the first report of a suspected novel coronavirus (Covid-19) in Wuhan. Amid concerns that the global response was fractured and uncoordinated, on 30 January 2020 the WHO declared the outbreak a public health emergency of international concern (PHEIC) under the International Health Regulations (IHR).

Warnings about the novel coronavirus spreading beyond China were raised by AI systems more than a week before official information abouttheepidemic was releasedby international organisations.A health monitoring start-upcorrectly predicted the spread of Covid-19, using natural-language processing and machine learning. Decisions during outbreaks of this nature need to be made on an urgent basis, often in the context of scientific uncertainty, fear, distrust, and social and institutional disruption. How can AI technologies be used to manage this type of global health emergency, without undermining protection of fundamental values and human rights? . [6]

Potential impacts and developments

In the case of Covid-19, AI has been used mainly to help detect whether people have novel coronavirus through the detection of visual signs of Covid-19 on images from computerised tomography (CT) lung scans; to monitor, in real time, changes in body temperature through the use of wearable sensors; and to provide an open-source data platform to track the spread of the disease. AI can process vast amounts of unstructure d text data to predict the number of potential new cases by area and which types of populations will be most at risk, as well as to evaluate and optimise strategies for controlling the spread of the epidemic. Other AI applications can deliver medical supplies by drone, disinfect patient rooms and scan approved drug databases for medicines that might also work against Covid-19. AI technologies have been harnessed to come up with new molecules that could serve as potential medications or even accelerate the time taken to predict the virus's RNA secondary structure. A series of risk assessment algorithms for Covid-19 for use in healthcare settings have been developed, including an algorithm for the main actions that need to be followed for managing contacts of probable or confirmed Covid-19 cases, as developed by the European Centre for Disease Prevention and Control.

Certain AI applications can also detect fake news about the disease by applying machine-learning techniques for mining social media information, tracking down words that are sensational or alarming, and identifying which online sources are deemed authoritative for fighting what has been called an infodemic. Facebook, Google, Twitter and TikTok have partnered with the WHO to review and expose false information about Covid-19. In public health emergency response management, derogating from an individual's rights of privacy, non-discrimination and freedom of movement in the name of the urgency of the situation can sometimes take the form of restrictive measures that include domestic containment strategies without due process, or medical examination without informed consent.

In the case of Covid-19, AI applications such as the use of facial recognition to track people not wearing masks in public, or AI-based fever detection systems, as well as the processing of data collected on digital platforms and mobile networks to track people's recent movements, have contributed to the draconian enforcement of restraining measures during the confinement aimed at containing the outbreak, for unspecified durations. Chinese internet search giant Baidu has developed a system using infrared and facial recognition technology that scans and takes photographs of more than 200 people per minute at the Qinghe railway station in Beijing. In Moscow, authorities are using automated facial recognition technology to scan surveillance camera footage in an attempt to identify recent arrivals from China, placed under quarantine for fear of Covid-19 infection. Finally, Chinese authorities are deploying drones to patrol public places, conduct thermal imaging, or to track people violating quarantine rules. The effectiveness of these AI applications will not only depend on their technical capacities but also on how human controllers and AI developers will supervise their implementation pathways in accordance to the established algorithmic standards, legal principles and ethical safeguards. [6]

How could AI and big data help us in the fight against COVID-19?

In recent years, the world has witnessed the rise of SARS, Zika virus, Ebola and now COVID-19. Epidemics are a rising threat.

- Our digital infrastructure needs strengthening to deal with the impact of COVID-19 and future public health crises;
- Better integration of Artificial Intelligence in to the public health response should be a priority;
- Analysis of big data relating to citizens' movement, disease transmission patters and health monitoring could be used to aid prevention measures.

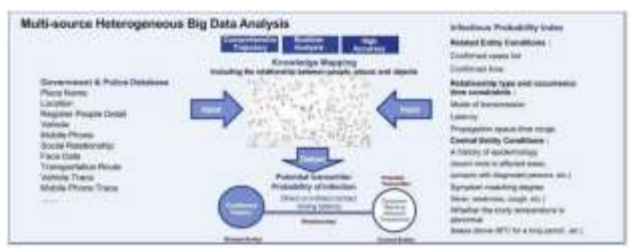
Cities across the world have made infrastructure innovation a priority to safeguard their physical systems so they can stay robust and antifragile during natural disasters such as earthquakes, tsunami and hurricanes. But pandemics have shown that these methods aren't enough when it comes to ensuring connectivity and accessing our society during biological disasters.

The primary challenge now, at the time of this crisis, is to integrate and streamline digital infrastructure at various stages of the public health response, particularly in the context of epidemic forecasting and decision-making. In the 17 years since SARS, a new age digital era has emerged; artificial Intelligence and the Internet of Things (IoT) could be instrumental in keeping this new virus within reasonable limits.

Pressure on digital infrastructure

Governments are now relying on ubiquitous instruments (sensors) and powerful algorithms instead of flesh-and-blood spooks. In the war against COVID-19, several governments have implemented these new surveillance tools.

Maps of the world show how the decrease in the transportation of people has drastically reduced carbon emissions across different countries, but what's the case for emissions from digital technologies? Will the volume of people working from home or using digital devices in quarantine cause an increase in emissions from other sources? What is being done by the large cloud-providers to address the capacity issue?



Using big data to fight pandemics

In the ongoing covid-19 pandemic, we are witnessing three major occurrences across the globe:

1. Wider acceptance of online services;

2. A humongous requirement for internet services for conventional industries;

3. Boosted connectivity among diverse types of industries.

These three data streams provide important, real-time data about travel patterns that spread disease and longitudinal alterations in populations at risk, which until recently have been very difficult to quantify on schedules related to a fast-moving pandemic. With an exponential rise in mobility and growing global connectivity, this information will be critical to planning surveillance and containment strategies.

Some researchers and private entities along with their respective state governments are developing a digital platform, HealthMap, which visually represents the disease outbreaks according to location, time and the type of contagious virus, bacterial disease that is being carried while entering into the city.

Digital infrastructure plays a pivotal role in predicting and modelling outbreaks. Take AI-supported services for a lung CT scan: the AI is premeditated to quickly detect lesions of likely coronavirus pneumonia; to measure its volume, shape and density; and to compare changes of multiple lung lesions from the image. This provides a quantitative report to assist doctors in making fast judgements and thus helps expedite the health evaluation of patients.

How to create real-time epidemic situation awareness

Mapping citizens

Governments across the globe are gradually developing the digital infrastructure and engineering capabilities to face the pandemic and alleviate the spread of COVID-19 through community-driven contact-tracing technologies. These enable citizens to react assertively and promptly to pandemic diseases with a set of digital tools to help spread timely and precise information to its citizens.

Many governments are encouraging private companies to develop innovative tools that make use of hundreds of millions of facial recognition cameras and people reporting their body temperature and medical condition. Through this authorities can quickly identify suspected coronavirus transporters and identify anyone with whom they have come into contact. An array of mobile apps warns citizens about their proximity to infected patients.

Roadmap for a better future

The virus has provided a new start for digital infrastructure development. Using the cloud, big data and AI applications creates room for industries to develop and build new business models that help citizens understand the severity of pandemic disease and ensure preventive measures.

A coalition of stakeholders (private and governmental) are supporting pharmaceutical enterprises with millions in funding to find a vaccine for the virus. To modernize, upgrade and update our digital infrastructure and to tackle this and future pandemics, different financial models will evolve such as Public-Private Partnership and consumption/outcome-based models to alleviate the financial crisis during the development phase.

It is now the moment for countries to fast-track the construction of new digital infrastructure, such as IoT along with AI, in addition to the hastening of vital projects and major infrastructure construction that's already included in countries' financial stimulus plans. [7]

How Artificial Intelligence, Data Science And Technology Is Used To Fight The Pandemic

Since the first report of coronavirus (COVID-19) in Wuhan, China, it has spread to at least 100 other countries. As China initiated its response to the virus, it leaned on its strong technology sector and specifically artificial intelligence (AI), data science, and technology to track and fight the pandemic while tech leaders, including Alibaba, Baidu, Huawei and more accelerated their company's healthcare initiatives. As a result, tech startups are integrally involved with clinicians, academics, and government entities around the world to activate technology as the virus continues to spread to many other countries. Here are 10 ways artificial intelligence, data science, and technology are being used to manage and fight COVID-19.

i. AI to identify, track and forecast outbreaks

The better we can track the virus, the better we can fight it. By analyzing news reports, social media platforms, and government documents, AI can learn to detect an outbreak. Tracking infectious disease risks by using AI is exactly the service Canadian startup BlueDot provides. In fact, the BlueDot's AI warned of the threat several days before the Centers for Disease Control and Prevention or the World Health Organization issued their public warnings.

ii. AI to help diagnose the virus

Artificial intelligence company Infervision launched a coronavirus AI solution that helps front-line healthcare workers detect and monitor the disease efficiently. Imaging departments in healthcare facilities are being taxed with the increased workload created by the virus. This solution improves CT diagnosis speed. Chinese e-commerce giant Alibaba also built an AI-powered diagnosis system they claim is 96% accurate at diagnosing the virus in seconds.

iii. Process healthcare claims

It's not only the clinical operations of healthcare systems that are being taxed but also the business and administrative divisions as they deal with the surge of patients. A blockchain platform offered by Ant Financial helps speed up claims processing and reduces the amount of face-to-face interaction between patients and hospital staff.

iv. Drones deliver medical supplies

One of the safest and fastest ways to get medical supplies where they need to go during a disease outbreak is with drone delivery. Terra Drone is using its unmanned aerial vehicles to transport medical samples and quarantine material with minimal risk between Xinchang County's disease control centre and the People's Hospital. Drones also are used to patrol public spaces, track non-compliance to quarantine mandates, and for thermal imaging.

v. Robots sterilize, deliver food and supplies and perform other tasks

Robots aren't susceptible to the virus, so they are being deployed to complete many tasks such as cleaning and sterilizing and delivering food and medicine to reduce the amount of human-to-human contact. UVD robots from Blue Ocean Robotics use ultraviolet light to autonomously kill bacteria and viruses. In China, Pudu Technology deployed its robots that are typically used in the catering industry to more than 40 hospitals around the country.

vi. Develop drugs

Google's DeepMind division used its latest AI algorithms and its computing power to understand the proteins that might make up the virus, and published the findings to help others develop treatments. BenevolentAI uses AI systems to build drugs that can fight the world's toughest diseases and is now helping support the efforts to treat coronavirus, the first time the company focused its product on infectious diseases. Within weeks of the outbreak, it used its predictive capabilities to propose existing drugs that might be useful.

vii. Advanced fabrics offer protection

Companies such as Israeli startup Sonovia hope to arm healthcare systems and others with face masks made from their anti-pathogen, anti-bacterial fabric that relies on metal-oxide nanoparticles.

viii. AI to identify non-compliance or infected individuals

While certainly a controversial use of technology and AI, China's sophisticated surveillance system used facial recognition technology and temperature detection software from SenseTime to identify people who might have a fever and be more likely to have the virus. Similar technology powers "smart helmets" used by officials in Sichuan province to identify people with fevers. The Chinese government has also developed a monitoring system called Health Code that uses big data to identify and assesses the risk of each individual based on their travel history, how much time they have spent in virus hotspots, and potential exposure to people carrying the virus. Citizens are assigned a color code (red, yellow, or green), which they can access via the popular apps WeChat or Alipay to indicate if they should be quarantined or allowed in public.

ix. Chatbots to share information

Tencent operates WeChat, and people can access free online health consultation services through it. Chatbots have also been essential communication tools for service providers in the travel and tourism industry to keep travelers updated on the latest travel procedures and disruptions.

x. Supercomputers working on a coronavirus vaccine

The cloud computing resources and supercomputers of several major tech companies such as Tencent, DiDi, and Huawei are being used by researchers to fast-track the development of a cure or vaccine for the virus. The speed these systems can run calculations and model solutions is much faster than standard computer processing.

In a global pandemic such as COVID-19, technology, artificial intelligence, and data science have become critical to helping societies effectively deal with the outbreak. [8]

Anticipatory policy-making

As a governance system, the WHO has limited enforcement tools, and its surveillance system is fully dependent on states' willingness to meet their good-faith reporting requirements. However, reporting compliance remains low, raising questions about the ability of low and middle-income countries (LMICs) to meet IHR obligations in the absence of adequate resourcing and financial support and about the effectiveness of the main legal framework of 'essential' capacities required by nations to prevent, detect and rapidly respond to public health threats. However, AI technologies have the potential to challenge the state's monopoly of information control and operationalise the WHO's right to receive reports from non-state sources, particularly if and when those reports contradict reports provided by the state. The development of vaccines and drugs in response to public health emergencies also presents particular legal and ethical challenges. The European Commission and the European Medicines Agency have put procedures in place to speed up the assessment and authorisation of vaccines for use during a public health emergency, either via the pandemic preparedness vaccine marketing authorisation or the emergency procedure. The EMA recently activated its plan for managing emerging health threats, while the Commission and the Innovative Medicines Initiative (IMI) have launched fast-track calls for proposals for the development of therapeutics and diagnostics to combat Covid-19 infections. Using the paragraph 6 system, provided by the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), countries are allowed to import cheaper generics made under compulsory licensing if they are unable to manufacture the medicines themselves. Adopting measures to counteract the potentially adverse health impact of IP protection and sharing preliminary research results with all actors in the response is a crucial component of any integrated global alert and response system for epidemics aimed at making the benefits of research available to local populations without undue delay. AI's capacity to search large databases quickly and process vast amounts of medical data should essentially accelerate the development of a drug that can fight Covid-19 but also raises questions about the criteria used for the selection of the relevant data sets and possible algorithmic bias. Most public health systems lack the capacity to collect the data needed to train algorithms that would be reflective of the needs of local populations, take local practice patterns into account and ensure equity and fairness.

As public health emergencies can be deeply socially divisive, stretch public-health capacities and limit rights to privacy and informational self-determination, it is important for policy-makers to consider the ethics of their crisis-management policies rationally. Although the Siracusa Principles may allow for limitation of, or derogation from the International Covenant on Civil and Political Rights (ICCPR), confining people during the outbreak of a lethal disease in emergency contexts should be ethically justifiable, necessary and proportionate. In all cases, the least liberty-infringing alternatives should be used to achieve the public health goal. The WHO guidance for managing ethical issues in infectious disease outbreaks and the guidance on ethical issues in research in global health emergencies could help to ensure appropriate ethical oversight and collaboration, to help combat the social stigmatisation of those affected, or perceived to be affected, by the disease.

However, given the absence of a comprehensive human rights framework that would underpin effective outbreak surveillance at international level, the management of the risks associated with infectious diseases is likely to remain an ongoing challenge for global health governance. The massive use of AI tracking and surveillance tools in the context of this outbreak, combined with the current fragmentation in the ethical governance of AI, could pave the way for wider and more permanent use of these surveillance technologies, leading to a situation known as 'mission creep'. Coordinated action on inclusive risk assessment and strict interpretation of public health legal exemptions, such as that envisaged in Article 9 of the General Data Protection Regulation, will therefore be key to ensuring the responsible use of this disruptive technology during public health emergencies. Accordingly, preventing AI use from contributing to the establishment of new forms of automated social control, which could persist long after the epidemic subsides, must be addressed in ongoing legislative initiatives on AI at EU level. [6]

AI and control of Covid-19 coronavirus

Artificial intelligence (AI) is being used as a tool to support the fight against the viral pandemic that has affected the entire world since the beginning of 2020. The press and the scientific community are echoing the high hopes that data science and AI can be used to confront the coronavirus (D. Yakobovitch, How to fight the Coronavirus with AI and Data Science, Medium, 15 February 2020) and "fill in the blanks" still left by science (G. Ratnam, Can AI Fill in the Blanks About Coronavirus? Think So Experts, Government Technology, 17 March 2020).

China, the first epicentre of this disease and renowned for its technological advance in this field, has tried to use this to its real advantage. Its uses seem to have included support for measures restricting the movement of populations, forecasting the evolution of disease outbreaks and research for the development of a vaccine or treatment. With regard to the latter aspect, AI has been used to speed up genome sequencing, make faster diagnoses, carry out scanner analyses or, more occasionally, handle maintenance and delivery robots (A. Chun, In a time of coronavirus, China's investment in AI is paying off in a big way, South China Morning post, 18 March 2020).

Its contributions, which are also undeniable in terms of organising better access to scientific publications or supporting research, does not eliminate the need for clinical test phases nor does it replace human expertise entirely. The structural issues encountered by health infrastructures in this crisis situation are not due to technological solutions but to the organisation of health services, which should be able to prevent such situations occurring (Article 11 of the European Social Charter). Emergency measures using technological solutions, including AI, should also be assessed at the end of the crisis. Those that infringe on individual freedoms should not be trivialised on the pretext of a better protection of the population. The provisions of Convention 108+ should in particular continue to be applied.

The contribution of artificial intelligence to the search for a cure

The first application of AI expected in the face of a health crisis is certainly the assistance to researchers to find a vaccine able to protect caregivers and contain the pandemic. Biomedicine and research rely on a large number of techniques, among which the various applications of computer science and statistics have already been making a contribution for a long time. The use of AI is therefore part of this continuity.

The predictions of the virus structure generated by AI have already saved scientists months of experimentation. AI seems to have provided significant support in this sense, even if it is limited due to so-called "continuous" rules and infinite combinatorics for the study of protein folding. The American start-up Moderna has distinguished itself by its mastery of a biotechnology based on messenger ribonucleic acid (mRNA) for which the study of protein folding is essential. It has managed to significantly reduce the time required to develop a prototype vaccine testable on humans thanks to the support of bioinformatics, of which AI is an integral part.

Similarly, Chinese technology giant Baidu, in partnership with Oregon State University and the University of Rochester, published its Linearfold prediction algorithm in February 2020 to study the same protein folding. This algorithm is much faster than traditional algorithms in predicting the structure of a virus' secondary ribonucleic acid (RNA) and provides scientists with additional information on how viruses spread. The prediction of the secondary structure of the RNA sequence of Covid-19 would thus have been calculated by Linearfold in 27 seconds instead of 55 minutes (Baidu, How Baidu is bringing AI to the fight against coronavirus, MIT Technology Review, 11 March 2020). DeepMind, a subsidiary of Google's parent company, Alphabet, has also shared its predictions of coronavirus protein structures with its AlphaFold AI system (J. Jumper, K. Tunyasuvunakool, P. Kohli, D. Hassabis et al, Computational predictions of protein structures associated with COVID-19, DeepMind, 5 March 2020). IBM, Amazon, Google and Microsoft have also provided the computing power of their servers to the US authorities to process very large datasets in epidemiology, bioinformatics and molecular modelling (F. Lardinois, IBM, Amazon, Google and Microsoft partner with White House to provide compute resources for COVID-19 research, Techcrunch, 22 March 2020).

Artificial intelligence, a driving force for knowledge sharing

In the United States, the White House Office of Science and Technology Policy met with technology companies and major research groups on 11 March 2020, to determine how AI tools could be used to, among other things, screen the thousands of research papers published worldwide on the pandemic (A. Boyle, White House seeks the aid of tech titans to combat coronavirus and misinformation, GeekWire, March 11, 2020).

Indeed, in the weeks following the appearance of the new coronavirus in Wuhan, China, in December 2019, nearly 2,000 research papers were published on the effects of this new virus, on possible treatments, and on the dynamics of the pandemic. This influx of scientific literature naturally reflects the eagerness of researchers to deal with this major health crisis, but it also represents a real challenge for anyone hoping to exploit it.

Microsoft Research, the National Library of Medicine and the Allen Institute for AI (AI2) therefore presented their work on 16 March 2020, which consisted of collecting and preparing more than 29,000 documents relating to the new virus and the broader family of coronaviruses, 13,000 of which were processed so that computers could read the underlying data, as well as information on authors and their affiliations. Kaggle, a Google subsidiary and platform that usually organises data science competitions, created challenges around 10 key questions related to the coronavirus. These questions range from risk factors and non-drug treatments to the genetic properties of the virus and vaccine development efforts. The project also involves the Chan Zuckerberg Initiative (named after Facebook founder Mark Zuckerberg and his wife Priscilla Chan) and Georgetown University's Center for Security and Emerging Technologies (W. Knight, Researchers Will Deploy AI to Better Understand Coronavirus, Wired, March 17, 2020).

Artificial intelligence, observer and predictor of the evolution of the pandemic

The Canadian company BlueDot is credited with the early detection of the virus using an AI and its ability to continuously review over 100 data sets, such as news, airline ticket sales, demographics, climate data and animal populations. BlueDot detected what was then considered an outbreak of pneumonia in Wuhan, China on 31 December 2019 and identified the cities most likely to experience this outbreak (C. Stieg, How this Canadian start-up spotted coronavirus before everyone else knew about it, CNBC, March 3, 2020).

A team of researchers working with the Boston Children's Hospital has also developed an AI to track the spread of the coronavirus. Called HealthMap, the system integrates data from Google searches, social media and blogs, as well as discussion forums: sources of information that epidemiologists do not usually use, but which are useful for identifying the first signs of an outbreak and assessing public response (A. Johnson, How Artificial Intelligence is Aiding the fight Against Coronavirus, Datainnovation, March 13, 2020).

The International Research Centre for Artificial Intelligence (IRCAI) in Slovenia, under the auspices of UNESCO, has launched an "intelligent" media watch on coronavirus called Corona Virus Media Watch which provides updates on global and national news based on a selection of media with open online information. The tool, also developed with the support of the OECD and the Event Registry information extraction technology, is presented as a useful source of information for policy makers, the media and the public to observe emerging trends related to Covid-19 in their countries and around the world.

Artificial intelligence to assist healthcare personnel

For their part, two Chinese companies have developed AI-based coronavirus diagnostic software. The Beijing-based start-up Infervision has trained its software to detect lung problems using computed tomography (CT) scans. Originally used to diagnose lung cancer, the software can also detect pneumonia associated with respiratory diseases such as coronavirus. At least 34 Chinese hospitals are reported to have used this technology to help them screen 32,000 suspected cases (T. Simonite, Chinese Hospitals Deploy AI to Help Diagnose Covid-19, Wired, February 26, 2020).

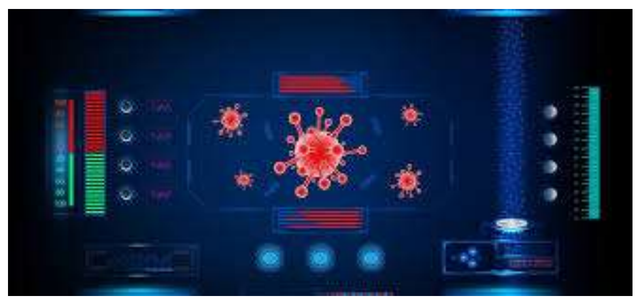
The Alibaba DAMO Academy, the research arm of the Chinese company Alibaba, has also trained an AI system to recognise coronaviruses with an accuracy claimed to be 96%. According to the company, the system could process the 300 to 400 scans needed to diagnose a coronavirus in 20 to 30 seconds, whereas the same operation would usually take an experienced doctor 10 to 15 minutes. The system is said to have helped at least 26 Chinese hospitals to review more than 30,000 cases (C. Li, How DAMO Academy's AI System Detects Coronavirus Cases, Alizila, March 10, 2020).

In South Korea, AI is reported to have helped reduce the time needed to design testing kits based on the genetic make-up of the virus to a few weeks, when it would normally take two to three months. The biotech company Seegene used its automated test development system to develop the test kit and distribute it widely. Large-scale testing is indeed crucial to overcome containment measures and this testing policy seems to have contributed to the relative control of the pandemic in this country, which has equipped 118 medical establishments with this device and tested more than 230,000 people (I. Watson, S. Jeong, J. Hollingsworth, T. Booth, How this South Korean company created coronavirus test kits in three weeks, CNN World, March 13, 2020).

Artificial intelligence as a tool for population control

The example set by Singapore in its control of epidemic risks, with the support of technology, is certainly unique and difficult to export because of the social acceptance of restrictive safety measures: issue of a containment order for populations at risk, verification of compliance with the measures by mobile phone and geolocation, random home checks (K. Vaswani, Coronavirus: The detectives racing to contain the virus in Singapore, BBC News, 19 March 2020). AI has been quite widely used in support of such mass surveillance policies as in China, where devices have been used to measure temperature and recognize individuals or to equip law enforcement agencies with "smart" helmets capable of flagging individuals with high body temperature. Facial recognition devices have, however, experienced difficulties due to the wearing of surgical masks, leading one company to attempt to circumvent this difficulty since many services in China now rely on this technology, including state services for surveillance measures. Hanvon thus claims to have created a device to increase the recognition rate of wearers of surgical masks to 95% (M. Pollard, Even mask-wearers can be ID'd, China facial recognition firm says, Reuters, 9 March 2020). In Israel, a plan to use individual telephone follow-up to warn users not to mix with people potentially carrying the virus has been developed (A. Laurent, COVID-19: States use geolocalisation to know who respects containment, Usebk & Rica, 20 March 2020 - in French only). In South Korea, an alert transferred to the health authorities is triggered when people do not comply with the isolation period, for example by being in a crowded place such as on public transport or a shopping centre (Ibid.). In Taiwan, a mobile phone is given to infected persons and records their GPS location so that police can track their movements and ensure that they do not move away from their place of confinement (Ibid.). In Italy, a company has also developed a smartphone application that can be used to trace the itinerary of a person infected with the virus and warn people who have had contact with him or her. According to the designer, privacy would be guaranteed, as the application would not reveal phone numbers or personal data (E. Tebano, Coronavirus, pronta la app italiana per tracciare i contagi: 'Così possiamo fermare l'epidemia', Corriere della Sera, 18 March 2020) In Lombardy, telephone operators have made available data concerning the movement of mobile phones from one telephone terminal to another (M. Pennisi, Coronavirus, come funzionano il controllo delle celle e il tracciamento dei contagi. Il Garante: «Non bisogna improvvisare», Corriere della Sera, 20 March 2020).

In the United States, tension can be perceived between guaranteeing individual rights and protecting collective interests during this health crisis. Thus, the GAFAM have at their disposal in the United States information which would be extremely valuable in times of crisis: an immense amount of data on the American population. Larry Brilliant, an epidemiologist and executive director of Google.org, claims that he can "change the face of public health" and believes that "few things in life are more important than the question of whether major technologies are too powerful, but a pandemic is undoubtedly one of them" (N. Scola, Big Tech faces a 'Big Brother' trap on coronavirus, POLITICO, 18 March 2020). The U.S. government has therefore asked these companies to have access to aggregated and anonymous data, especially on mobile phones, in order to fight the spread of the virus (T. Romm, E. Dwoskin, C. Timberg, U.S. government, tech industry discussing ways to use smartphone location data to combat coronavirus, The Washington Post, March 18, 2020). However, these companies have been cautious in view of the legal risk and potential image damage (S. Overly, White House seeks Silicon Valley help battling coronavirus, POLITICO, 11 March 2020). Data regulation would likely have helped frame the public-private dialogue and determine what types of emergencies should be subject to the collective interest over individual rights (as well as the conditions and guarantees of such a mechanism), but Congress has made no progress in the last two years on such a law.



Finally, attempts at misinformation have proliferated on social networks and the Internet. Whether it concerns the virus itself, the way it spreads or the means to fight its effects, many rumours have circulated ("Fake news" and disinformation about the SARS-CoV2 coronavirus, INSERM, 19 February 2020). AI is a technology already used with some effectiveness by platforms to fight against inappropriate content. UNICEF adopted a statement on 9 March 2020 on misinformation about the coronavirus in which it intends to "actively take steps to provide accurate information about the virus by working with the World Health Organization, government authorities and online partners such as Facebook, Instagram, LinkedIn and TikTok, to ensure that accurate information and advice is available, as well as by taking steps to inform the public when inaccurate information appears". The enactment of restrictive measures in Council of Europe member States to avoid fuelling public concern is also envisaged. However, the Council of Europe Committee of Experts on the Media Environment and Media Reform (MSI-REF) underlined in a statement of 21 March

2020 that "the crisis situation should not be used as a pretext to restrict public access to information. Nor should States introduce restrictions on media freedom beyond the limits allowed by Article 10 of the European Convention on Human Rights". The Committee also highlights that "member States, together with all media actors, should strive to ensure an environment conducive to quality journalism".

Artificial intelligence: an evaluation of its use in the aftermath of a crisis

Digital technology, including information technology and AI, are therefore proving to be important tools to help build a coordinated response to this pandemic. The multiple uses also illustrate the limits of what can currently be achieved by this very technology, which we cannot expect to compensate for structural difficulties such as those experienced by many health care institutions around the world. The search for efficiency and cost reduction in hospitals, often supported by information technology, should not reduce the quality of services or compromise universal access to care, even in exceptional circumstances.

It should be recalled that Article 11 of the European Social Charter (ratified by 34 of the 47 member States of the Council of Europe) establishes a right to health protection which commits the signatories “to take, either directly or in co-operation with public and private organisations, appropriate measures designed in particular to : 1°) to eliminate, as far as possible, the causes of ill-health; 2°) to provide consultation and education services for the improvement of health and the development of a sense of individual responsibility for health; 3°) to prevent, as far as possible, epidemic, endemic and other diseases, as well as accidents.”

Finally, it should be possible to evaluate the emergency measures taken at the end of the crisis in order to identify the benefits and issues encountered by the use of digital tools and AI. In particular, the temporary measures of control and mass monitoring of the population by this technology should not be trivialized nor become permanent (Y. N. Harari, Yuval Noah Harari: the world after coronavirus, The Financial Times, 20 March 2020).

Standards relating to data protection, such as Convention 108(+) of the Council of Europe, must still be applied fully and under all circumstances: whether it be the use of biometric data, geolocalisation, facial recognition or the use of health data. Use of emergency measures should be carried out in full consultation with data protection authorities and respect the dignity and the private life of the users. The different biases of the various types of surveillance operations should be considered, as these may cause significant discrimination (A.F. Cahn, John Veiszlemlein, COVID-19 tracking data and surveillance risks are more dangerous than their rewards, NBC News, 19 March 2020).

2. Blockchain

Covid-19's highly infectious nature means that there is a pressing need to find appropriate solutions, from speeding up the detection of virus carriers and halting the spread of the virus to developing a vaccine. Blockchain technology has recently emerged as a key technology in the critical domain of epidemic management. Blockchain applications could provide a robust, transparent and cheap means of facilitating effective decision-making and, as a result, could lead to faster responses during emergencies of this kind. In the context of this pandemic, blockchain has the potential to become an integral part of the global response to coronavirus by tracking the spread of the disease, managing insurance payments and maintaining the sustainability of medical supply chains and donation tracking pathways.

Blockchain applicationscould can monitor disease outbreaks over time by creating 'ledgers' that are both secure and updated hundredsof times per day. Additionally, using blockchain can improve diagnostic accuracy and treatment effectiveness, streamline the rapid isolation of clusters of cases, track drug supply chains and medical supplies, manage medical data and identify disease symptom patterns. In cases such as a virus outbreak, where high numbers of real-time incoming data are released, blockchain can reduce uncertainty and offer computational trust, and an automated platform for recording and exchanging consistent factual information between multiple parties. Beyond blockchain's value as a health data monitoringandtrackingtool,health authorities can make use of permissioned blockchain systems to tackle the healthcare interoperability challenge, and help expedite clinical trials by facilitating data storage and sharing between researchers, while ensuring the trustworthiness of clinical trial data collection and reporting. In order for application of blockchain to bring added value to a public health emergency context compared with traditional surveillance mechanisms it should make extensive use of its encryption characteristics combined with decentralised peer-to-peer engagement so as to improve security, regulatory compliance, durability, consensus, selective privacy and timing. [6]

Potential impacts and developments

Using encrypted data and records to track transactions, several blockchain technologies have been launched to solve the challenges posed by the Covid-19 crisis and bring innovative solutions to the problems associated with this major disruption. First, in the area of donation tracking, blockchain allows donors to oversee where their funds are needed, receive notifications when the donations have been received and then track donations made for the treatment of people infected with the coronavirus in the Wuhan region. Ant Financial's online mutual aid platform, Xiang Hu Bao, is a blockchain-based collective claim-sharing platform that processes coronavirus insurance claims not only by reducing paperwork (hence mitigating the risk of infection from face-to-face contact, as the platform is able to process transactions without human involvement), but also by allowing all parties to monitor the entire process.

The borderless nature of Covid-19 and the global mask shortage require more thoughtful and planned collaboration to deal with supply chain vulnerability. Blockchain seems to offer a variety of solutions in this regard. A blockchain-based platform has been launched to enable users to trace demand and supply chains of medical supplies, given the shortage of facial masks, and to rise to the challenges associated with the management, allocation and donation of relief supplies. It reviews, records and tracks demand, supplies and logistics with regard to epidemic prevention materials.

In the context of outbreak data tracking, one blockchain-enabled tracker has a special dashboard to track infections, deaths and recoveries world-wide in real time, ensuring that every piece of shared information cannot be manipulated or modified. The Singapore-based blockchain company, Algorand Foundation, has recently launched an application called IReport-Covid to allow symptomatic and non-symptomatic users to directly report any information they wish about the virus anonymously by filling in a survey. In Hangzhou, a program has been developed on WeChat that can generate QR codes to enable residents to enter gated communities on the basis of personal information collected, encrypted and stored in blockchain-base cloud servers, while in Xi'an, in Northwest China's Shaanxi province, an online consultation and screening system was recently launched.

Blockchain can manage health records securely, ensuring interoperability without compromising security and patient privacy. Another blockchain-based application helps government agencies keep track of patients and suspected new cases, and allows doctors to analyze patient symptoms and monitor diagnostics data in real-time, integrating patient medical history data. All these applications reflect the capacity of blockchain to create incentives for tracing medical needs and identifying gaps in medical supply chain management but also for creating rewards in the form of tokens issued on a blockchain platform for citizens complying with containment and social distancing rules. [6]

Why COVID-19 makes a compelling case for the wider integration of blockchain

The COVID-19 crisis has revealed a general lack of connectivity and data exchange built into our global supply chains.

Future resiliency will depend on building transparent, inter-operable and connective networks.

When it became clear that many of us would soon be working from home, a majority took a cursory glance at their home office set-ups and decided it needed upgrading. What ensued was an unanticipated rush and surge of online orders for office desks, chairs, lamps and computer hardware. However, such was the sudden spike that it has unsurprisingly caught suppliers large and small unprepared, off guard and exposed gaping holes in their ability to track purchases from one end of their supply chains to the other. Some customers, who have spent no small amount on revamping their home offices are still waiting to do so, without the consolation of being able to see where their orders are, or when they can expect to receive them.

Of course, no one could have foreseen the unprecedented upheaval caused by the novel coronavirus (COVID-19) pandemic which has disrupted and dislocated economies and ecosystems across the planet but COVID-19 has brought supply chains to their knees. In addition, while it would be easy to point fingers at consumer-facing companies caught unawares, what's important now is rebooting and rebuilding the global trade network by putting into practice the harsh lessons we are forcibly learning now.

What has become abundantly clear over the last three months is a general lack of connectivity and data exchange built into our global supply chains. Quite staggering considering the fourth industrial revolution (4IR) era and Internet of Things (IoT) days we are living through. The fact we can track our Uber driver but not shipment placed three weeks ago from a department store less than 10 miles from our home is startling, humiliating and needs addressing.

The World Economic Forum has produced a toolkit on responsible deployment of blockchain in global supply chains. The first-of-its kind Blockchain Deployment Toolkit provides insights from more than 100 experts and provides key guidelines on topics such as risk, consortia formations, security and ecosystem collaboration.

The toolkit is delivered through the Forum's Centre for the Fourth Industrial Revolution (4IR), that shapes the development and deployment for new technologies and provides a space for global cooperation to create understanding and policies that accelerate these technologies' positive impact for the individual and the society. The acceleration of the post COVID-19 economic rebound through 4IR-technologies such as blockchain is an important task for the 4IR-centre today.

If there were any lingering doubts over the value of blockchain platforms to improve the transparency of businesses that depend on the seamless integration of disparate networks, COVID-19 has all but wiped them away. We should look at this healthcare crisis as a vital learning curve that can show us how to build transparent, inter-operable and connective networks.

Blockchain is supporting efforts around the globe to battle the virus. The technology is helping us ship medicines from pharmaceuticals to areas of the world stricken by the COVID-19 outbreak. It is improving the efficiency of movement permits to residents in a near future of controlled social movement.

Closer to home, it's keeping economies moving. It's facilitating cash-flow management for start-ups and ensuring timely payments for their products and pilots. It's even helping consumers track their home office chair to improve their quality of life under lockdown conditions.

The "visibility, traceability, and interoperability" of blockchain platforms to fortify, better connect and improve the resilience of supply chains will also be critical to getting the recovery underway in the world beyond the COVID-19 crisis.

Getting there won't be easy. Indeed, research carried out by the Centre for the Fourth Industrial Revolution UAE (C4IR UAE), in collaboration with Accelliance, prior to the publication of a whitepaper at Davos 2020, analyzed the key challenges and success factors in wider blockchain deployment.

In response to these challenges, the World Economic Forum, in association with its international blockchain community, including C4IR UAE, co-developed the Redesigning Trust: Blockchain Deployment Toolkit, with a supply chain focus. The toolkit is designed to guide an individual, and their organization, through the development and deployment of a new blockchain solution. The toolkit provides tools, resources, and know-how to organizations undertaking blockchain projects. "The aim of the toolkit is to support decision makers in effectively deploying blockchain technology in their respective entities," explained Nadia Hewett, project lead for Blockchain and Digital Currency at the World Economic Forum. [9]

Anticipatory policy-making

In an inter-connected world facing serious interoperability challenges, blockchain technologies could contribute to a robust epidemic alert system. However, as blockchain is still in its early stages of development, several legal questions may have yet to be answered:

- Who should be in charge of the data?
- Who should be able to access it?
- How should patients and public health organizations be identified in the database?
- Who monitors the blockchain?
- Where are the servers located, and what types of digital and physical controls exist?

The application of blockchain technologies in an emergency context comes with specific limitations. These relate to their costs in terms of computational power, their lack of integration with legacy systems, their open character that can become a liability in environments that have stringent privacy requirements, their energy-intensive nature and an inability to scale.

The vulnerability of blockchain systems to 51 % attack constitutes another major challenge as shown by the recent hacking of the Argentinian government's blockchain-based official gazette website where false statements regarding the coronavirus were spread. As sensitive data of a medical nature or location are urgently needed by governments to track the spread and transmission of the disease as well as by biotechnology companies to train their algorithms, privacy restrictions may soon have to be loosened. Will that affect blockchain applications as well? Recently, the Human Medicines Committee (CHMP) of the European Medicines Agency called for the pooling of research resources into large multi-centre, multi-arm clinical trials to generate sound evidence on Covid-19 treatments. Blockchain technologies with their built- in layers of interoperability, patient privacy, transparency and data integrity may need to be employed in the context of these clinical trials in order to reduce trial timelines, help with credibility, security and transparency and take a major step toward reproducibility.

Blockchain could in fact facilitate an EU-wide ethics review of the proposed multi-site, collaborative clinical studies given the immutable record-keeping, automatable protocol amendments and direct connectivity between stakeholders it allows. A centralized ethics review process of this kind will be necessary to meet the critical need for robust data to determine which investigational or repurposed medicinal products would be safe and effective for the treatment of Covid-19. Such centralized EU-wide ethics reviews can be based on the modalities and best practices developed in the context of the long-established EU ethics appraisal procedure that concerns all activities funded within the Horizon 2020 programme and aims to ensure that provisions on ethics in the H2020 regulations and its rules for participation are upheld. Without being in a legal position to provide the ethics clearance required by the EU rules on clinical trials, this procedure has been simplified over the years and serves as a model for thorough, credible and nuanced ethics controls that take into account the ethical and cultural particularities of Member States in a constructive and operational manner. Many Member States and also several EU agencies have set up their ethics review procedures and mechanisms in accordance with this model, which is dynamic by nature.

Against this backdrop, legal concerns associated with the storage of patient data on a public blockchain and the terms of future access to consent already given by a patient have to be addressed. In this rapidly evolving context, where state authorities are asking companies to share data to help track the virus or use individual phone-tracking to warn users away from engaging with those infected with Covid-19, the success of the application of blockchain technologies will depend on their ability to facilitate the data-sharing process without undermining the privacy of its users, and the immutability of its operations. [6]

3. Open-source technologies

During disease outbreaks, rapid data sharing is critical as it allows for a better understanding of the origins, spread of the infection, and can serve as a basis for effective prevention, treatment and care. The capacity of information technologies to allow for low-cost dissemination and collaboration of data have led to the establishment of a multitude of repositories and information technology platforms for data sharing. Most of these data-collection activities are coordinated by international organizations such as the World Health Organization (WHO) and the European Centre for Disease Prevention and Control. At the same time, an increasing number of bottom-up, open-data initiatives and open-source projects have also been developed, facilitating access to research data and scientific publications as well as sharing blueprints for production of critical medical equipment such as ventilators and face shields.

The placement of the first genome of the 2019-nCoV virus, which was the most rapid characterization of a novel pathogen in history, in an open database on January 8 2020, paved the way for scientists around the world to start working on the development of a treatment or vaccine as it allowed laboratories to develop the necessary diagnostics within a very limited timeframe. Making this data open was the first and most important data-sharing initiative that helped scientists to grow the live virus and build up a picture of how the virus is spreading.

Since then, public health institutions and universities around the world have publicly shared over 183 sequences of variants of SARS-CoV-2 in a monumental effort to develop an effective vaccine against this new virus. In fact, the most important initiatives to prevent and monitor the spread of the disease have been based on an ever-growing ecosystem of open science, open-data and open-source platforms that share dashboards, information and resources of vital importance for decision-makers.

For instance, public health authorities, universities and clinical laboratories are releasing genomic data from Covid-19 specimens at unprecedented speed, the WHO provides daily status reports including new cases, while more than 30 leading publishers have agreed to make all of their Covid-19-related publications immediately accessible in public repositories to openly inform the public health response. Major publishers, including Elsevier, Springer Nature, Wiley Online Library, Emerald and Oxford University Press, have set up a featured open access resources page. In the domain of data-sharing, open-source technologies can bring to the fore a broader set of important concepts such as accessibility of information, open standards that enable all stakeholders to contribute and rapid prototypes that can lead to rapid discoveries. In this context, several initiatives have been developed around the world to develop new low-cost and open-source designs for everything from ventilators to face shields. [6]

How open source is helping to fight Covid-19

In open-source project, Netstrain, which harnesses scientific and public health information about the genetic data of known infection-causing pathogens, is being used to track the transmission of the coronavirus, Covid-19.

And another open source project, #OpenCovid19Initiatve, has been set up to develop and share open source methodologies that will enable the safe testing for the presence of Covid-19 (scientific name SARS-CoV-2) using multiple approaches.

By mapping the genetic mutations of the Covid-19 virus, the Netstrain software tool, which is also used to track such common viruses as mumps, measles and tuberculosis, is able to track the Covid-19 virus movement around the world. It can determine whether all people in the world with coronavirus have been infected by the same strain of the virus, and if not, where new cases of the virus are coming from.

While this type of information won't stop the spread of the virus, or predict where it is going next, it does enable health authorities to determine whether the new cases that are arriving in their countries are the result of international travel, or whether the virus is being transmitted locally. This will have an effect on decisions around travel restrictions, school closures, whether or not to cancel public cultural and sporting events, quarantine requirements and so on.

Mutating genetic code

Netstrain analysis to date clearly shows that the virus's genetic code has mutated since it was first identified in China in December last year. The mutations are not significant – so far, they do not appear to have changed the actual biology of the virus itself – but they are enough to identify its origins. It is clear that in many regions, different 'strains' of Covid-19 are infecting people.

However, while all the sequenced data in the latest available Netstrain analysis includes a common 'ancestor' that emerged between mid-November and mid-December 2019, the Covid-19 that reached Italy was actually introduced at least twice (from different sources). From there, it spread through the Italian community. This then led to a cluster of mutated virus sequences in six countries, where cases appear to have exported from Italy.

The #OpenCovid19Initiative brings together a group of concerned individuals around a non-profit organization, Just One Giant Lab (JOGL), which operates out of Paris, France. JOGL's goal is to create an open platform for scientific collaboration on a wide range of issues facing humanity.

On its Web site, JOGL maintains that humanity has far too many problems to expect traditional institutions to fix in a conventional manner. It therefore wants to offer anyone the opportunity to challenge themselves by launching or contributing to collaborative initiatives that are focused on some of humanity's most urgent and important problems.

One of these is clearly the Covid-19 pandemic. The group is therefore seeking to create an open source method that will enable better management of the cases spreading across the world.

To date, the group has collected a variety of resources and has started hosting conference calls to discuss best practices for testing for the virus. [10]

Potential impact and developments

Open-source analytics tools for studying the Covid-19 coronavirus outbreak have contributed to the immediate sharing of collective intelligence about the virus and the generation of bottom-up insights that can inform decision-making in a collaborative and accessible manner and have even helped to address the shortage of testing equipment and ventilators. Responding to concerns about the lack of testing components to test for Covid-19, the Just One Giant Lab developed an open-source coronavirus test methodology to share designs so that certified labs could produce test kits easily. NextStrain is an open-source application that tracks the evolution of viruses and bacteria, collects all the data around the world from labs that are sequencing the SARS-CoV-2 genome, and centralizes them in one place in the form of a genomic tree. Researchers have also been sharing new findings about the genomic profile of the virus through open-source publications and preprint sites such as BioRxiv and Chinaxiv.

There are currently seven open-source hardware projects working to combat Covid-19 in various ways including the scaling-up of Covid-19 testing, the design of quick-development OpenLung low resource ventilators and the simulation of protein dynamics, including the process of protein folding and the movements of proteins implicated in a variety of diseases. Open-source products have also been developed by several state authorities worldwide. The Israeli government recently released the Shield open-source app, which collects location data from users' phones in an attempt to determine if they might have been exposed to the Covid-19 coronavirus. Singapore's Government Technology Agency decided to offer the protocol that powers the TraceTogether contact-tracing app to the open-source community. There's also an open-source Covid-19 library of resources for DIY engineering efforts and the Open Air Project, a group that aims to address Covid-19 challenges through open-source technology, a GoFundMe DIY ventilator project, and a Hackaday project to develop a blueprint for an open-source ventilator. One of the most important initiatives is OpenCovid19, which is developing and sharing open-source methodologies for a community-driven procedure to test for the presence of the virus safely. DeepMind recently made structural predictions of under-studied proteins of SARS-CoV-2 freely available to the research community. Alibaba has, meanwhile, developed an open-source platform to track the spread of Covid-19, to help health authorities prevent and prepare for new cases. Various open-source graph databases such as the Neo4j and Nebula Graph are vital when it comes to modelling the pathways and the spread of Covid-19, while the newly open-sourced CHIME enables hospitals to enter information about their facility and population and then modify assumptions around Covid-19's spread and behavior.

Last but not least, it is worth mentioning that several engineers are currently sharing designs for DIY ventilators online as the coronavirus pandemic spreads, while an open-source predictive model that identifies people who are likely to have a heightened vulnerability to severe complications from Covid-19 has recently been developed. The development of the above-mentioned open repositories, applications and hardware projects indicates the potential of open-source technologies and bottom-up data-sharing structures to address many Covid-19-related challenges. Such initiatives can help citizens exercise their digital freedoms – without necessarily involving data intermediaries – and become shapers of an expanding data ecosystem. [6]

Anticipatory policy-making

Despite the increasingly important role of data-sharing in all these efforts, most of the initiatives described above seem disconnected from the main technological trajectories that have been developed to address this fast-developing public health crisis. Thus, there is a need to streamline and coordinate the main open-source activities of the same kind so as to unlock the public interest value of the data collected and the open software, and harness their potential so as to accelerate international action to fight the pandemic. This is a rather daunting task as issues of financial sustainability, reliability, technical maintenance, complexity and licensing persist. The establishment of open databases also raises concerns about safeguarding privacy and security, and also about the ownership of the data disclosed and the expertise needed to access and make use of the data. Most of the challenges in establishing a sustainable open-data ecosystem center on data interoperability and quality, as well as their structure, authenticity and integrity, all necessary for the exploitation of the data value and the effective combination of data from different sources. Furthermore, open-source hardware equipment needs to be fully tested and found to be reliable before being distributed and replicated, which may also prove a challenging process for small-scale collaborating initiatives.

Data sharing and open-source initiatives face more than just technological obstacles. They are being shaped in a legal vacuum. At international level, various WHO initiatives in the field of data-sharing can provide some guidance. Examples are the 2016 Policy Statement on Data Sharing in the context of public health emergencies, the Pandemic Influenza Preparedness Framework and its recent code of conduct for the open and timely sharing of pathogen genetic sequence data during outbreaks of infectious disease. None of these documents can generate legal obligations of information-sharing among states and/or replace the various regional or bilateral data-sharing agreements. At EU level, a report by the High-Level Expert Group on Business-to-Government Data Sharing concluded that much of the potential for private-sector data and insights to be used by public-sector bodies to tackle societal challenges remains untapped. Several organizations are currently asking the EU to ensure that all technical measures to manage the coronavirus are transparent, remain under public control and make use of free/open-source software when designing public interest applications. In a recent EU-FOSSA 2 survey, open-source communities called on the EU to help developers make software more secure and to increase the stability of their coding by supporting, and sponsoring them to work on specific aspects of their code. As there is a pressing need for an open analytics environment that allows all interested stakeholders to analyze, interpret, and share Covid-19 data, open-source initiatives could address the regrettable lack of data sharing and considerable analytical obfuscation, but also empower groups of people to share local knowledge and pool the rights they have over their data. [6]

4. Telehealth technologies

The Covid-19 pandemic is posing unique challenges to healthcare delivery. States across the world are shutting down non-essential services and in several cases issuing stay-at-home restrictive orders to flatten the curve and help overcrowded hospitals remain functional. Alternative technologies, conducive to self-quarantine, could therefore offer an essential link between patients and clinicians, circumventing the need to travel to overburdened hospitals. Given the high transmission rates of the disease, especially within hospitals, telehealth

technologies can be a cost-effective means to slow the spread of the virus and to lessen the pressure on hospital capacity by operating as a possible filter, keeping those with moderate symptoms at home while routing more severe cases to hospitals.

Telehealth technologies allow patients to be seen and diagnosed remotely by doctors via an audiovisual, real-time, two-way interactive communication system. This includes video 'visits' through webcam-enabled computers, tablets, and smartphones, chatbotsand automated algorithms. Remote delivery of clinical care services with audio-visual conferencing technology offers several crucial advantages. First, it allows hospitals to be kept clear for confirmed cases; second, it reduces virus transmission rates, as there is no risk of being exposed to the pathogen; and third, since it is available anytime, it can handle more patients than in-person care.

Hospitals, public health authorities, and digital health companies around the world are currently deploying online symptom checkers to screen patients for signs of Covid-19 and to obtain detailed travel and exposure histories. Telemedicine is also unique as it can bring the skills of infectious disease specialists to people in geographic locations that do not have access to such specialty care. Furthermore, it can improve the effective triage – the sorting of patients before they arrive in the emergency department – and coordination of care for those suspected with Covid-19 or people that have been exposed to a confirmed Covid-19 patient. [6]

Potential impacts and developments

As part of its efforts to manage the extensive strain on clinicians' time and hospital resources, the US administration announced a major expansion of telemedicine options, allowing US citizens enrolled in Medicare to talk to a doctor by phone or video chat for no additional cost. The US Center for Disease Control and Prevention (CDC) is offering a coronavirus self-checker, in the form of an online bot nicknamed Clara – for people who are concerned that they may have symptoms of the disease. Eighteen states plus Washington DC have enacted emergency regulations to increase the use of telehealth to protect health-care workers and high-risk patient populations.

Several telehealth companies that have quickly deployed online symptom checkers to screen patients for signs of Covid-19 have recently seen a 50 % increase in demand in the US and the UK. Startups like General Atlantic-backed Doctolib and insurer Axa-supported Qare in France, Swedish Kry International's unit Livi, the UK's Push Doctor and Germany's Compugroup Medical offer virtual doctors and are reaping the financial benefits. Telehealth giants such as Amwell and Teladoc are now advertising their availability for coronavirus-related appointments and Teladoc's stock prices spiked in late February. Doctolib, the top French startup helping to set up medical appointments, reported a 40 % increase in the last of March 2020. It clocked up 130 000 video consultations last year, which was its first year in business. Meanwhile, the Sheba Medical Centre, the largest hospital in Israel, launched a remote patient-monitoring programme last month, in an attempt to control the spread of the virus.

However, a number of constraints can affect the deployment of telehealth technologies on a large scale.

These include the technological capacity and accessibility of the systems, the capacity of most public health systems to take these technologies on board, and the need for extensive training of already overworked caregivers to deliver virtual care. The recent surge in popularity of these technologies has left clinicians and telehealth companies in the US facing huge backlogs. Incorporating telemedicine as a critical asset in Covid-19 outbreak response systems with important implications across the entire health-care delivery spectrum comes with several challenges that need to be tackled at both legal and political levels. [6]

Anticipatory policy-making

When considering whether and how to implement telemedicine systems as part of Covid-19 response schemes, providers need to consider an array of legal, regulatory and contracting issues. At EU level, telemedicine is considered both a healthcare service and an information and telecommunication service from a legal standpoint. Moreover, there are still some legal gaps when it comes to EU norms, for instance on medical liability or standard of care. As responsibility for creating and delivering telemedicine services falls on Member States, there are discrepancies from country to country in relation to reimbursement and insurance rules. The European Commission and Member States should consider defining an interoperability EU framework for telehealth, telemedicine and telecare. This should be based on open, international standards to allow interoperability between the diverse existing systems and also to ensure that patients in remote areas or those who are socioeconomically disadvantaged have access to this type of technology.

Special attention should be given to a possible shortage of bandwidth, as the pressure on the internet resulting from increased use may be accentuated by possible connectivity gaps; thought should also be given to the EU's digital divide.

The introduction of telehealth services also raises a series of ethical concerns in relation to privacy, confidentiality, affordability and a possible dehumanization of medicine. Although certain regulatory, technological and ethical challenges remain, the Covid-19 outbreak could provide the right impetus for EU lawmakers and regulatory agencies to relax strict regulatory and technology requirements and introduce exemptions that would even allow communication through smartphones to qualify as telehealth. Telehealth services may need to be offered for free for a certain period, enabling all available encryption and privacy modes when using such applications so as to protect sensitive health information. The Office for Civil Rights at the US Department of Health and Human Services recently decided to ease restrictions and allow doctors to make use of applications such as Apple FaceTime, Facebook Messenger video chat, Google

Hangouts video or Skype to provide telehealth without risk of penalty for noncompliance with the Health Insurance Portability and Accountability Act.

Although telehealth, in its various applications and forms, is considered a safety valve for a strained healthcare system in the context of the Covid-19 pandemic, it should be considered only as a screening tool that supplements testing happening in a clinical care situation and not as a practice intended to replace medical consultation. It is essential for individuals to understand both the strengths and limitations of this technology in the context of the relevant informed consent process. Although it may be difficult to set up an entirely technological service in a very limited time-frame, it is important for policy-makers to take immediate steps to seize all possible technical and legal opportunities to expand and fast-track telehealth access and use amid the coronavirus pandemic. Overcoming all possible technological and regulatory barriers to increase availability may mitigate the risk of spreading the disease, while reaching more patients, triaging them more quickly to maximize resources, and improving care collaboration, coordination and communication.

5. Three-dimensional printing

Given the high risk of healthcare system capacity being exceeded, including the availability of medical hardware (face masks, ventilators and breathing filters) to treat Covid-19 patients, governments around the world are taking increasingly drastic measures to boost production and optimize the supply of the necessary medical equipment. As the coronavirus continues to put a strain on hospitals around the world, three-dimensional (3D) printing can play an important role as a disruptive digital manufacturing technology in sustaining the effort of hospital workers in the middle of this emergency and in keeping patients alive.

3D printing is an additive manufacturing technique where objects are created by joining or printing layer upon layer of material, based on digital models. The major advantage of this technique is that parts that are needed in only small quantities can be produced at a low cost, as only one type of manufacturing machine is needed and the blueprints for designs, computer-aided design (CAD) files, can be distributed or replicated at the cost of locally-sourced materials.

Given its accessibility, tangible design and product testing and flexibility, 3D printing becomes valuable when the supply chains of critical products are strained, as in the case of the Covid-19 pandemic where hospitals and healthcare systems around the world are facing acute shortages of supplies of protective medical equipment. 3D printing can play a pivotal role in producing vital equipment when it is hard to source, thus easing short-term medical supply shortages in times of crisis. [6]

Potential impacts and developments

Manufacturers have been joining forces to address supply problems during the Covid-19 pandemic, producing ventilator valves, breathing filters, test kits and face mask clasps. They are also creating entirely new products such as plastic door handle adaptors that enable easy elbow opening to prevent the further spread of the virus. It is important that organizations that hold proprietary design files for medical equipment make them immediately available so they can be produced anywhere. A public Google Sheet has also been set up to gather makers from all four corners of the world to provide their 3D printing services for components such as oxygen valves. Responding to the urgent request of the European Commission to activate alternative ways of producing equipment, the European Association of the Machine Tool Industries and related Manufacturing Technologies (CECIMO) recently asked its members to assist in 'producing equipment' that European hospitals are lacking owing to the coronavirus outbreak. At the same time, designs for 3D printable medical products to use in tackling the outbreak are multiplying.

A group of Italian volunteers used their 3D printer to make unofficial copies of a patented valve, which was in short supply at Italian hospitals, and distributed them to a hospital in Brescia where 250 coronavirus patients were in need of breathing machines. In addition to the 3D-printed face shields emerging from Hong Kong's Polytechnic University, Ultimaker is also making its global network of 3D printing hubs, experts, and designers directly available to hospitals, and a company in New York has turned its 3D-printer business into a manufacturing site for face shields to be used by health workers performing the tests for Covid-19.

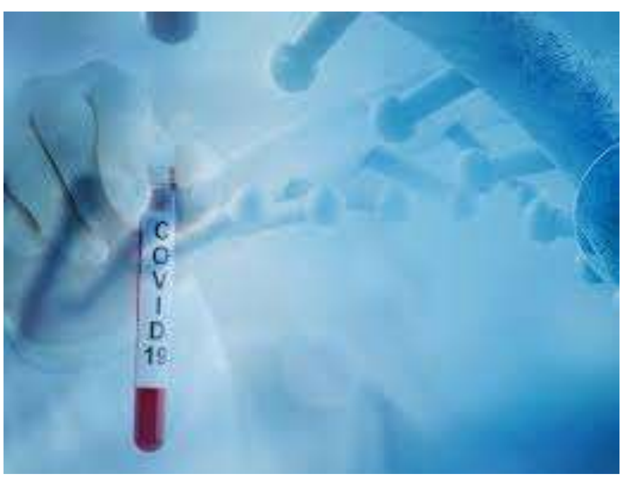
Meanwhile, 3D manufacturers around the world are developing 3D-printed face shields, inspired by the 3D- printed N95 mask designed to filter out airborne particles that could carry the virus, and in China, more than 5 000 pairs of 3D printed safety goggles for medical professionals were designed, fabricated and donated to Chinese hospitals in the space of just two weeks.

A New York hospital is currently 3D printing around 2 000 to 3 000 nasal swabs a day for immediate use on the front line of this pandemic. An architectural 3D printing company based in China, has shipped 3D-printed quarantine rooms to Xianning Central Hospital in Hubei Province, while an open-source project produced a 3D-printed ventilator validation prototype in just one week and a 3D printing service made available a hands-free door opener model that was originally designed in Belgium allowing manufacturers across the world to 3D print the door opener locally. [6]

Anticipatory policy-making

3D printing raises many questions in different areas of law, such as contract law, civil liability, consumer protection law, data protection, safety and intellectual property law including issues of copyright, patents, designs, three-dimensional trademarks and even geographical indications. As a novel technology, its applications also raise questions about the exact legal nature and categorization of this technology given its custom-made character and the lack of any regulatory guidance about its use in the context of EU law.

Questions of informed consent, access to care, autonomy, quality, protection of vulnerable groups, protection of medical data, clinical effectiveness and good care are only addressed in a fragmented manner.



In the context of the Covid-19 pandemic, given the urgent need to produce medical equipment, the mushrooming of manufacturing initiatives and the accessibility of the technology, special attention will have to be paid to whether 3D products are properly tested and approved for clinical use in accordance with the set legal requirements prior to their deployment. As these products are produced in a very short time-frame, attention should be paid to the safety and quality of certain 3D print materials used for the design of the greatly needed medical equipment, their suitability for use in medical situations and whether some of the 3D print developers are familiar with the complexity of medical practice. Furthermore, there are concerns about the ability of most 3D developers to manufacture at scale and to deal with part-to-part variation, about limited capabilities in data preparation and design, and regarding the ability to meet quality standards in decentralized, localized manufacturing facilities. Thus, there is a clear need to vet the technical specifications and reproducibility of open medical hardware, but also to reshape the testing regime around the production process rather than around individual products.

It is likely though that many developers or even Member States will ask for a temporary waiver of certain Medical Devices Directive procedural requirements given the urgency of the situation and introduce a fast-track procedure. In this respect, on 16 March 2020, the European Commission adopted Recommendation 2020/403 on conformity assessment and market surveillance procedures within the context of the Covid-19 threat. The recommendation reminds EU Member States that they can authorize derogations from conformity assessment procedures under Article 11(13) of the Medical Devices Directive and, from 26 May 2020, under Article 59 of the Medical Devices Regulation. In the US, the US Health Resources and Services Administration (HRSA) has been granted a waiver to the Paperwork Reduction Act so as to reduce regulatory burdens to support the Covid-19 response. It is important, at this stage, for the ecosystem of 3D developers and users to ensure that reliable digital files become available and that there is a clear designation of responsibility between all parties involved along the chain when making a 3D-printed object, to allow speedier and more cost-effective certification of all materials, processes and products. Last but not least, the European Commission should prevent files and protected objects from being downloaded illegally and unlawful objects from being reproduced but also encourage an 'open-source mindset towards 3D files so as to increase the accessibility of 3D medical products that are urgently needed in hospitals worldwide. As international pressure mounts to create masks, gowns, respirators using 3D printing in the context of Covid-19, the 3D printing community needs to depart from its ad-hoc, decentralized way of operating and mobilize its members to offer their capacity and expertise to print supplies but also find a way to overcome the necessary regulatory hurdles and deliver 3D-printed supplies to hospital locations on time.

6. Gene-Editing Technologies

The international community is currently focused on containing the largest human coronavirus severe-disease outbreak we ever seen (Covid-19). As it spreads, governments, academic institutions and pharmaceutical companies are racing to develop treatments to combat the pandemic. At the moment, there are no approved medicines to protect people from or treat them for Covid-19, although some antiviral therapies are being tested. Could gene-editing technologies help in the diagnosis and treatment of this pandemic disease and become humanity's next virus killer?

In the case of Covid-19, it only took two weeks from public health officials reporting the virus to the World Health Organization (WHO) for scientists to isolate the virus and figure out the full sequence of its genetic material. The disclosure of this genetic code may shed light on the origins and the spread of the disease, and also point to potential pharmaceutical targets for drug development.

There are already at least 20 coronavirus vaccines currently in development, and the first phase-I clinical trial for a potential Covid-19 vaccine began in Seattle, Washington in mid March. The trial involves 45 participants receiving varying first doses of the vaccine over six weeks, followed

by a second dose 28 days later. Time is of the essence on the frontline of this viral outbreak, therefore advancements in gene-editing technologies – in particular of CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats)-Cas9 (CRISPR-associated protein 9) – may need to be harnessed in order to accelerate the ongoing efforts to develop drugs and diagnostics. [6]

Potential impacts and developments

Researchers have used CRISPR to treat muscular dystrophy and Alzheimer's in mice, fight drug-resistant bacteria, and breed tastier tomatoes. Although several clinical trials using the CRISPR-Cas9 approach to treat human genetic diseases are underway, there is stillroom to improve the efficiency, specificity and delivery of this technology for its broader application in medicine. Even though the results of clinical trials of CRISPR genome editing so far have been promising, researchers say that it is still too soon to know whether the technique will be safe or effective in the clinic. Scientists have been testing CRISPR's much less controversial ability to disable or correct problematic genes in other cells in order to treat a host of diseases. Doctors at the Casey Eye Institute of Oregon Health & Science University in Portland recently used CRISPR gene editing on a patient for the first time.

Despite their experimental nature, gene-editing technologies could help in the fight against increasingly resistant bacterial infections and rapidly mutating viruses. They could facilitate a better understanding of host-pathogen interactions and improve diagnosis, or potentially provide a new way to treat infectious disease in a faster and less expensive manner, given their potential to treat latent and persistent viral infections, as was also seen in the frame of DARPA's 'Prepare' programme. CRISPR-Cas9 technology is advancing the understanding of microbe-host interactions in a way not previously possible and is being applied to develop new diagnostics for infectious diseases. A number of exciting successes have already been reported in diagnosing and treating infectious diseases and treating chronic viral infections using CRISPR. Recently devised CRISPR-technologies represent an unprecedented opportunity to reshape epidemiological surveillance and molecular diagnostics by developing express-diagnostic tools in the form of easy-to-use kits for the quick detection of a virus in human samples.

CRISPR-based diagnostics could soon see their first direct application as the Covid-19 outbreak accelerates development timelines. It should be noted that Mammoth Biosciences, co-founded by one of the scientists who discovered CRISPR gene-editing technology, is currently working with the University of California in San Francisco to validate a test that it has developed for Covid-19. The test uses CRISPR to search for and highlight the genetic material of the virus and can take just 30 minutes. Currently in the US, suspected coronavirus samples are shipped to Centers for Disease Control and Prevention, where it takes six or more hours to complete the test. A CRISPR-Cas13-based strategy under the name PAC-MAN (Prophylactic Antiviral CRISPR in huMAN cells) for viral inhibition that can effectively degrade SARS-CoV-2 sequences and live influenza A virus (IAV) genome in human lung epithelial cells has recently been demonstrated. The scientists involved state that the PAC-MAN approach is potentially a rapidly implementable pan-coronavirus strategy to deal with emerging pandemic strains. Moreover, researchers at the New York Genome Center have recently developed a new kind of CRISPR screen technology to target RNA, including RNA viruses like coronavirus.

This novel CRISPR-based editing tool, which enables researchers to target mRNA and knockout genes without altering the genome, was created by using the CRISPR-Cas13 enzyme.

Anticipatory policy-making

Although scientists on the cusp of developing a way to make gene-editing technology safer, one of the main obstacles to the translation of CRISPR/Cas9 into clinically useful tools is the possibility of off-target effects that can result in malignant transformation and other unforeseeable consequences. There are concerns about the power and technical limitations of CRISPR technology, including the possibilities of limited on-target editing efficiency, incomplete editing and the possible transfer of the edited genes to future generations, potentially affecting them in unexpected ways. Efficient targeted delivery of CRISPR technology in vivo, without significant on- or off-target toxicity, remains a challenge.

Given that there is a lack of a transition of CRISPR-based therapies from preclinical observations to proven and approved therapies, no approved CRISPR-based therapies are available and only a limited number of early clinical trials are ongoing. Given these uncertainties, questions arise about the potential for such products: how could they obtain regulatory approval even under fast-track procedures, if they cannot be properly tested in human clinical trials? Who would be liable in the event that harmful side effects occur during the widespread use of a new medical countermeasure, such as a novel gene-editing technique during a pandemic emergency of this kind? One major concern with the use of CRISPR/Cas9 in the clinical setting relates to the potential risk that by lowering technical barriers the technology could be misused for biological weapon development. More specifically, CRISPR could facilitate the editing of an existing pathogen to make it more damaging, edit a non-pathogenic organism to incorporate pathogen genes and traits, and even, theoretically, synthesize a novel pathogen.

Despite CRISPR's affordability, ease of use, and widespread availability, it remains ethically controversial and vulnerable to potential malicious misuse or even accidental mishap. In view of these challenges and, as gene-editing technologies appear to be part of the international race to test coronavirus antiviral drugs and vaccines, the development of CRISPR-based diagnostics and of possible vaccines or therapies will require strong ethical oversight, strong evidence demonstrating a sufficient degree of safety and efficacy of such interventions, and the demonstration of the advantages of somatic gene editing over other antiviral strategies and standardized methods for safe treatment delivery. [6]

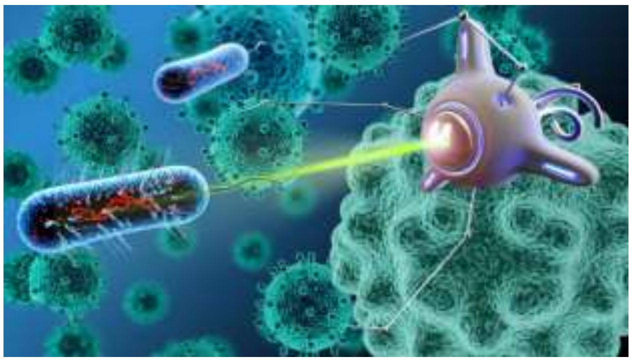
7. Nanotechnology

Covid-19 is spreading rapidly over the globe, but there are few specific tools available to control the growing pandemic and to treat those who are sick. Quarantine, isolation, and infection-control measures are all that can be used to prevent the spread of the disease and those who become ill must rely on supportive care.

What is lacking is a specific antiviral agent to treat the infected and subsequently, decrease viral shedding and transmission. Nano-based products are currently being developed and deployed for the containment, diagnosis and treatment of Covid-19. An experimental nano-vaccine has become the first vaccine to be tested in a human trial. However, is nanotechnology mature enough to address clinical needs efficiently in the context of a pandemic?

Nanotechnology is a multidisciplinary field that makes use of nano-sized particles and devices for various applications,including diagnostics,targeted drug delivery and the production of new therapeutic materials. Nanoparticles such as gold and silver have been used in biomedical and diagnostic applications, for the detection of viral particles for instance.

Nanotechnology has been shown to help in treating viral infection by means of various mechanisms.



Nanoparticles can act as antiviral drug delivery systems; they can interact and bind to a virus and thereby prevent it from attaching and entering the host cell; and they can be designed to exhibit antiviral effects. All together, the use of nanotechnology in the development of new medicines has been recognized as a key enabling technology, capable of providing new and innovative medical solutions to address unmet medical needs. [6]

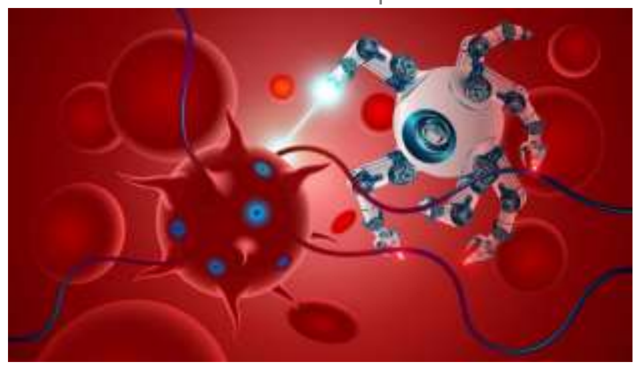
Potential impacts and developments

Nanomedicine has already been used in drug delivery. In the case of an RNA-based vaccine, which consists of messenger RNA (ribonucleic acid) strands, lipid nanoparticles have been used to pack the RNA molecule and deliver it within the body. While no RNA vaccine has ever been licensed, a US-based biotechnology company specializing in messenger RNA therapeutics recently announced that its mRNA-based vaccine candidate (mRNA-1273) for the novel coronavirus disease (Covid-19) had just entered Phase 1 study.

Novavax, meanwhile, also recently initiated the development of a vaccine candidate for Covid-19, using its proprietary recombinant nanoparticle vaccine technology.

A group of scientists from the University of Washington's Institute for Protein Design have been manufacturing nanoparticles to create a more efficient vaccine against Covid-19 via computational models to predict and design self-assembling proteins. Furthermore, a group of researchers from the University of Lille and Ruhr-University Bochum have recently demonstrated that the addition of gold nanoparticles and carbon quantum dots (CQDs) to the cell culture medium before and during infection with coronaviruses considerably reduced the infection rate of the cells.

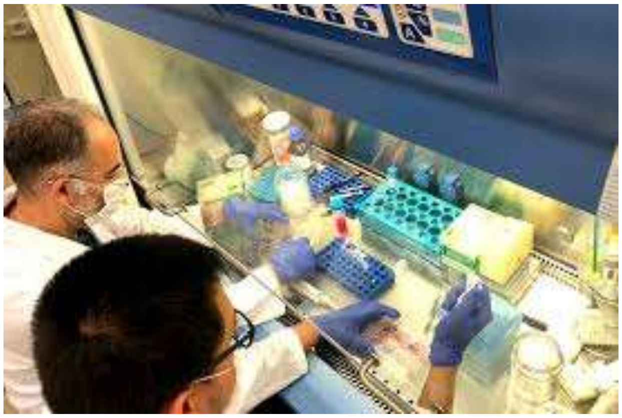
Sona Nanotech has developed a lateral-flow



screening test to identify the novel Coronavirus, 2019-nCoV, in less than 15 minutes, applying its proprietary nanorod technology. The European Commission and the Spanish Ministry of Science and Innovation meanwhile recently announced their intention to fund a research project, CONVAT, to develop a rapid Covid-19 test based on nanobiosensors. CONVAT will provide a new device based on optical biosensor nanotechnology that will allow the detection of coronavirus directly from the patient's sample within about 30 minutes, without the need for testing in centralized clinical laboratories.

The project also aims to extend beyond the current pandemic and human diagnosis, with plans for the new biosensor device to also be used for the analysis of different types of coronavirus present in reservoir animals, such as bats, in order to observe and monitor possible evolutions of these viruses and prevent future outbreaks in humans.

An Israeli startup, Sonovia, has developed a nanoparticle-infused fabric that can be used in medical masks, protective clothing and hospital materials, while researchers at the Hong Kong University of Science and Technology have developed a multilevel antimicrobial polymer (MAP-1) coating that is effective in killing viruses, bacteria and even hard-to-kill spores, which could provide lasting protection against microbial contamination to public venues. Similarly, nanopolymer-based disinfectants that can eliminate bacteria, viruses, yeasts, moulds and other microorganisms with a declared effect of up to 21 days are meanwhile being tested in Prague's public transport to fight Covid-19. Finally, a company in Hong Kong recently announced the production of patented antibacterial and antiviral nanoDiamonds technology masks, which can help to fight the Covid-19 pandemic. This could help solve the shortage of preventive gear, such as surgical masks, with nanotechnology-enabled N95 masks also key to halting the spread of coronavirus. [6]



Anticipatory policy-making

Their size means that nanoparticles can seep into other parts of the body. The potential for unforeseen risks and side-effects, the toxicity of nanoparticles and nanomedicine, and the uncontrolled function and self-assembly of nanoparticles raise a number of questions. Nanomedicine is not regulated separately under EU law. The EU's Medical Devices Regulation, which applies to nanomedicine only to a certain extent and will become fully applicable in May 2020, addresses information requirements (labelling) for nanomaterials and assessment of the safety of these materials.

The regulation requires the reduction, as far as possible, of any risks linked to the size and the properties of nanoparticles that are or could be released into the user's body. Devices incorporating or consisting of nanomaterials fall under the highest risk class, Class III, which in effect means that they should be subject to very strict evaluation procedures. However, in a crisis situation evaluation processes may be reconsidered. In 2008, the European Commission adopted a Code of Conduct for Responsible Nanosciences and Nanotechnologies Research, with a recommendation to use it as the basis for further initiatives, aiming to ensure the safety, and ethical and sustainable nature of research into nanosciences and nanotechnologies in the EU.

The application of nanotechnology in medicine raises particular legal questions concerning the adequacy of current risk assessment procedures to evaluate the efficacy, effectiveness, and safety of nanomaterials given that they have no common properties other than size. The identification of nanomaterials, in particular when built into products, i.e. measuring particle size and size distribution, which is crucial for identifying whether nano-specific provisions apply, remains a challenge. Although the European Commission has adopted a recommendation on the definition of the term 'nanomaterial', the term is currently not defined in a consensus-based, regulatory or binding way, so the terms of its regulatory control depend on the specific regulatory context. In its guidance on the determination of potential health effects of nanomaterials used in medical devices, the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) states that the potential risk from the use of nanomaterials in medical devices is mainly associated with the possibility of release of free nanoparticles from the device and the duration of exposure. In addition to the challenges associated with the absence of a uniform definition of nanomaterial, there is a need to establish validated methods and instrumentation for detection, characterization and analysis, completing information on the hazards of nanomaterials and developing methods to assess exposure to nanomaterials.

From an ethical point of view, data ownership, privacy, data confidentiality, informed consent and benefit- sharing are some of the main considerations when nanotechnology is applied for health purposes. Although there is still a long way to go before the establishment of a comprehensive regulatory framework for nanomedicines, with the establishment of harmonized definitions throughout the EU and the development of protocols for the characterization, evaluation and process control of nanomedicines, nanotechnology could deliver an effective response to this pandemic challenge. Its effectiveness will certainly be facilitated by the recent agreement between the European Commission and the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (Cenelec) to make a number of European standards for certain medical devices and personal protective equipment immediately available so as to facilitate an increase in production.

8. Synthetic biology

In synthetic (lab-based) biology, scientists take a multidisciplinary approach, using biology, engineering, genetics, chemistry and computer science to substantially alter the genotype of viruses. This can contribute to advances in fields ranging from drug and vaccine development to pest control of invasive species. In response to the current pandemic, synthetic biologists are applying cutting-edge tools to speed up the development of a successful vaccine. Their efforts illustrate synthetic biology's potential to design, build, and test solutions for an unanticipated challenge such as Covid-19.

Conventionally, researchers study a virus by isolating it from cells of a sick patient and growing it in a petri dish.

However, when a disease outbreak occurs far away, it can take months for laboratories to access physical samples. In such situations, researchers can use a synthetic version of the virus, known as an infectious clone, so as to be able to start studying it without losing time. The synthetic virus is just a substitute for the actual virus. Yet, scientists can manipulate this DNA clone by removing or adding genes and study questions like how the germ gains access to human cells and what makes it spread. Furthermore, artificial copies can also help scientists keep up with the outbreak's unpredictable path. Another major advantage of synthetic biology is that scientists can run computer models of millions of different protein sequences to find one that will spontaneously form the ideal nanoparticle, i.e. the optimal shape and protein composition. A new type of vaccine that can be stored at warmer temperatures, removing the need for refrigeration, has already been engineered using a synthetic protein scaffold that could revolutionize the way vaccines are designed, produced and stored. In the context of the Covid-19 pandemic, synthetic biology has been viewed as the next step in the advancement in vaccination development as it is being used as a design tool to make vaccines more effective than ever. [6]

Potential impacts and developments

In the case of Covid-19, the Bill and Melinda Bill and Melinda Gates Foundation and the National Institutes of Health have invested in the emerging field of synthetic biology, aiming to engineer vaccines. A vaccine, developed through synthetic biology would not just be 'scalable to a level of billions' but would also work even without needing to be refrigerated. The synthetic biology powerhouse Ginkgo Bioworks is giving $25 million worth of resources to public and private teams working to cure, prevent and treat the novel coronavirus. A number of companies in the field of synthetic biology have been developing experimental vaccines containing synthetic strands of RNA or DNA that code for protein molecules on the surface of the virus. One of these vaccines, INO-4800, which is currently in phase I trials in humans, uses a 'DNA vaccine' approach, meaning that it delivers synthetic genes into a person's cells.

Collaborating with the World Health Organization and the US military, researchers at Distributed Bio are creating 'pseudo-virion' versions of the disease that can be examined without posing a significant risk, to discover antibodies against the disease quickly. To address this, GenScript is offering researchers a free high- tech test for the SARS-CoV-2 that can measure the amount of an infectious agent in the bloodstream. It has also received urgent requests from partners to synthesize the genes of SARS-CoV-2 as quickly as possible.

Since 2018, under the DARPA Pandemic Prevention Platform (P3) programme, AbCellera has been developing a technology platform for pandemic response capable of developing field-ready medical countermeasures within 60 days of isolation of an unknown viral pathogen. Meanwhile, researchers from the Vanderbilt Vaccine Center recently built a comprehensive 'toolkit' to identify and analyze antibodies isolated from the blood of survivors for their ability to neutralize SARS-CoV-2. Similarly, a Cambridge laboratory has used synthetic biology to locate a critical area of the virus's genetic code that may help them develop a vaccine ready for testing within a very short time frame, while Twist Bioscience has announced the availability of synthetic SARS-CoV-2 RNA controls to provide quality control for the development, verification, and ongoing validation for diagnostic tests. Additionally, Swiss scientists recreated the coronavirus in a lab in just a week using yeast, a published genome, and mail-order DNA. Their synthetic virus could help more labs to develop drugs, vaccines, and diagnostic tests for Covid-19. [6]

Anticipatory policy-making

Despite the potential benefits of synthetic biology, there are nonetheless several scientific, legal and ethical uncertainties. These are associated with the development of synthetic life, cells or genomes and are concerned with their potential impact on the environment, biological diversity and human health. These risks include the possibility that artificial organisms could escape into the wild and cause environmental havoc, raising safety concerns around engineered biological systems and concerns over the harmful, unintended effects of new synthetic technologies. The recent entry of an unproved synthetic vaccine directly into clinical trials has also raised safety concerns as no tests were performed on animals prior to those on human volunteers, exposing them to possible risks.

The domain of synthetic biology also raises issues with regard to intellectual property concerning what would be a suitable basis for applying for a new patent and what is considered an invention. A major challenge in the field of synthetic biology relates to its dual use or misuse potential inasmuch as it can to be used for both beneficial and harmful purposes. Given that engineering viruses can also lead to the creation of even more deadly pathogens by those who intend to harm, synthetic biology presents biosecurity concerns in terms of access to expertise, materials and plausibility. At the same time, this enabling technology raises ethical questions that relate to benefit sharing as well as to whether it is appropriate to patent an artificially synthesized genome.

Although international and EU Law touches upon many of the asymmetric risks associated with synthetic biology, its responsible use in the context of pandemic responses relies largely on the proportionate application of sector-specific legislation rather than on a technology-specific framework. However, given that synthetic biology seems to be expanding the pool of agents of concern, there is a need to develop harmonized monitoring systems and proactively introduce safeguards that would prevent possible chemical and biological threats. Therefore, synthetic biology governance must focus on how biosecurity threats can be mitigated in specific regulatory areas including export control, the screening of synthetic biology research prior to public dissemination and regulatory approval of proposed experiments in the light of potential dual-use implications and harm. The safe development of synthetic biology in its various contexts ultimately depends on the standardization of its risk assessment methodologies and on governance requirements that should be iteratively reviewed and improved as more quantitative information becomes available. Taking together the general uncertainty surrounding the potential risks of synthetic biology, including the absence of data regarding the hazards, exposure, and consequences of organisms engineered and the lack of comprehensive regulatory guidance, the clinical trial process for candidate synthetic vaccines must be designed carefully; it is really important not to take shortcuts. [6]

9. Drones

From disinfection and street patrols to food and medicine delivery in quarantined districts, drones are being deployed on the front line to contain the spread of the novel coronavirus. The Chinese government adapted and co-opted industrial drones to enforce the world's largest quarantine exercise. The modification of drone's software by state agencies and drone manufacturers to enforce restrictive measures, and to boost disease detection and crowd management makes a compelling case about the risks of pervasive surveillance and overstretched law enforcement.

In the context of the Covid-19 pandemic, drones are being used to monitor quarantine measures, to facilitate aerial broadcasting, to spray disinfectant, conduct aerial thermal sensing, monitor traffic and deliver medical supplies in infected areas. As the situation is becoming more serious, drone software is being rewritten to acquire a multitude of functions, with drones being used to replace helicopter patrols and traditional regular disinfection, forlaw enforcement purposes and for transportation to shore up epidemic prevention and control in several countries. The use of drones and other aerial surveillance technologies in the Covid-19 pandemic can facilitate the tasks of enforcing containment and social distancing measures, helping reduce the number of face-to-face contacts but also freeing up crucial human resources (such as health workers and law enforcement officers) and minimizing their exposure to the virus, thereby reducing the chances of contamination. Given the growing use of surveying, mapping and delivery drones in containing the coronavirus outbreak, should public health systems consider incorporating drone technology into their planning to mitigate Covid-19 in a more systematic manner? [6]

Potential impacts and developments

The main advantage of using drones to contain the spread of Covid-19, beyond their ability to perform technical tasks in an efficient way, lies in their capacity to minimize direct human exposure to the virus by involving fewer people in several operations. This could be critical to controlling infections by keeping some health workers out of hot zones and allowing medical staff to identify new potential cases without having to touch those who might be infected. At the same time, delivering consumer items and medical samples by drone can ensure that people in remote or quarantined areas have access to supplies, significantly reducing unnecessary human contact.

Antwork, a group company of Japanese industrial drone maker Terra Drone, began experimenting with flying medical samples and quarantine materials in China during the height of the epidemic. Drones originally designed to spray pesticides for agricultural applications have been adapted in China to spray disinfectants in some public spaces and to transport goods between impacted areas, while South Korea has deployed them to help disinfect areas in Daegu, an epidemic hotspot. Police have been using drones equipped with thermal sensors, night-vision cameras, high-definition zoom lenses and loudspeakers to enforce movement restrictions in Spain, France, Belgium, the UK, Greece, Lithuania, Bulgaria and California during lockdown campaigns, whereas in China their role is becoming more crucial in keeping millions of people at home and identifying those who are not wearing masks in public places by means of 40x zoom cameras. The Italian Civil Aviation Authority (ENAC) recently confirmed the approval of drones to allow local police in Italy to use drones to monitor the movements of citizens during the coronavirus pandemic. While in many cities the use of drones is seen as a necessary step to facilitate the enforcement of lockdown rules, in certain cases their use has been criticized, as in the case of Derbyshire police force, who posted drone footage online showing a couple of people walking innocently through the area's Peak District National Park.

As the pandemic spreads, new coronavirus-specific

detection drones are being developed to perform more sophisticated functions such as detecting temperature, heart and respiratory rates, and/or detecting people sneezing and coughing in crowds. One such 'pandemic drone' is being developed by University of South Australia researchers. [6]

Anticipatory policy-making

Without questioning the role that drones are playing in managing the Covid-19 outbreak, their widespread use and multi-tasking potential raises questions about the type of data that is collected, the data-processing methods and the informed consent procedures that are followed. The use of drones and of other surveillance technologies in an emergency context could pave the way for increased identification of individuals, affect people's right to anonymity and help foster discrimination and stigmatization. The legitimacy and ethical soundness of their use will ultimately depend on whether restrictive measures are reinforced through persistent surveillance methods and data retention procedures. As in public health emergency situations of the present kind, the massive use of surveillance technologies may temporarily be justified to contain the disease, public authorities are expected to grant waivers on restrictions that might hamper these operations and to shorten the relevant notification procedures.

In addition to questions of transparency, discrimination, profiling and proportionality, the use of drones in an emergency context such as the one created by this pandemic may signify a securitization of civil problems, with potentially irreversible implications for human rights. The modification of the software and repurposing of agricultural drones to combat Covid-19 may also raise serious dual-use and/or misuse concerns that could be accentuated by civil drones' vulnerability to hacking given their unencrypted communication. This could result in anything from illegal information processing to hijacked control over a drone's command and control system and its use for malicious or even criminal activities.

As Europe has become the epicentre of the Covid-19 outbreak, calls for continuous aerial surveillance to enforce transport limitations and lockdown measures may become stronger, while the regulatory process for authorizing the use of drones in the context of the Covid-19 pandemic will probably be fast-tracked in accordance with the principle of reciprocity. Although there are provisions in both Article 6 and Article 9 of the General Data Protection Regulation that allow for the collection, use and necessary sharing of personal data for 'reasons of public interest in the area of public health, such as protecting against serious cross-border threats to health', any widespread use of drones for large-scale data collection must abide by the principles set out in a recent statement of the European Data Protection Board (EDPB) on the processing of personal data in the context of the Covid-19 outbreak. The Board advised public authorities against 'systematic and generalized' monitoring and collection of data related to health and recommending they first seek to process location data in an anonymous way. According to the ePrivacy Directive, when it comes to the processing of telecom data, such as location-tracking data collected by drones, location data can only be used by the operator when made anonymous or with the consent of individuals. Recently, the chair of the EDPB clarified that safeguarding public health may fall under the national and/or public security exception of Article 15 of the Directive, which enables the Member States to introduce legislative measures pursuing national security and public security. Although many of the exceptional measures controlling the use of drones are based on extraordinary powers, only to be used temporarily in emergencies, specific safeguards need to be introduced so that full protections are afforded to personal data once the state of emergency is lifted. [6]

10. Robots

Like drones, robots are another new technology being deployed to contain the spread of Covid-19. From the initial outbreak of coronavirus (Covid-19) in China to its spread across the globe, robots have been used to provide services and care for those quarantined or practicing social distancing. Robotics developers are responding quickly to public health concerns and needs and the pandemic has fast-tracked the 'testing' of robots and drones in public, with all stakeholders seeking the most expedient and safest way to grapple with the outbreak and limit its further spread.

Robots are being deployed across the globe in the fight against the coronavirus pandemic. From robots that disinfect whole hospitals, decontaminate public and private sites, handle biohazardous waste or deliver food andmedication,torobotsthattake patients' temperatures and act as medical assistants, robotics technology is being used to reduce the risk of person-to-person transmission – especially in pandemic hotspots – as an intelligent solution to combat the coronavirus. [6]

Potential impacts and developments

Beyond the efficient completion of dirty, dangerous and dull tasks, robots are also used to minimize human contact and exposure to the virus, and to make hospitals safer for front-line healthcare workers by reducing the risk of clinical staff contracting and spreading Covid-19. Hundreds of self-driving ultraviolet disinfection autonomous robots are being used to disinfect designated areas, including hospitals, isolation wards, intensive care units and operating rooms by spreading UV light that can rapidly wipe out pathogens. Six types of robot that can offer assistance in the areas of security, inspection, disinfection and delivery were donated to Chinese hospitals by CloudMinds. In early March, a coronavirus field hospital ward opened in Wuhan, staffed by robots that carry out tasks including taking patients' temperatures, delivering meals and disinfecting the facility. It is a trial designed to relieve exhausted health-care workers. Robots have also been deployed at a Shenzhen hospital specialized in treating Covid-19 patients to perform tasks that include providing video conferencing services for patients and doctors and monitoring the body temperatures of visitors and patients. A germ-killing robot known as GermFalcon, designed to sanitise aeroplanes, is currently being used at the Los Angeles International Airport, San Francisco International Airport and John F. Kennedy International Airport as part of their emergency response efforts.

In Hong Kong, China and South Korea, the Israeli Temi robot has been deployed in nursing homes to enable families to communicate with residents who are quarantined until further notice through video calls, and has also been deployed in hospitals, airports and the workplace. Meanwhile the humanoid called Cloud Ginger provides patients with useful information and entertainment through the medium of dance. These service robots, which have autonomous navigation systems, can also take remote heat samples, distribute sanitary items to each room, ask residents to wash their hands regularly, remind them of their mealtime schedule and play different songs for each resident, depending on their tastes. Video-calling robots have also been deployed in elderly care homes in Belgium to help elderly people stay connected with their families as there is a ban on family visits. In China, police have been using robots for patrolling and monitoring purposes at toll gates, to monitor mask use and take body temperatures with infrared thermometers, while, in Shanghai, robots patrol the streets to inform the public about disease prevention, identify people not wearing masks and give out hand sanitizer.

Meanwhile, high-tech driverless road sweeping vehicles have been helping to keep Chinese cities clean and delivery robots, (such as Little Peanut), have been deployed across China to serve food to quarantined travelers. In several Chinese hospitals, autonomous delivery robots are being used to transport drugs around buildings but robots are also being used in the drug-development process as labs use robotics to facilitate the evaluation of molecules being tested for their capacity to fight the spread of the virus. Doctors used a telemedical robot to treat the first person known to have been admitted to hospital in the US with coronavirus. The robot was equipped with a camera, microphone and stethoscope enabling the patient to communicate with doctors and the medical staff to listen to the heart and lungs of the patient, while also communicating with nursing staff in the room. Robots as medical assistants and telepresence bots that allow remote video communication, patient health monitoring, the removal of bedsheets, the disposal of medical waste, and the safe delivery of medical goods and food are growing in number in hospitals in all affected areas in China. Spain recently announced plans to use robots to test 80 000 people a day for the coronavirus so as to expand testing capacity and reduce human exposure to infection.

Fighting the Coronavirus with innovative robot tech

Dr Cristiano Huscher has long used robotics and artificial intelligence for surgical procedures at the Policlinico Abano chain of hospitals in Italy. So when six doctors contracted COVID-19 at his hospital in Sardinia two months ago, he once again turned to technology — in this case, UVD Robots — to disinfect the rooms.

The robot moves autonomously through a room, using ultraviolet-C light to kill the DNA in the virus, effectively destroying it, along with bacteria.

“This robot kills 99.99% of viruses, bacteria and fungal spores,” said Huscher, chief of oncological surgery, robotics and new technologies. “We don’t have any nurses, doctors or patients with coronavirus since we started to use the robots.” He expects the robots to eventually become mandatory at hospitals.

The Italian hospital chain is among a surging number of businesses rushing to adopt innovative technology to combat the COVID-19 pandemic. These include robotic dogs that monitor parks for social distancing, thermal sensors that detect fevers from 10 feet away, and hand-washing sensors.

The coronavirus relief law, which offers funding for tech upgrades in the United States, is also spurring companies to embrace shiny new technology faster — and more willingly — than in the past.

“This is going to accelerate it,” said Victoria Petrock, principal analyst at eMarketer, a market research, data and analysis company.

Tech that uses UVC light has been particularly hot. UVD Robots, a unit of Blue Ocean Robotics in Odense, Denmark, started developing its disinfection robots in 2014.

"Each year millions of patients are infected, and thousands of patients die, due to infections acquired during hospitalization," said Claus Risager, co-founder and chief executive of Blue Ocean Robotics.

Risager said scientists had long lauded UVC light as a weapon against SARS, MERS and other viruses. So the company built a mobile UV Disinfection robot that can move around a room, zapping airborne viruses and bacteria from surfaces in 10 to 15 minutes. It hit the market in 2018.

"I could see its potential," said Darren Smith, an early investor in UVD Robots from Brisbane, Australia, adding that demand has soared beyond expectations during the coronavirus. UVD Robots are now used in hospitals, airports in Southern Europe, a prison in Southeast Asia and a hotel group in Ireland, according to Per Juul Nielsen, the company's chief executive.

Other companies making UV robots include Xenex, Tru-D, Puro Lighting and Surfacide. Many of these are stationary — rather than mobile — robots.

The ADDAMS robot, developed at the Viterbi School of Engineering at the University of Southern California, goes one step further. It is equipped with a Universal Robots arm that can pick up items, open drawers, move objects, and even open and close doors remotely while disinfecting the room with UV light and chemical hydrogen peroxide spray.

Professor Satyandra K. Gupta, director of the school's Center for Advanced Manufacturing, sees UV robots being used in hospitals, shopping malls, movie theaters, train stations, schools and grocery stores.

The Metropolitan Transportation Authority in New York City recently began a pilot program to use Puro's UV lamps overnight to clean subway cars and buses.

However, UVC light cannot be blasted into rooms where people are. Prolonged exposure to it can cause skin cancer, cornea damage and other problems.

Healthe of Melbourne, Florida, has created disinfectant devices that use a different technology, far-UVC light, which scientists say is a safe version of UVC for humans. The technology uses a shorter band of wavelength that cannot penetrate the skin, and therefore will not damage the cells and tissue under it, said David Brenner, director of the Center for Radiological Research at Columbia University.

However, it can still zap microbes, bacteria and viruses on surfaces and in the air.

"One of the useful properties of UV light in general is that it doesn't distinguish between drug-resistant bacteria and drug-sensitive bacteria," Brenner said. "All it does is damage the DNA or RNA in that bacteria and kill it," he added, noting that, "we realized it also applied to viruses."

Fred Maxik, a former NASA scientist and founder of Healthe, said he had been promoting the technology for about three years, but it took COVID-19 to get people to respond. "I really did believe that a pandemic of this magnitude was possible," he said. "It sometimes takes things as terrible as this is to bring it to focus."

Magnolia Bakery in Manhattan is installing Healthe's far-UVC tech devices at two of its retail locations.

Then there's Spot, a robotic dog built by Boston Dynamics, which wanders around a popular park in Singapore, enforcing social distancing rules. The robot, which has sensors and a 360-degree camera, is steered around the park remotely and uses its built-in speaker to play a recorded message when it comes across people defying social distancing rules.

Sensors and wearable IoT (internet of things) devices are also big in the coronavirus battle. Triax Technologies of Norwalk, Connecticut, makes sensors for construction sites. Its Spot-r sensor, worn on a belt, automates the check in/check out process, which eliminates the need for workers to line up at entry-points or turnstiles. It also tracks workers on a job site, gets notification of a fall and allows workers to report emergencies by pushing a button.

In April, Triax added a new device, Proximity Trace, that beeps if employees stand less than 6 feet from each other. It also tracks a worker's daily movements: If the virus is found in a worker, the tracker can identify the people and equipment that might have been exposed to the infected person.

The Gilbane Building Co., based in Providence, Rhode Island, started using Spot-r sensors at many of its construction sites three years ago, and then added the proximity tracers in April.

"When Spot-r first came onboard three years ago there was some pushback — it was seen as kind of a Big Brother device," said Michael McKelvy, president and chief executive of Gilbane. "But those apprehensions are no longer the case."

However, Petrock urged caution. "When you start collecting personal data, companies are going to have to start treading very carefully."

Temperature sensors are also in demand. Hitachi created a device that detects elevated body temperature from up to 10 feet away. It has infrared cameras that allow a company to flag someone with a high body temperature, giving the business a chance to pull aside high-risk people for secondary screenings or quarantine before they enter a property.

Justin Bean, global director of Smart Spaces Marketing at Hitachi, said he believed temperature scans could become the new normal at airport and train stations — the way the confiscation of nail files and water bottles at airport checkpoints became the norm after 9/11.

Then there's Hitachi's automated hand-washing monitoring device, which detects whether workers wash their hands sufficiently — for at least 20 seconds — in a company restroom. The device monitors activity and provides the data — without names — to managers.

However, are these tech devices temporary tools, to be tossed away when the pandemic passes?

Risager noted that there had been three outbreaks of serious viruses — SARS, MERS and COVID-19 — over the past two decades.

"This is the third in 20 years — it's not something unusual — it's just unusual that we didn't manage to contain this one," he said. "This will not just be forgotten." [11]

Anticipatory policy-making

Despite the many benefits associated with integrating robotics applications into the multitude of public health responses to this particular pandemic, the snowballing use of robots raises a multitude of ethical and social risks and significant tensions in the legal system. The risks and challenges mostly depend on the type of robot in operation. The concerns raised by human-guided robots such as disinfection robots or robots used for drug deliveries, the transportation of medical devices, waste removal, and temperature-checking relate primarily to safety, radiation-related health effects and effectiveness concerns as most UV (ultra-violet) robots have only recently been deployed. The Machinery Directive 42/2006 and the General Product Safety Directive 95/2001 along with some voluntary standards, including ISO/TS 15066:2016, ISO 14971 and IEC 60601, IEC 80601-2-77, IEC 80601-2-78 and IEC TR 60601-4-1 set out some minimum requirements regarding the operation of these particular healthcare collaborative robots. The introduction of robots that perform routine medical work for contagious patients may signify the replacement or elimination of health-care workers. Robots used for surveillance purposes need to adhere to the main principles of the General Data Protection Regulation, in particular those relating to data minimization and proportionality. When autonomous care and testing robots are used with patients and/or elderly people in the context of this pandemic consideration must be given to the potential impact upon privacy, human dignity and autonomy, and the possibility of technical and (false) emotional dependencies, that may be accentuated owing to the loneliness and other vulnerabilities generated by the quarantine and social distancing norms adopted. The introduction of care robots also raises particular issues of deception and dignity in a public health emergency context. It also raises safety issues given that these service robots operate in hospitals and elderly care homes, which are unstructured and highly unpredictable environments, with people present.

There are obvious concerns that robots are incapable of fulfilling the emotional needs of patients that are in isolation, such as the need for empathy, human contact and companionship. The increasing use of robots in the context of the Covid-19 pandemic poses pressing questions as to whether they realistically could replace nurses or other caregivers. Robots might be able to replicate some vital care services provided by humans, but what about the important companionship and empathic aspects of human care? The possible dehumanization of healthcare in emergency settings through the use of robotics may at first sight seem justified owing to the shortage of human resources in most national public health settings, which are facing the worst public health crisis in a generation. However, the high-cost of building these technologies into healthcare systems may further exacerbate inequalities between countries in terms of their preparedness to fight a pandemic.

What must be noted is that although the special value of robotics in contributing to the fight against Covid-19 cannot be questioned, efforts must be made to ensure that in the vast application of robots, their motions are predictable and are aligned with values such as transparency, accountability, explicability, auditability and traceability, and neutrality or fairness. In the absence of an EU robotics-specific legislative framework, special attention has been given to the need to introduce an ethical governance scheme for robotics, irrespective of whether applications are based on the capacities of artificial intelligence. Such a scheme should ensure that decisions in the field of robotics, including which type of data is being communicated and how it is being translated into a decision, are communicated transparently to users, and are based on the principles of the supervised autonomy of robots, intelligibility, fairness, reversibility and privacy by design. Although such thorough ethical and legal supervision of the operation of such a vast range of robotic applications may be difficult to achieve in an emergency context, special attention must be paid to the terms of application of the human computer interfaces that are essential in enhancing the efficiency of robot control. [6]

ICT and Public Health

ICT for Immediate Relief and Medical Response

Testing and Diagnosis

Before any successful containment strategy can begin to take shape, medical personnel must gain an accurate portrait of who is infected and who they, in turn, have potentially infected. The first step in this process, and the step which has provided the most difficulty so far for nations dealing with this pandemic, has been the delivery of testing at a large enough scale to paint this portrait.

ICT can do little directly to address the material shortage in testing, which has more to do with shortages of swabs and chemical reagents. If, however, enough tests can be manufactured to meet the demand of an entire population, ICT can play a significant role in addressing both human resources constraints and geographical challenges. For example, testing for COVID-19 involves conducting a simple genetic sequencing of the residue from a nasal swab, which seeks to identify the well-documented, telltale RNA patterns of the novel coronavirus. As this process requires no particularly specialized medical knowledge, batches of tests can easily be processed en masse at scale and on site with the aid of technology to identify these sequences.

In dense urban areas, where patients can easily provide samples for same-day testing, such a solution can and is currently being used to increase testing rates and accelerate turnaround time.

In rural areas, however, lower population density and fewer equipped medical personnel make such a strategy unfeasible. For regions where frequent mass testing is unfeasible, ICT can again help fill the gap. Before mass testing was available in China, individuals who were concerned they had been exposed to the virus were asked to describe their symptoms on a government website. If their reported symptoms matched those of the coronavirus, they were directed to specialized fever clinics for further care and observation. To expand on this approach, a threat assessment app currently under development would use machine intelligence to analyze a mobile phone-based survey and identify those most likely to require a test based on history, exposure to known infection clusters, risk factors and potential symptoms. Were such individuals in a location where they could not easily reach a testing site, they could be sent of the several types of at-home tests currently in production and be linked digitally with a medical provider pending the results of the test.

For medical teams working to trace clusters in the field, ICT can also lend an invaluable hand. Mobile technology allows for coordination between investigative teams and central authorities while providing for instant data analysis and correlation of observations to the known existing body of cases. During the initial outbreak in China, for example, technology played a critical role in managing data for the contact tracing of as many as 70,000 known cases, while simplifying the investigative role of field personnel and coordinating tracing efforts between these teams and central government.

With the involvement of ICT, tracking a disease may not even require direct human involvement. Smart devices, or the "internet of things," can aid in the passive recognition of potential epidemics before they become a threat. For years, Kinsa Health, a company which manufacturers smart thermometers, has published an online map of recorded body temperatures, which has successfully predicted the onset of the seasonal flu ahead of the CDC's own systems for the past two years. With over 90% of known coronavirus patients experiencing a fever, such an approach could theoretically be adopted in order to anticipate new localized disease outbreaks and contain them before they grow to reach larger scales. Given the high rate of adoption for wearables such as Fitbit that promote personal fitness in the past five years, the health data which could identify and locate an outbreak in progress may already exist, being collected passively from millions of smartwatch users per day. Research is currently taking place to determine whether the data collected by these devices is sufficient to identify likely cases, possibly even before the onset of symptoms.

Finally, internet users may generate sufficient data over the course of their ordinary online activities to identify emergent outbreaks, and even previously unknown symptoms of the disease, when analyzed in aggregate. Researchers at University College London have found a strong geographical correlation between Google searches for disease symptoms, such as fever, anosmia, and shortness of breath, and community outbreaks of COVID-19. Most intriguingly, the surges in these search results predated the public identification of these locations as infection clusters, meaning the same passive analytical tools could be applied to anticipate outbreaks and take preventative measures before they spiral into the public eye and out of control. Researchers even used search result correlation to identify a potential new symptom which had not previously been reported – eye pain. Although this outcome has not been definitively confirmed by medical professionals, if the results stand, they would imply that any unusual burst in search activity for medical symptoms confined to a geographic area could serve as evidence for the emergence of a pathogen, regardless of whether or not its presence was previously known. Such passive big data epidemiological analysis could even be automated by identifying a master list of symptom-related search results and designing an algorithm to track unusual spikes in search activity correlated by location. [1]

Patient-Centric Record Keeping and Case Management

One component of e-health, Electronic Health Records (EHRs), is essential for tracking and treatment alike. Pandemics create enormous data management burdens which health systems must navigate swiftly in order to outflank the advance of the disease. For patients who have tested positive, providers must be ready to access health histories at a moment's notice to determine if the patient has any special risk factors or comorbidities, and if so, what specialized treatment if any may be appropriate. Epidemic trackers must also be prepared to pursue the primary, secondary, and tertiary contacts of those who have tested positive, a constantly shifting and evolving task which can only be completed rapidly enough to contain the advance of the disease with the assistance of data analytics and data management technology. Health systems reliant on obsolete paper records, which must be physically accessed any time any of the above information is required, cannot hope to access patient information or analyze it in conjunction with data on community spread rapidly enough to make a meaningful difference in the trajectory of the disease.

In the United States, obsolete records-keeping systems have dramatically hindered the public health response to the coronavirus outbreak on multiple fronts. Reliance on paper files, phone calls, and fax machines has slowed down processing of requests in the best of times. But now, the failure of many health providers to migrate their records to digital archives which can be accessed instantly regardless of time or location has served as a bottleneck for the exchange of vital health information between doctors, laboratories, and health officials. The health sector has seen significant IT upgrades over the past decade, but unfortunately, the public labs which were responsible for conducting the majority of testing in the early stages of the outbreak did not sufficiently upgrade doctor-lab communication systems as part of their investments in modernization. Namely, even though individual EHR systems were upgraded, competition between for-profit providers within the US healthcare system meant that little investment went into improving interoperability between EHR systems as a means of efficiently communicating complete, accurate information to support rapid decision-making. As a result, the backlog of missed calls, voicemails and even paper mailings which doctors have had to sift through in order to find out a patient's test results have crippled surveillance and outbreak intervention efforts – initiatives for which speed is of the essence.

If there is a silver lining to this breakdown in the system, it has forced a reckoning over the hiccups which continue to slow down this response. A more resilient, fluid implementation of EHR is essentially being built in flight to meet the country's testing and health data management needs, lessons from which can and should be adopted by other countries as rapidly as possible in order to streamline their own testing pipelines before it is too late. For instance, practitioners at University of California San Diego Health (UCSDH) have developed a suite of EHR tools designed specifically to limit the spread of the virus through electronic systems for patient check-in, secure messaging, telemedicine, real-time data analytics, and test result communication. Such integrated health platforms resolve the compatibility issues which hamper interoperability between EHR systems, and by extension, accelerate the entire testing and tracking response. By investing in such systems, health providers are adapting their disaster preparedness infrastructure to accommodate not just the physical and material burden of an influx of thousands of new patients, but the information and communications burden as well. [1]

Contact Tracing and Investigation

Once positive cases have been identified through a scaled-up, widespread testing program, the next phase of preventative measures within a containment program involves identifying those individuals who have potentially contracted the disease by coming into contact with a carrier. Traditionally, this process involves a highly labor-intensive in-person investigative program. Such programs are not only time-consuming, wasting one of the most precious resources available to health officials when combatting a disease outbreak. In addition, these investigators often must don extensive full-body Personal Protective Equipment (PPE) to guard against traveling to potentially infectious environments, risking their own health, and possibly even becoming vectors for the disease themselves. In cases such as the 2014 West African Ebola outbreak, the sight of investigators wearing such equipment so scared local communities that many, fearing a virus which may have already been circulating in their communities, barred the entry of these perceived dangerous outsiders. As a result, the institutional trust which was necessary to promulgate disease prevention efforts advocated for by the authorities was undermined by the very actions intended to slow the spread of the virus, potentially prolonging the outbreak.

Fortunately, advances in ICT have made contact tracing without the invasive presence of these medical teams far more feasible. Where personal technology such as smartphones are widespread and institutional trust is high, as in the East Asian countries which have most successfully battled the coronavirus so far, the tracing process can almost entirely be automated. Where such technology is not prevalent, or where low levels of societal trust may inhibit compliance with quarantine measures, low-tech applications of ICT can augment more traditional tracing approaches. By adding a human touch to what would otherwise be a highly impersonal process, these approaches can bolster a sense of social solidarity and personalized care, which is essential for maintaining the cohesiveness of society throughout the long trajectory of the crisis.

Early in the course of the pandemic, Singapore released the TraceTogether app, setting a standard which few countries have been able to meet with one of the most visionary applications of ICT to the problem of contact tracing to have emerged from the global health crisis so far.

After users download TraceTogether, smartphones equipped with the app utilize their Bluetooth capability to catalogue the physical proximity of other users. If a user tests positive for the virus, all users of the app who came within close physical proximity of that user, and potentially contracted the virus as a result, are sent a notification and a set of instructions for self-isolation.

If mimicry is the greatest form of flattery, then the number of countries which have begun piloting their own tracing apps after witnessing Singapore's success with TraceTogether should stand as testament to the benefits of this approach. India, for instance, is currently piloting its own Bluetooth-powered tracking app, termed CoWin-20, and Israel has unveiled its own app, called HaMagen, or "The Shield."

TraceTogether and its siblings have experienced significant adoption and success, but they are not a perfect solution to the challenge of contact tracing. Their main weakness is that as third-party apps, they do not have seamless interoperability with Android or iOS devices. As a result, the app causes phones to consume more battery life when operating in the background and can on occasion fail to begin functioning at startup, or may experience interruptions in Bluetooth connectivity. This weakness is a minor, but significant hole in what would otherwise be a tight surveillance network. Far more significant of a weakness is the fact that the app is not mandatory, and is offered on an opt-in rather than an opt-out basis. This significantly shrinks the user base, and as a result, the proportion of society which the app can successfully serve.

Moreover, since those who have paid little heed to health guidelines are both less likely to download the app and may be more likely to carry the virus, the app's userbase may self-select away from likely carriers of the disease in a way, which underestimates the level of social distancing required to stop the spread of the illness. To address these shortcomings, Google and Apple have partnered to design tracing software for direct incorporation into the operating systems of their smartphones. This software, which would allow users to opt out in deference to privacy concerns, would be more reliable and efficient than an external app and would create a denser surveillance network by virtue of a larger user base. Direct integration into mobile operating systems may also increase coverage in the developing world by reducing barriers to uptake. However, regardless of the virtues of the underlying technology, such techniques will do little good if they are not paired with digital records of test results which can be seamlessly communicated between laboratories, the medical officials who maintain testing databases, and the software companies which would forward any necessary alerts to end users.

Furthermore, such a centralized surveillance approach runs into serious obstacles in countries with highly individualistic cultures and an endemic distrust of government. It was for this reason that Massachusetts, when presented with the opportunity to apply a technology-forward method of contact tracing similar to what was applied in these East Asian success stories, instead opted for what at first seems like a low-tech approach for a developed country, and one ill-suited to the level of technology the general population has access to. Rather than automating contact tracing digitally, the state has enlisted over 1000 people in a contact tracing program in which tracers make personal calls to the cell phones of those identified as contacts through traditional means.

Such a system is highly labor intensive, and has the seeming disadvantage of missing casual interactions between strangers in public places, which nonetheless have the potential to spread the virus. However, what this method lacks in thoroughness, it makes up in interaction quality. The system, in which phone bankers call up an average of ten contacts per newly identified case, was pioneered by Partners in Health (PiH), a nonprofit famed for its successful initiatives against infectious diseases, namely tuberculosis, in some of the world's poorest countries.

According to PiH's founder, Paul Farmer, nothing ensures compliance with an epidemiological program so much as a bond of trust. In compliance with this principle, over the course of a half hour on the phone, contacts receive not only reassurance from their tracers, but have the opportunity to voice any specific concerns and needs for social support they will require over the course of their time in isolation. The result is a more holistic approach to the challenges posed by the need for strict quarantine, and one, which leverages ICT to enlist thousands of new health workers and safely engage them in the constructive work of cornering the disease.

Other observers have witnessed the success of the phone banking approach and proposed that it be taken to an entirely new scale. Jeffrey Sachs, acknowledging the need for mass identification, tracing, and isolation of the infected as a prerequisite to slowing and eventually halting the advance of the disease, has proposed the organization of mass phone banks at national and subnational levels around the world. These phone bankers would check in on a daily basis with confirmed cases in order to follow symptoms, trace family and work contacts, and identify any needs these individuals have for public services in order to ensure they remain in social isolation.

Contacts who reported any symptoms would be placed on a priority list for testing, be placed under the same temporary isolation, and receive the same assertive social support. An aggressive intervention along these lines, which successfully resulted in the self-isolation of all infected individuals within the first day of reporting symptoms, as illustrated in a technical demonstration, which Sachs contributed to, would dramatically reduce the r-value of the disease, or rate of new infections per new case, below one, and lead to the organic decline of the epidemic. [1]

Telemedicine during a Pandemic

Regardless of the symptoms, characteristics or deadliness of any particular disease, the greatest challenge faced by any health system during a pandemic is the sheer number of cases, which must be processed within a short amount of time. The threat of hospitals being overwhelmed by a surge of life-threatening cases beyond their capacity to treat has been the motivating force behind appeals to "flatten the curve," or slow the spread of the disease enough that the peak number of cases where hospitalization is necessary remains below the ceiling of total hospital treatment capacity. Even so, however, in the worst hotspots, the universal shortage of hospital space means that routine and nonessential consultations must be done outside of traditional spaces. Even for a disease as potentially severe as COVID-19, patients who have not come down with symptoms which absolutely require hospitalization have been requested to remain home in order to preserve space for the worst cases. Likewise, going to the hospital now poses such a significant risk of exposure that many patients wishing to undertake nonessential procedures have been turned away both for their own safety and to reduce the risk of further spread.

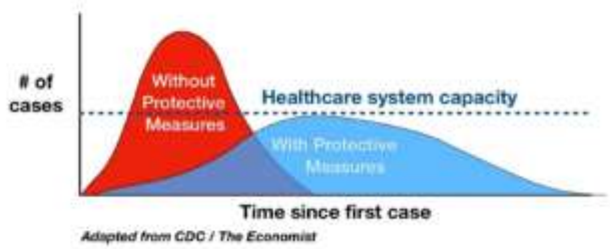


Figure: Slowing the rate of spread through protective measures, or "flattening the curve," is an essential part of maintaining the capacity of hospitals to manage an outbreak. Telemedicine plays an important role both in promoting the distancing necessary for this and in opening hospital space desperately needed for urgent treatment. Source: ABC News.

In such a constrained environment, telemedicine becomes an essential tool for maintaining public health, for those who have tested positive for the disease and for those with more routine conditions alike. Telemedicine is an umbrella term referring to the many ways in which ICT can be engaged in the service of health care without necessitating personal contact between physicians and the sick. This ranges from the low-tech, such as phone calls and text messaging between patients and doctors, to more advanced techniques involving wearable medical devices and high-resolution imaging software. For all but those cases requiring the most immediate medical intervention, telemedicine can serve as an adequate stopgap, which maintains normal standards of care while allowing physical hospitals to focus on crisis management.

Telemedicine has experienced a global boom during the current coronavirus outbreak. Over the course of its epidemic trajectory, China has been able to move 50% of all medical care online, opening space in its medical facilities to treat COVID-19 patients while maintaining safe distance for ordinary patients. Among the normal procedures of these remote checkups, temperature monitoring was conducted over the phone twice a day for suspected positive cases in order to track the emergence of any fever and, if necessary, identify patients who may need to be sent to special fever wards. Nor has the rise of a policy preference for telemedicine been limited to Asia. New York State, to provide one example, has eliminated co-pays for telehealth services for the duration of the crisis.

More public-facing telemedicine initiatives have gained currency around the world, not just those involving the private relationship between patients and doctors. Monthly consultations on JD Health, one of China's largest online pharmaceutical platforms, grew tenfold to over two million over the first two months of the outbreak, growing even more once the platform rolled out a free online medical consultation tool linking overseas Chinese to physicians through the platform. Similarly, Alibaba's health arm, Ali Health, provided 100,000 remote consultations for Hubei residents under lockdown within five days, and Tencent's WeDoctor app connected 20,000 physicians to patients on a volunteer basis.

The boom in online telemedicine hasn't been limited to for-profit companies, either. Dingxiang Yuan, China's largest online community of medical professionals, experienced a large surge both in visits and online users, created a heat map of COVID-19 infections which has been viewed over 2.5 billion times, and has published a multilingual set of guidelines both for home isolation and prevention procedures and for treating coronavirus patients in hospital settings which have since gone viral. [1]

Treatment

Enforcing Quarantines and Social Distancing

Once positive cases have been definitively identified, sick individuals must be placed into social isolation to allow them to recover from the disease without the possibility of infecting anybody else. Without strict enforcement of quarantines, there is little prospect of the r-value of a disease dropping low enough for the overall number of cases to decline until enough people fall ill an recover that some degree of herd immunity can be achieved. Such an approach constitutes not only a deadly roll of the dice for the millions of people who would become dangerously sick as a result, but also a tenuous bet on the so far unproven theory that those who recover from the disease maintain their immunity in the long term. In other words, quarantining the sick and making sure they stay isolated, while providing them with the resources they need, adds up to a moral obligation regardless of the infringements on liberty involved which would otherwise be unacceptable in normal circumstances. ICT can contribute to the enforcement of quarantines for the sick, and ICT tools have seen successful applications in various East Asian nations so far.

However, a careful balance must still be struck between transparency of information provided and protection of privacy, should the social stigma resulting from becoming a publicized patient and potential spreader prove as deadly as the disease.

South Korea has, to this point, been the global leader in using ICT to aid the enforcement of quarantines for sick individuals. Following the mass testing of segments of the population suspected to have come in contact with spreaders, including the asymptomatic, those who test positive are ordered to self-quarantine and directed to download a smartphone app, which continuously tracks their location. If the GPS data generated by the patient's movements indicates that they leave their residence during the quarantine period, police are automatically notified, the patient's movements are cross-referenced using CCTV footage and credit card records, and the individual faces a fine of up to 8000 USD. At the nation's most recent peak, over 30,000 suspected carriers in South Korea had been ordered to self-quarantine under these restrictions. Taiwan has taken the South Korean approach a step further by treating the boundaries of a patient's home as an "electronic fence" under direct enforcement by the police.

Within 15 minutes of a quarantined individual traveling beyond this boundary as determined by their location data, they are contacted or even directly visited by the authorities to investigate, with the potential for an additional fine. No Western countries have yet taken the step of implementing such a severe system. However, the United Kingdom, after initial gestures toward the herd immunity approach, has considered using location data to track people's movements in a similar fashion.

Arguably, the more information that is published about the identity and backgrounds of carriers, the more likely those who have traveled within the same circles will consider themselves at risk of contracting the disease and take the appropriate steps to get tested and, if necessary, self-isolate. However, excessive publishing of information about the infected can easily cross the line from the marginally useful to the downright invasive, especially when fear and the power of stigma mobilizes online mobs to seek out the identities of these individuals. Initially, South Korea took a maximalist approach to publicizing data about the identities of patients, in concordance with a suite of additional measures, which may have seemed draconian in the moment but were, in hindsight, necessary. However, the information published by the South Korea authorities, which went beyond data such as age, sex, and location to include potentially embarrassing details such as the place of presumed infection (in one man's case, while attending a sexual harassment class) which, in some cases, revealed the identity of the individual. The result was a wave of cyberbullying of the infected which some patients described as "scarier than coronavirus." In a society, which already suffered from widespread online harassment, the effective publicization of patients' identities, in addition with unnecessary and often misleading details about adulterous relationships, plastic surgery appointments, alleged prostitution and the like, has caused sufferers of the disease to report anxiety, feelings of guilt, and even suicidal thoughts.

When a pandemic moves beyond the initial containment phase, detailed information about individual patients ceases to serve any public benefit. This is particularly true because anonymized location data collected over the course of normal tracking, tracing and quarantine surveillance efforts is perfectly adequate to provide an accurate portrait of geographical risk.

Hong Kong has published perhaps the world's best example of caseload mapping, publishing a building-by-building map illustrating the number of cases at every single address in the entire city without any additional identifying information. Few other locales have made such detailed, granular and useful information public, but some have attempted to use the location data they have at their disposal to generate anonymized, yet useful illustrations of the virus' progress throughout their communities. New York City, for instance, currently the global epicenter of the pandemic, recently published a map of the number of verified cases in each of the city's ZIP codes. [1]

Applied AI and Machine Learning for Tracking and Treatment

Months into the global pandemic, medical professionals around the world remain in the dark about what sorts of treatments are useful for patients suffering from COVID-19. Drugs for other disease such as the anti-malarial hydroxychloroquine and the antibacterial azithromycin have shown some murky promise in limiting the worst symptoms of the disease, such as the deadly autoimmune response known as a cytokine storm in which the body begins attacking its own cells in a futile attempt to hunt down the virus. However, other medical professionals believe that administering these drugs could be even more harmful than going without. Through this point, doctors and researchers alike remain in the dark on how to medicinally confront a disease whose disparate and seemingly unrelated complications have ranged from acute respiratory distress to sudden cardiac arrest to liver failure, and in at least one case, a blood clot necessitating the amputation of a leg.

In other opaque and complicated drug development scenarios, AI and machine learning techniques have provided a way forward for identifying new compounds or preexisting drugs, which could meet the need for a new treatment. In the normal drug development pipeline, biologically useful compounds are systematically modified using techniques such as 3D molecular structure prediction, ligand design, and docking. With sufficient provision of data, AI offers the chance to accelerate this pipeline through deep analysis of data from research results, clinical trials, and even the biology of the cell itself. Current AI methods, such as Bayesian network analysis, lack the sophistication to interpret findings for more complex disease, especially when high-quality, clean data is scarce. But new, cutting-edge algorithms offer the promise of replicating the pharmaceutical development pipeline, and possibly gaining new insights human researchers would not have naturally reached, through virtual analysis. If there is one thing the pandemic will not create a shortage of, it will be clean, high-quality, medically relevant data from millions of patients with the same disease. The prospects of AI playing a role in developing treatments and an ultimate cure should therefore be seen as quite bright. [1]

Hospital Management

As discussed, improved implementation of ICT plays a clear role in the testing and tracking process, specifically in streamlining the communication of EHRs between patients, laboratories and medical providers. However, ICT will also play a critical part in assuring that hospitals themselves continue to run smoothly, and that doctors are insulated to the greatest degree possible from the stress of rapidly rising caseloads, insufficient resources, and heartbreaking moral dilemmas. By fully integrating EHRs into patient care, clinicians can keep consistent track of specific patients' needs without having to waste valuable time pulling information from an opaque system. Digital schedule management can adaptively shift staffing to surge personnel during times of high-anticipated need while giving doctors and nurses much-needed rest during anticipated lulls. Moreover, should hospitals reach the point where triage of patients becomes necessary, clinical algorithms can help make objective, humane decisions about which resources to direct to which patients in a way which avoids any extra psychological burden on those of whom so much has already been asked. [1]

Contact Tracing

Background

Coronavirus disease 2019 (COVID-19) is caused by the SARS-CoV-2 virus, and spreads from person-to-person through droplet and contact transmission. To control the spread of COVID-19, interventions need to break the chains of human-to-human transmission, ensuring that the number of new cases generated by each confirmed case is maintained below 1 (effective reproduction number < 1). As part of a comprehensive strategy, case identification, isolation, testing and care, and contact tracing and quarantine, are critical activities to reduce transmission and control the epidemic.

Contact tracing is the process of identifying, assessing, and managing people who have been exposed to a disease to prevent onward transmission. When systematically applied, contact tracing will break the chains of transmission of an infectious disease and is thus an essential public health tool for controlling infectious disease outbreaks. Contact tracing for COVID-19 requires identifying persons who may have been exposed to COVID-19 and following them up daily for 14 days from the last point of exposure. This document provides guidance on how to establish contact tracing capacity for the control of COVID-19. It builds upon WHO considerations in the investigation of cases and clusters of COVID-19.

Critical elements of the implementation of contact tracing are community engagement and public support; careful planning and consideration of local contexts, communities, and cultures; a workforce of trained contact tracers and supervisors; logistics support to contact tracing teams; and a system to collate, compile, and analyze data in real-time.

For contact tracing to be effective, countries must have adequate capacity to test suspect cases in a timely manner. Where this is not possible, testing and contact tracing strategies may instead focus on specific high-risk settings with vulnerable individuals, such as hospitals, care homes, or other closed settings (e.g. dormitories).

Because individuals may transmit COVID-19 while pre-symptomatic or asymptomatic, this guidance also emphasizes the importance of quarantining contacts to further reduce the potential for secondary transmission. [12]

What is contact tracing?

Contact tracing is a little like detective work: Trained staff interview people who have been diagnosed with a contagious disease to figure out who they may have recently been in contact with. Then, they go tell those people they may have been exposed, sometimes encouraging them to quarantine themselves to prevent spreading the disease any further. Think of it as part public health work, and part investigation.

The technique is a “cornerstone” of preventative medicine, says Dr. Laura Breeher, medical director of occupational health services at the Mayo Clinic. “Contact tracing, it’s having a moment of glory right now with COVID because of the crucial importance of identifying those individuals who have been exposed quickly and isolating or quarantining them,” she says.

Contact tracing was used during the 2014 Ebola virus outbreak, as well as in the SARS outbreak in 2003. It’s also used to combat sexually transmitted infections and other communicable diseases like tuberculosis. And as COVID-19 has gone global, countries like South Korea and New Zealand have aggressively used contact tracing in an attempt to control outbreaks

How does contact tracing work?

Once someone has been confirmed to be infected with a virus, such as through a positive COVID-19 test, contact tracers try to track down others who have had recent prolonged exposure to that person when they may have been infectious. Typically, that exposure means being within 6 feet of the person for more than 10 minutes, says Dr. Breeher, though in a health care setting, such as a hospital, the bar is lowered to five minutes.

Healthcare workers then make an effort to reach out to every one of those contacts, tell them that they may have been exposed, and giving them instructions on what to do next. That may include telling them about possible symptoms or directing them to self-isolate.

What are the limitations of contact tracing?

For one, contact tracing is a laborious process. Interviewing infectious patients and reaching out to dozens of contacts takes time. For that reason, contact tracing works best when there are low levels of infection in a community, says Dr. Frank Esper, a pediatric infectious disease specialist at the Cleveland Clinic Children's Hospital. "When you get to a point where there is a lot of people who are sickened with a particular disease, it quickly overwhelms the health departments' response to be able to contact trace all those individuals," he says.

With a virus like COVID-19, which spreads through the air, things can get complicated quickly. Contact tracers might end up trying to find those who sat near an infected individual on a plane or a bus, for instance, even if the sick person never met them. That's a radically different task from contact tracing with a sexually transmitted infection like HIV, which tends to involve a much shorter, more well-defined list of contacts for investigators. Health care workers may also have trouble getting in touch with contacts if phone records aren't up to date, or if an infected patient is already too sick to help identify their recent contacts.

Contact tracing also isn't much help when states and localities have already issued lockdown orders, and when most people are self-isolating anyway. "You ride that out, which is what we're doing [with COVID-19], until the number of cases, and the number of new cases, becomes much more manageable, and then you can reestablish contact tracing once you're on the downslope," says Dr. Esper. Those efforts, coupled with rigorous testing, can counteract a potential second wave and prevent cases from spiking again.

Contact tracing COVID-19 infections has proven particularly difficult, as some infected people don't have symptoms, and the period of time between getting infected and becoming infectious appears to be relatively short. Still, even at the height of a pandemic, contact tracing can still be useful within smaller community settings, such as in health care facilities or nursing homes. [13]

Contact tracing for COVID-19: New considerations for its practical application

As lockdowns lift, talk is turning to whether and how to track those infected with COVID-19, as well as those they might have had contact with prior to testing positive. Here's how contact tracing works—and some of its benefits and limitations.

Contact tracing is a decades-old tool for helping control the spread of infectious diseases.

It has been used successfully in efforts to contain Ebola, SARS, MERS, tuberculosis, and other disease outbreaks.1 It is now a critical part of the fight against COVID-19. In practice, contact tracing begins with those who test positive for COVID-19. Those with whom they have had close contact are then identified, as they may have been infected too. These contacts are notified and supported through a period of quarantine—until they develop symptoms, pass the window of risk, or are proven not to have been exposed. Widespread testing enables optimally effective contact tracing

A cost-effective alternative to blanket lockdowns

Contact tracing enables a targeted approach: rather than imposing a blanket society-wide lockdown, authorities are able to isolate those potentially infected. Lockdowns are necessarily applied where the authorities do not know who has COVID-19. A highly effective program of testing, tracing, isolation of cases, and quarantining contacts can achieve similar benefits as a lockdown while allowing the vast majority of the population the freedom to conduct day-to-day activities. In a world where herd immunity and a vaccine are still far off, even a moderately effective contact-tracing program is an important tool for enabling countries to reopen society.

Contact tracing identifies and supports in quarantine the contacts of those who have tested positive for COVID-19.

Testing

Contact tracing begins with those who have tested positive for COVID-19. The method is most effective when integrally linked to widespread testing.

Identification

Contacts are identified and listed: those who have had meaningful exposure to the diagnosed individual during the period of potentialtransmission, which begins before the onset of symptoms.

Notification

Contacts are notified of their status, and informed of implications and next steps, such as how to end care. Depending on local public health guidance, quarantine or isolation could be required for high-risk contacts.

Follow-up, monitoring, and support

Contacts are monitored regularly for symptoms and tested for infection. Results of monitoring help determine the most appropriate intervention, including quarantine.

Approaches to contact tracing share basic elements but can differ in terms of technology: traditional contact tracing uses telephone and in-person contact; newer approaches use mobile apps and data. Governments need to evaluate the implications of alternative approaches to tracking and tracing for privacy and individual liberties.

The cost of an effective contact-tracing

The cost of an effective contact-tracing program can be substantial. For the United States, for example, a recent cost estimate for one proposal was $3.6 billion. The relative societal cost of a full lockdown, however, is far greater. Contact tracing is most effective when it is supported by widespread testing and advanced isolation and quarantine approaches, but it can have significant impact on its own in limiting the spread of the disease.

Many countries seen as having had the most successful responses to COVID-19, such as South Korea and Iceland, made contact tracing a pillar of their approach. Most countries with high case counts, including the United States and Germany, have made contact tracing a priority for the reopening phase of their response. The case for a program of testing, tracing, isolation, and quarantine has been included in the strategies of the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and other public-health organizations.

New programs, new considerations

For countries and organizations now developing contact-tracing programs, several important new considerations have emerged. First, nonsymptomatic cases make contact tracing for COVID-19 more difficult, though still valuable. Second, some countries and localities are far behind others in their contact-tracing efforts. A further consideration is that the private sector will play a major role in the effort in many locations. Finally, effectiveness can be greatly enhanced by technological enablers, such as contact-tracing mobile apps, but these raise important questions about privacy.

Nonsymptomatic cases make contact tracing harder

Contact tracing is simplest and most effective when two conditions are met: a) all cases are symptomatic, and b) the presence of symptoms is perfectly correlated with the risk of transmitting to others. These conditions are approximately (though not perfectly) true of Ebola, which makes contact tracing an especially potent tool in fighting that disease. However, things are more complicated with COVID-19 because we know that the disease can be transmitted by people who will never develop symptoms (asymptomatic transmission) and by those who have not yet developed symptoms (presymptomatic transmission).

Of these, presymptomatic transmission is easier for a contact-tracing program to manage. When a person is diagnosed with COVID-19, identification of their close contacts should include those potentially infected in the days prior to the onset of symptoms. This condition increases the importance of rapid identification and isolation of cases and quarantining of contacts. It does not prevent the usefulness of contact tracing as long as programs move fast. In contrast, asymptomatic cases may never come to medical attention, making it harder to trace chains of transmission.

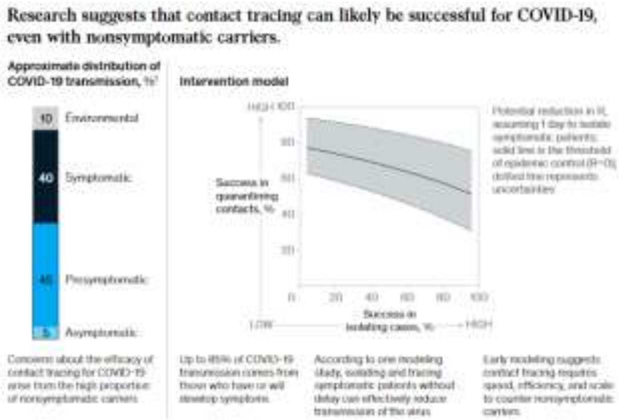
An influential paper recently estimated that 85 percent of transmission events originate from patients who have or will develop symptoms, compared to 15 percent from asymptomatic and environmental transmission. Since that paper appeared in March 2020, serological surveys appeared suggesting that the rate of asymptomatic disease is higher than originally recognized.

More research is needed, but early modeling suggests that transmission can be reduced by tracing and isolating symptomatic carriers without significant delay, in a process potentially enabled by technology. In the meantime, many countries are concluding that the disproportionate weight of symptomatic cases in driving transmission makes the aggressive pursuit of contact tracing well worth the effort.

Many countries and jurisdictions are starting late

Contact-tracing programs begin with confirmed cases, from which chains of disease transmission.

Research suggests that contact tracing can likely be successful for COVID-19, even with nonsymptomatic carriers are mapped and contacts are supported in



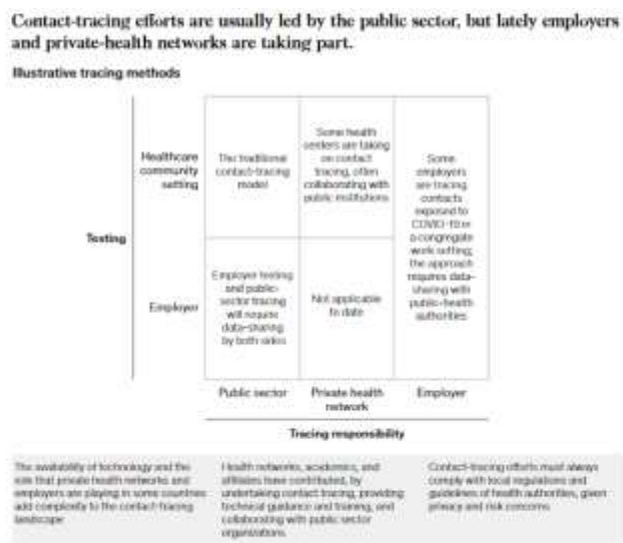
quarantine. The process works best where cases are relatively few in number. Most countries that have deployed contact tracing successfully during this epidemic have maintained relatively low case counts. Some countries have in-depth experience with contact tracing from SARS, MERS, Ebola, tuberculosis, and other infectious diseases that disproportionately affect lower-income populations. Other countries have no such experience. Either way, however, to begin a contact-tracing program in an environment defined by hundreds or thousands of daily confirmed cases is a daunting proposition—especially since known cases represent only a fraction of the total.

We can, however, draw on the experience of the West Africa Ebola outbreak of 2014–16, which was the largest Ebola epidemic in history. Initial contact-tracing efforts could not cope with the scale of the challenge. Eventually, programs were built out and became a key factor in ending the outbreak. The number of cases of COVID-19 is more than 100 times that of the Ebola outbreak, but many of the countries worst affected by COVID-19 have far more resources than do Guinea, Liberia, and Sierra Leone, where Ebola was most concentrated.

The experiences in low-income settings are highly instructive. One important lesson is that the perfect must not be allowed to become the enemy of the good. A minimum scale is required for contact tracing to be effective, but a program need not identify and isolate every contact to slow transmission. COVID-19 will unfortunately be with us for many months to come, so countries should think of contact tracing as a medium-term investment. They will strengthen and improve their program over time, as one important tool in the overall set of solutions. The more effective the program, the fewer the sick, and the greater the level of economic freedom society will enjoy.

The private sector will play a bigger role than in prior contact-tracing efforts

Public-health institutions have led contact-tracing efforts in most past disease outbreaks. The global scale of the COVID-19 pandemic makes it a unique crisis with many parts. It has, for example, expanded into domains where the private sector plays a more prominent role in healthcare. To address the sheer number of cases in particular areas, authorities are assembling many partners, including from the private sector, in contact-tracing efforts. The use of technological enhancements is also drawing in companies with an array of specialized capabilities. Private healthcare organizations and employers are playing an important role in both testing and tracing. The complexity of those invested in controlling this pandemic creates both challenges and opportunities for contact tracing.



In the United States, contact-tracing efforts under way in Massachusetts and California are supported to varying degrees by private-sector companies, including private healthcare institutions.

In Massachusetts, a more centralized statewide effort is being rolled out, in which private and public partners have come together. Participants include the state's COVID-19 Response Command Center, Executive Office of Health and Human Services, Department of Public Health, Commonwealth Health Insurance Connector Authority (CCA), Partners In Health (a nonprofit with global contact-tracing experience), Salesforce, local health departments, and others. The Massachusetts League of Community Health Centers, Blue Cross Blue Shield, and other groups are starting to support the contact-tracing plan directly.

In California, statewide tracing efforts were just announced, but around the state, collaborative efforts have already begun. On the testing side, the governor announced the creation of 80 to 100 high-throughput testing sites, working in partnership with OptumServe and other organizations. Also announced was a program to train up to 10,000 contact tracers. Kaiser Permanente, a managed-care consortium, and other private healthcare institutions are establishing facilities to process 10,000 daily tests. This capability will become a critical link in high-efficiency contact-tracing programs.

Prior to broader announcements, counties and cities in California began to act. In San Francisco, a number of organizations and institutions, public and private, have come together to support tracing, including the city health department, the University of California at San Francisco, and Dimagi, a tech company. Participants in these collaborative efforts are providing diverse support, including testing, tracing, training, technical guidance, and technology.

Globally, employers can be seen taking a more proactive approach to testing and contact tracing, to ensure the protection of their own workforces. This approach has been taken mainly by organizations and institutions with significant resources, such as Fortune 500 companies, those that must operate in congregate settings, such as universities or nursing homes, and those that operate essential services, such as pharmaceutical manufacturers or healthcare providers.

These efforts usually include HR or a central health team that encourages employees to self-report if they have symptoms or a positive test. The team swings into action in the event of a confirmed or presumptive case. It identifies and notifies other employees (and sometimes contractors, customers, or visitors) who may have been in proximity, making recommendations for isolation or quarantine. Some employers are considering treating employee families and even local communities. For employers designing such programs, they should consider how their efforts would best fit with the broader public-health effort against COVID-19. Other considerations include privacy concerns, legal constraints, and local regulatory compliance. On a practical level, planners would have to determine the data, technology, and people needed for identification, notification, and follow-up monitoring and support. [14]

Information technology

Types of tools Electronic tools and information technology are not essential for contact tracing but can make it more efficient and facilitate implementation on a large scale. The Go.Data software application, for example, has been designed to support contact tracing and surveillance in outbreaks.

Other tools exist for self-reporting of symptoms by contacts, as well as proximity applications that track people's movements to indicate potential exposures to and from other persons. WHO is conducting a more comprehensive review of information technology tools for contact tracing that will be published shortly.

Data protection

The ethics of public health information, data protection, and data privacy must be considered at all levels of contact tracing activities, in all training activities for contact tracing, and when implementing contact tracing tools. In particular:

- Safeguards must be in place to guarantee privacy and data protection in accordance with the legal frameworks of the countries where systems are implemented.
- Everyone involved in contact tracing must adhere to the ethical principles of handling personal information, to ensure responsible data management and respect for privacy throughout the process.
- How data will be handled, stored, and used needs to be communicated to those concerned in a clear and transparent manner.
- This is important for buy-in and engagement as well as to avoid misperceptions that could jeopardize the effectiveness of a contact tracing programme.
- Digital tools used for contact tracing should be assessed before use to ensure safeguarding data protection according to national regulations

The promise and challenges of technology

In the context of contact tracing, technological solutions can increase productivity, limit exposure of the workforce, and lower costs. They can also increase the speed of response, which modeling shows to be critical to the overall success of contact tracing. In South Korea, for example, automated tracing helped reduce the amount of time spent on each case from one day to ten minutes. However, the technology has also raised privacy and civil-liberty concerns. Around the world, technology is being deployed in all parts of the contact-tracing process, in identifying and notifying contacts, providing follow-up monitoring and support, and even alerting contacts when the status has changed. The following examples are simply descriptions of how technology is being used; we make no endorsements of particular uses, tools, or approaches.

- ***Identification***. Those afflicted with COVID-19 and their supporters are using technology to identify contacts, entering names into lists or using digital data to create such lists. Massachusetts uses a back-end system to enter and keep track of contacts. In Nigeria, surveillance officers and others are using a system developed for the contact tracing of polio. On the higher end of the technology spectrum, some countries are using digital data in applications that help automatically identify contacts by GPS or Bluetooth technology. In some of these countries, like Iceland, the backbone of the response was still manual contact tracing. By the time the application was rolled out, up to half of the diagnosed cases had already been in quarantine, a good illustration of how digital and manual contact-tracing solutions can support one another. (Iceland is also supporting isolation cases digitally with an AI-powered remote-care app.) Apple and Google's collaboration on a Bluetooth-based contact-tracing application program interface (API), to be released in May, will likely increase the attractiveness of more tech-enabled approaches to supplement current efforts.
- ***Notification***. Technology is also being used to notify contacts and to generate anonymized mapping to notify the public of high-risk areas. (This helps reach those without access to mobile apps.) Often the contact notification is directly built into the identification system, so those who are identified are automatically notified. Some technologies offer both notification and mapping functions, such as MIT's Safe Paths. The MIT solution comprises both a smartphone application (COVID Safe Paths) and a web application (Safe Places). Digital contact tracing uses overlapped GPS and Bluetooth trails, which allow an individual to check if they have crossed paths with someone who was later diagnosed with the virus. On Safe Places, public-health officials can redact location trails and broadcast location information, with privacy protection for carriers.
- ***Monitoring and support***. A number of technological solutions are being used for monitoring and support. Some allow daily digital check-ins or compliance monitoring. Healthy Together, a support application used in the US state of Utah, allows individuals to input symptoms and can direct people to testing locations as well as share test results.

Among country-level responses, South Korea and China deployed high-tech solutions within centralized data systems, alongside significant human resources.

- **In South Korea**, at-scale testing has been followed by rigorous tracing. The Korea Centers for Disease Control and Prevention, in collaboration with other government agencies, telecommunications, and credit-card companies, launched a COVID-19 data platform. Once a case is confirmed, officials work out the patient's movements and contacts in great detail, through interviews, mobile-phone data, CCTV recordings, credit-card records, and other sources. The government shares major locations through text-messaging and making location data public, to help people avoid places where the virus is spreading. Millions have downloaded privately developed apps to help them view this location data, including Corona Maps and Corona 100m, which alerts users when they come within 100 meters of a location where an infected person has been. South Korea has also launched self-quarantine applications to monitor and support contacts under mandatory quarantine.
- **In China**, the government introduced an app-driven access system to help ensure adherence to local regulations. This is the green-amber-red health-code system hosted by Alibaba's mobile payments app and Tencent's messaging app WeChat. Using both self-reported data, and data from authorities, the app segments users into three-color codes: green (healthy), amber (contact with infected individual), and red (symptomatic or tested positive). Those with green classifications can travel freely, whereas those with amber or red classifications may face travel restrictions and quarantine or isolation requirements.

Some technology-driven approaches have raised privacy and civil-liberty concerns. Some applications will be generally noncontroversial, while others will raise concerns. Worth noting is that some privacy and civil liberty considerations can be addressed through the design of technologies and the approaches through which they are deployed. Organizations will have to think through the means by which they will identify individuals and gather, share, manage, and retain data. Bias reduction must be a priority, with due consideration given to disadvantaged groups, including those that may be disproportionately underrepresented or misrepresented by the technology used.

Consent can be an integral part of the process for identification and enrollment. Organizations can indicate directly what data will be collected and how it will be used. Developing data-sharing guidelines, minimizing data collection, and anonymizing and encrypting data can all be done in order to support privacy rights. Clear conditions can furthermore be established on how and when data will be deleted. With these considerations in mind, organizations can aim to use technology to enable a safer, more efficient, and faster response that could support reopening. It will be important to watch how these solutions evolve.

Many public-health assessments and much practical experience indicate that contact tracing has been an essential part of the most effective strategies to control COVID-19. As World Health Organization guidelines make clear, contact tracing is one of three backbone elements to its response to epidemics, along with widespread testing, isolation, and quarantining. There is more to learn as contact tracing is rolled out in additional locations, so leaders should build learning and improvement into their processes from the start. As localities develop and improve their own responses, they must negotiate a delicate path between the urgency of controlling the pandemic, the need for societies to reopen safely, and the privacy concerns that technological solutions continue to provoke. [14]

How Digital Contact Tracing Slowed Covid-19 in East Asia

As Covid-19 steamrolls across international boundaries, public health officials are paying close attention to countries that are flattening the curve, slowing the spread of infection. Can other countries emulate their success? Top of mind has been whether authoritarian regimes have an edge over democracies, because they can mandate top-down measures like lockdowns and digital tracking of infected people's movements and contacts. Indeed, China's foreign minister Wang Yi proclaimed "Only in China and only under the leadership of President Xi can there be such effective measures to put this sudden and fast-spreading epidemic under control."

However, the latest information from Our World in Data, which shows the doubling rate of cases by country, indicates that the type of regime is less important than it might seem. Both the top and bottom performers in Covid-19 containment span the spectrum from autocratic to democratic. It's true that China is effectively flattening the curve, but so is South Korea, a vibrant democracy. Other democracies — the U.S., Spain, Italy, and France, are faring less well.

What, then, do the countries that have so far been effectively flattening the curve have in common? Part of the answer is that they tend to be in East Asia — China, South Korea, Taiwan, Singapore and to a lesser extent Japan — where a collectivist spirit may encourage civic-minded embrace of and a more willing compliance with governments' infection control. In addition, these countries tend to be actively deploying technology to collect data on the virus's progress and efforts to contain it, including tracking those who are infected and their contacts. These two aspects of East Asian societies do not work independently; they reinforce each other.

Clearly, applying technology in these ways can be an important tool in containing the pandemic. But this use of technology raises sobering policy questions about data sovereignty and privacy, issues that are more contentious in Western democracies than in the more collectivist societies of East Asia. The most effective deployment of technology for tracking individuals' infection status, movements, and contacts hinges on three critical conditions that might each present difficult dilemmas for Western democracies: The adoption of the needed technologies (whether they are just strongly encouraged or made mandatory); a digital infrastructure enabled and activated by the government; and seamless data sharing between government and business that may afford few privacy protections.

Let's look at each in detail.

Technology adoption

Drawing on the experience of countries that are effectively using technology for contact tracing, the first step — and a requirement — is to encourage, or, better yet, mandate, the installation of tracking apps on phones. In East Asian countries, this has been more mandatory than voluntary. In Singapore, a country known for its efficiency and no-nonsense government, citizens are encouraged by the government to install TraceTogether, which exchanges Bluetooth signals between mobile phones in close proximity. This is a modern counterpart to the traditional and time-consuming contact-tracing method, which relies on fallible human memory. A government poll reported in Nikkei Asian Review found that more than 70% of respondents supported this move. Hong Kong, which has also seen effective containment, recently implemented a mandatory 14-day quarantine upon entry for all overseas arrivals. To enforce this, the Hong Kong government required each new arrival to download the StayHomeSafe app and gave them a paired wristband that uses geofencing technology to help catch violators, and, as reported in Quartz, warned anyone violating the quarantine that they could face up to six months in prison and a $3,200 fine.

The more striking case of curve-flattening is South Korea, where The Washington Post reports that private developers took it upon themselves to develop apps that supplement official government contact tracing efforts, which many find insufficient. Corona 100m, which, according to MarketWatch, South Koreans downloaded over one million times in just a few weeks with "overwhelmingly positive reviews," collects data from public government sources that alert users of any diagnosed Covid-19 patient within a 100-meter radius along with the patient's diagnosis date, nationality, age, gender, and prior locations. Corona Map similarly plots locations of diagnosed patients to help those who want to avoid these areas and, as Business Insider reports, was the second-most-downloaded app in Korea. A vibrant democracy that has also won praise for its Covid-19 containment, Taiwan is believed to be the first to have used mobile phone tracking to enforce quarantines, which the government reportedly reinforces by calling those in quarantine twice a day to ensure they do not evade tracking by leaving their phones at home.

While mobile tracking of infectious disease has been available for at least a decade — Cambridge University's voluntary FluPhone app developed in 2011 is an early example — the adoption rate varies dramatically across regions. Wired reports that fewer than 1% of the people in Cambridge signed up for FluPhone, for example, compared to the widespread adoption of mobile contact tracing we're now seeing in East Asian countries. Concerns in Western democracies about privacy and civil liberty could create substantial impediments to rolling out such technologies in these countries and may have contributed to FluPhone's low penetration. Even within democracies, there are clear cross-national differences in the degree of voluntary adoption of contact-tracing technologies. But without widespread adoption, such contact tracing efforts will fail.

Digital infrastructure

South Korea's aggressive response to Covid-19 appears to have been enabled by its recent experience in handling epidemics. In 2015, the MERS outbreak there infected 186 and killed 36. Some consider the country's aggressive data-sharing on Covid-19 to be a correction for the government's reportedly opaque approach that marred its MERS response. A survey of 1,000 South Koreans found that most supported the government's transparency in sharing travel details of Covid-19 patients and that most "preferred the public good to individual rights."

Similarly, Taiwan was among the hardest hit during the 2003 SARS outbreak. It subsequently established a disaster-management system that enabled its rapid response to Covid-19, both technologically and institutionally: In one day, relevant institutions integrated infected patients' past 14-day travel history with their identification data, which then facilitated ongoing mobile tracking. Later, Taiwan launched the Entry Quarantine System that sought to expedite entry by providing passengers with a health declaration pass via SMS, with all hospitals, clinics, and pharmacies gaining access to patients' travel histories shortly after.

In an epidemic, timing is everything. South Korea's and Taiwan's experience indicate that the extra time gained from having a system of disaster-response infrastructure in place ready to be deployed proved critical in shaping the pandemic's trajectory. The same lesson can be gleaned from China's Covid-19 management, although China didn't leverage an existing epidemic-response capability but rather repurposed its vast existing system of digital surveillance for Covid-19 tracking, The Economist reports. This approach has afforded the Chinese authorities a "more tailored approach" by "allowing most people to resume their normal lives while monitoring those who might be infected."

As research by two of us (Yasheng and Meicen) with MIT's Work of the Future Task Force has shown, China's repurposing of existing digital technology in addressing Covid-19 is not limited to contact tracing. The Chinese high-tech firms, SenseTime and Megvii, for example, both known for their facial recognition technology, have developed and deployed AI-based contactless temperature detection software. SenseTime has also developed and deployed a "Smart AI Epidemic Prevention Solution" which, by integrating AI algorithms with infrared thermal technology, detects a fever within 0.3 C accuracy and identifies individuals not wearing a face mask with over a 99% success rate. China's maturation in this arena of contactless detections, including facial recognition, has been actively supported by, and demanded from, the government.

Business-government collaboration

In China, impediments to information sharing among authorities, particularly on the local level, appear to have severely limited its effective response to Covid-19 especially in the earlier stage of the outbreak. The actors that hold the key to a data-driven pandemic response, the central government has long recognized, are giant tech firms such as Alibaba and Tencent. By harvesting colossal amounts of user data in real-time, these firms may know more about population movement than the government itself.

Efforts to control Covid-19 shine a spotlight on the advantage enjoyed by so-called "super apps" like WeChat. It is not just the amount of data amassed by WeChat that makes it "super" — a little over a billion active users and more than double the average time spent on the app than on Instagram as of December 2019. Rather, it is the integration of social media, instant messaging, payment, food delivery, ride hailing, health care and thousands of other apps into its own platform that has made it a target of envy for the likes of Facebook.

This public dependency on one app can be weaponized to coerce the public into compliance when a pandemic requires it. The Chinese public's heavy reliance on the mobile payment app Alipay was effectively leveraged by the Alipay Health Code that was recently rolled out by Alibaba's sister company Ant Financial and that has since been adopted nationwide. The Health Code dictates users' freedom to travel, The New York Times reports, by assigning them into one of three categories based on their Covid-19 risk factors calculated using self-reported and collected data: green for unrestricted travel, yellow for a seven-day quarantine, and red for a two-week quarantine. There are two broad concerns here: One is the issue of algorithmic black-box in generating the codes. Users have no idea why the app is quarantining them, as some have complained on Chinese media. The other one, perhaps more pernicious from a privacy perspective, is how it apparently uses troves of user data such as travel history gathered through integration with other apps like Alipay.

This technocratic approach in East Asia satisfies three requirements in an exponential-growth phase of a public health emergency: Scale, speed and a degree of compulsion. Can Western democracies achieve the results seen in East Asia without emulating their means? Probably not. There is likely a fundamental conflict between these requirements and deeply entrenched Western liberal values, such as the expectation of privacy, consent, and the sanctity of individual rights. Israel, the BBC reports, has invoked emergency powers to enforce its quarantine order and in effect has suspended some individual rights.

At the time of publication, at least three local governments in the United States are considering adoption of a contact-tracing app developed in a project led by MIT, Reuters reports. The app, called PrivateKit, combines encryption, open-source and Bluetooth technologies that preserve user anonymity and limit the scope of data being gathered. The download is voluntary and it is too early to tell how quickly and at what scale these technologies might be adopted to combat Covid-19. Another MIT-led team has developed a protocol called Private Automatic Contact Tracing (or PACT) which also uses Bluetooth communications to permit contact tracing while ensuring that no private information is revealed. And Google and Apple have teamed up to put software into billions of phones worldwide that would permit them to perform contact tracing on an opt-in basis, The New York Times reports. But for such technologies to be effective, compliance must be nearly universal. Without a government mandate in the U.S, it's hard to imagine universal voluntary adoption of even a privacy-protecting tracing app.

Maybe Covid-19 is a sign of our future steady state. Different societies will make different choices about how to respond to the next pandemic. For Western democracies the time has come to either rethink our values around the tradeoff between personal privacy and public safety in a pandemic or to accelerate technology innovation and policy development that can preserve both. [15]

Tech's role in tracking, testing, treating COVID-19

As the cases of COVID-19 increase, we are seeing a rise in digital epidemiology tools, chatbot helpers, EHR guidance tools and rapid-response test kits.

With the incidence of new COVID-19 cases growing by the day, healthcare stakeholders are continuing to search for tools and medications to help stem the tide.

We have seen the digital health community release a slew of new tools aiming to monitor the spread of the disease and facilitate better treatment. And it sounds as if there's still more to come, as just this morning CNBC reported that tech giants Facebook, Amazon and Google were sitting down with the World Health Organization to talk about their role in combating the spread of disease, as well as misinformation.

As of this morning, there were over 2.6 million laboratory-confirmed cases of the virus, **according to WHO**. The medical community has rushed to search for solutions to the spread of the disease with a big push for vaccine and medicine research.

Tech has a history of helping the medical industry track and treat viruses. Among more recent examples is flu tracking. In 2018, the US experienced a particularly severe flu season. During this time, aggregated user data collected through Kinsa's smart **connected thermometers** indicated illness spikes across the country.

Even more recently, a **Scripps Research Translational Institute** study published in The Lancet Digital Health found that resting-heart-rate and sleep-duration data collected from Fitbit devices could help inform timely and accurate models of population-level influenza trends.

In terms of COVID-19, we are seeing another rise in digital epidemiology tools, chatbot helpers, EHR guidance tools and rapid-response test kits.

Read on for a list of how health organizations, governments and digital health vendors are using technology to tackle the COVID-19 crisis:

COVID-first virtual care. Telemedicine company Fruit Street Health launched a new risk assessment, triage and video consult platform designed specifically to handle potential COVID-19 cases.

Called CovidMD, the tool is built on the Salesforce Service Cloud and incorporates Conversa Health's automated communications offering. Patients who go to the company's webpage will fill out a free assessment regarding their history and current symptoms, and from there are given personalized guidance and the option to connect for a telemedicine appointment. These virtual visits will run $79 for those with private or no insurance, and "will likely" be completed on the same day.

More psychiatric therapeutics. Pear Therapeutics is **rolling out its new digital therapeutic** aimed at treating schizophrenia for limited distribution, after the FDA loosened up its regulations for digital psychiatric disorders devices during the coronavirus crisis.

The new tool, called Pear-004, uses multimodal neurobehavioral interventions combined with antipsychotic medications. Patients with schizophrenia can use the tool for social skills training, cognitive behavioral therapy for psychosis and for illness self-management training. Pear-004 has to be used under a doctor's supervision. The company is collaborating with select healthcare providers and academic institutions for the initial distribution.

"Thanks to **FDA's Emergency Guidance**, Pear is pleased to have the opportunity to help people suffering from schizophrenia by providing temporary access to our product candidate, Pear-004, during this time of greater need," Dr. Corey McCann, president and CEO of Pear Therapeutics, said in a statement. "We embrace FDA's guidance to temporarily expand the availability of experimental digital therapeutics to facilitate patient use during a time of heightened stress and to reduce potential exposure to COVID-19."

Telemedicine integrations to meet new demands. Chronic disease patients relying on DarioHealth's mobile glucose management system will soon have **in-app access** to medical specialists, thanks to a new telemedicine integration with MediOrbis' MySpecialistMD network.

The virtual services now on offer through the app include primary and acute care; chronic disease management for conditions such as diabetes, hypertension and COPD; and specialty consultations or second opinions for more complicated medical concerns.

DarioHealth wrote in its announcement that the deal and its resulting platform expansion were largely driven by COVID-19, which poses an even greater risk to those living with a chronic disease. The company sees MediOrbis' doctor network as a substantial value add for the 50,000 people it says are using its disease management platform.

New online training resource. UK-based health tech firm Medical Realities **has launched** a free online resource to train healthcare workers in essential, safe and core practices for COVID-19.

The resource, called Covid MedEd, brings together training, research and guidelines for medical students, the NHS and healthcare professionals worldwide. Features include access to latest COVID-19 guidelines, reviews of the latest pandemic data and relevant tests on the key clinical areas.

"We saw a need for a central credible repository of information for healthcare workers," Shafi Ahmed, chief medical officer and cofounder of Medical Realities, said in a statement. "It took three weeks of hard work to launch the platform and we are adding new content of best practice, research, videos and other resources every day."

Consumer-initiated antibody testing. Lab test company Quest Diagnostics **announced** that it would be offering a "consumer initiated" COVID-19 antibody test for $119.

Dubbed Quest Direct, the service will let consumers request the antibody test through an online platform. Once the request is initiated it is sent to a licensed physician, who greenlights the testing order. Patients can then go to a Quest service center to get their blood drawn, and get results within one to two days via an online portal.

The antibody testing will be based on tests from Abbott and EUROIMMUN. Patients can also tap into telehealth services to discuss their results with a doctor.

Aussies all over tracing app. According to a recent statement by Australia's Health Minister Greg Hunt, **the country's newly launched COVIDSafe contact tracing app** has already seen more than 2 million downloads, just over 24 hours since the app was available for registration on 26 April.

The smartphone-based app helps state and territory health officials to quickly contact people who may have been exposed to COVID-19. State and territory health officials can only access app information if someone tests positive and agrees to the information in their phone being uploaded. The health officials can only use the app information to help alert those who may need to quarantine or get tested. It is the only contact tracing app that is approved by the Australian Government.

Chan Zuckerberg Initiative digs in. In an attempt to understand the scope and spread of the coronavirus in the San Francisco Bay Area, the Chan Zuckerberg Initiative pledged $13.6 million to a research collaboration that includes UC San Francisco, Stanford University and the Chan Zuckerberg Biohub.

The funds will be put towards two studies. One is to specifically understand the scope of the coronavirus in the area and then give the data to policy makers. The second is zeroing in on healthcare workers in the area and looking at whether the antibodies from COVID-19 protect them from reinfection.

Tech resources look to Castlight. Health-navigation company Castlight Health has found its national COVID-19 test-site finder tool embedded into information resources offered by Google, the Michigan Department of Health and Human Services, Ford Motor Company and others. The tool has also entered services from health companies like 98point6, Premise Health and Forward.

Data on data on data. Verizon Media announced today the release of a new dataset, API and interactive dashboard. Each tool is designed to help developers and others understand COVID-19 data available to the public. It is powered by the company's Yahoo Knowledge Graph.

Available today under a Creative Commons license, the Yahoo Knowledge COVID-19 dataset sources the case, recovery and death information from hundreds of government and health organization websites, and is already set to fuel tracking updates on Yahoo Search, Yahoo Finance and Yahoo Weather. The API will help developers explore and build the tool into their own services, while the dashboard provides an example of how the data could be visualized.

Nursing home tracing. Senior-focused digital health company CarePredict rolled out a new set of contract-tracing tools designed for senior living facilities that can be used to track COVID-19.

Named PinPoint, the new set of tools is broken up into four types of tracing: contact tracing, location tracing, path tracing and room traffic. The company said it used indoor location tech to identify where a staff member or patient was in the facility and who they came into contact with.

Plasma donation. Microsoft has developed a new chatbot to help folks who have recovered from the COVID-19 virus determine if they can donate plasma to help with clinical research and treatment.

Dubbed the CoVIg-19 Plasma Bot, it was designed to help screen patients before they donate plasma in person. The bot asks patients questions about their COVID-19 status and how long it has been since they had a negative test result. It will also ask typical blood donation questions, including weight cutoffs, age and HIV status. Participants can also put in their ZIP code, and the bot will provide them with the closest plasma donation center.

Finding patients for clinical trials. A new public health tool dubbed World without COVID launched this morning with the goal of connecting patients to coronavirus clinical trials across the country. The new product, which is powered by digital clinical trial company Clara Health, is aimed at helping propel clinical research and treatment surrounding the virus.

Tracking in Denmark. The Danish Government teamed up with IT service provider Netcompany to create digital solutions to ease the country's national lockdown restrictions. The Danish tech company and the National Board of Digitisation have developed 'COVIDmeter,' which allows users to input and monitor coronavirus symptoms, and the 'Mobile Proximity App,' which tracks the spread of the virus.

Shoot me a message. Clinical messaging app Pando Health has been added to the NHS Library after official approval by NHS Digital. The app, which was launched in 2018, was founded by NHS staff and designed with NHS staff in mind. The platform allows staff to communicate safely with each other between wards and care teams to share advice, test results and other information, and is NHS England compliant. It has seen a 700% increase in engagement since COVID-19 struck.

At-home testing. On April 21, LabCorp's COVID-19 RT-PCR test became the first diagnostic test in the U.S. to be greenlit for COVID-19 at-home sample collection.

Patients can use Q-tip-style nasal cotton swabs and saline included in LabCorp's designated self-collection kit – which the company is branding as the "Pixel by LabCorp COVID-19 Test." These samples are mailed to a LabCorp facility in an insulated package for molecular testing.

Looking to real-world evidence. Aetion and HealthVerity joined forces to launch a new set of tools to support biopharmas and regulators gauging new COVID-19 treatments. The first, called the Real-Time Evidence Platform, is built on an instance of Aetion's platform and focuses on up-to-date usage, safety and effectiveness data. The Real-Time Trend Reporting and Interactive Data Visualizer, meanwhile, looks to demonstrate COVID-19's overall impact and how patients are currently accessing health care.

VR for stress. In Italy, Limbix Italia gave virtual reality headsets to Schiavonia COVID Hospital in an attempt to improve the psychological and emotional wellbeing of its staff. The VR hardware uses visualization and guided breathing techniques to reduce stress and anxiety in healthcare workers to support staff working long shifts treating patients suffering from coronavirus.

X-ray tool. Mumbai-based healthcare **AI startup Qure.ai** announced that it has deployed its advanced diagnostic software at Bolton NHS Foundation Trust, U.K. The tool automates the interpretation of

COVID-19 proliferation from chest X-rays, making it easier for healthcare professionals to monitor the extent and rate of viral infection progression.

New test. Singapore-based biotech start-up MiRXES announced that it has received Provisional Authorization from the Health Sciences Authority (HSA) Singapore to supply the Fortitude Kit SARS-CoV-2 real-time RT-PCR (reverse transcriptase polymerase chain reaction) test. With technology licensed from Singapore's Agency for Science, Technology, and Research (A*STAR) and the HSA Provisional Authorization, MiRXES becomes a legal product owner to manufacture and distribute the Fortitude Kit.

VR for training. Returning and redeployed clinicians drafted to NHS ICUs to help with the COVID-19 pandemic are now able to get up to speed with ventilation skills by using a new online tool from FundamentalVR, which specializes in developing immersive simulations for training surgeons.

The tool will help hospitals to retain and boost their capacity at a time when resources are stretched by high patient numbers and clinical staff absence.

Tech giants tackle COVID-19, together. Apple and Google announced plans to launch APIs that will enable interoperability between iOS and Android products by way of official apps from public health authorities. The companies said these apps would be available for consumers to download from the App Store and Google Play Store starting in May.

In the longer term, the two companies have also committed to building a Bluetooth-based contact tracing functionality into their underlying operating systems. The companies said that this strategy would be designed as an opt-in functionality, but would open the door for more participants and deeper data integration with health apps and governments' public health initiatives.

"Privacy, transparency, and consent are of utmost importance in this effort, and we look forward to building this functionality in consultation with interested stakeholders," the companies wrote in their announcements. "We will openly publish information about our work for others to analyze."

Addressing mental health. Consumer telehealth and mail-order prescription services Hims and Hers are kicking off their behavioral health services with anonymized group therapy sessions, which the brands are currently offering free of charge in light of COVID-19 stress. These sessions are led by a licensed mental health practitioner.

Exploring genomics' role in treating COVID-19. 23andMe is interested in exploring whether or not an individual's genes may play a role in the severity of their COVID-19 infection. The consumer genomics-testing company said that it is hoping to enroll hundreds and thousands of its U.S. customers in a longitudinal genome-wide association study, with the end goal of identifying specific genetic variants that might be associated with disease severity.

“Ultimately, we want to publish our research findings in order to help provide more insight on COVID-19 for the scientific community," Joyce Tung, VP of research at 23andMe, said in a blog post from the company.

Walgreens expands telehealth. Walgreens has announced the expansion of its telehealth program to include a COVID-19 risk assessment, information on clinical trials and a greater number of providers. The platform consists of a mobile health app and website, and looks to help patients navigate to health systems and telehealth providers where they can connect with a doctor or nurse practitioner.

National and regional partners have been added for patients to virtually connect with more than 30 providers, including many in states currently most impacted by COVID-19, such as New York, California, Illinois, New Jersey, Michigan and Florida. New Walgreens Find Care collaborations include AmWell, Hospital Sisters Health System Medical Group, McLaren Health Care and Novant Health, while the pharmacy has expanded its services with Providence St. Joseph Health's ExpressCare Virtual, Heal and Village Medical.

Strict tracking and tracing. The Kingdom of Bahrain has launched a COVID-19 tracking program that relies on GPS-tracking electronic bracelets and a coronavirus contact tracing app. The system alerts a government monitoring station when an infected individual leaves isolation or if the bracelet loses its connection. In addition, Ministry of Health officials may randomly send picture requests to which self-isolating individuals must respond with a photo that clearly shows their face and bracelet.

Mental health in the age of coronavirus. Healthcare provider Kaiser Permanente and digital health specialist Livongo have teamed up to offer Livongo's myStrength behavioral health app to Kaiser Members.

The partnership allows Kaiser's members to have 24/7 access to the app through their mobile devices or their computer, which includes myStrength's selection of digital behavioral health tools to combat stress and bolster mental health. These include COVID-19-specific modules that can help individuals manage heightened stress and ideas to manage social isolation, a thing that can contribute markedly to a deterioration in health.

More access to stress, anxiety management. Omada Health announced that U.S. employers and health plans would be able to provide the chronic-disease-management startup's Behavioral Health Program to their members at no cost. The digital program matches members with a dedicated live coach and other resources to help reduce their stress, anxiety or depression.

Virtual triage. Sanitas USA, a healthcare provider active in Florida, New Jersey, Texas and Connecticut, has tapped health-data startup Innovaccer to support a virtual COVID-19 screening and triage program. The app-based resource will facilitate virtual calls and remote-monitoring features, help providers compile clinical notes and auto-fill forms necessary for state health department case-reporting requirements.

Facebook's latest Data for (coronavirus) Good. Facebook has rolled out three maps through its Data for Good program aimed at tracking the potential spread of COVID-19. The Menlo Park company will share the maps, which are based off aggregated Facebook data, with research and public health organizations.

The first map is a co-location map, used to determine the probability that Facebook users will come into contact with each other. The second shows whether people are staying at home on a county-by-county level, while the third is focused on insights around Facebook connections, such as Facebook Friends, across geographic lines.

Google releases GPS mobility reports. Google also **released** an open online resource that aggregates anonymized location-tracking data from mobile devices to share large-scale mobility and behavior trends.

The end results are downloadable Community Mobility Reports that highlight movement-trend differences at country, state, county or regional levels. These generally reflect mobility data from two or three days prior, according to the company, and never display absolute visit numbers.

Instead, users are shown a percentage change in visit volume for location types – for instance, a 56% decline in mobility trends for Massachusetts parks from the February 16 reporting baseline to the most recent data collection date of March 29.

Telemedicine partnership increases capacity. Acute care telemedicine technology and services vendor SOC Telemed and clinical practice management company SCP Health have announced a partnership to deliver scalable, flexible emergency and hospital medicine services via telemedicine.

As a result, SCP Health will conduct rapid-cycle deployments of SOC Telemed's IQ platform in multiple SCP Health emergency- and hospital-medicine programs. The services are staffed by SCP Health clinicians and will enable surge coverage needs during the COVID-19 crisis and beyond.

Two minds are better than one. UCSF Health Hub has launched a new program to help connect healthcare and tech stakeholders seek solutions to the coronavirus crisis. Dubbed the UCSF Volunteer Patriots, the goal is to help develop diagnostics and care at a faster pace by working together.

Chatbot help. Jefferson Health system inked a partnership with LifeLink to launch the former's chatbot across the provider's 14 Philadelphia locations. The chabot uses AI and machine learning to help pre-screen for coronavirus symptoms. Patients can also use the bot to help figure out the right path for their treatment.

"We must find ways to engage a high volume of patients that are coming to us for help," Neil Gomes, EVP and chief digital officer at Jefferson Health, said in a statement. "LifeLink chatbots have already proven to be effective for us at increasing digital appointment requests."

No skimping on exercise. British company iPrescribe Exercise is looking to address access issues by providing its virtual service to medical rehab facilities and providers who have closed their offices due to the coronavirus pandemic.

“We’re all in uncharted waters at the moment but one thing is certain — exercise to help maintain a healthy lifestyle and immune system is more important than ever,” Carron Manning, founder of iPrescribe Exercise, said in a statement. “For those who already incorporate exercise as part of their daily lifestyle this shouldn’t be too challenging, with the prevalence of exercise guides available. However, what about those who have a health condition and need more specialist help with fitness programmes? It is vital that they continue to exercise through quarantine."

Organizing services. Health Catalyst has launched a COVID-19 Response tool that includes seven different services. The new feature will be available to Health Catalyst customers, but it is opening up a module focused on patient safety to all healthcare organizations. The seven new services include a patient and staff tracker, public health surveillance, staff-augmentation support, COVID-19 registry, COVID-19 dashboard, a capacity-planning tool and a financial-impact and analysis resource.

“Our growing suite of COVID-19 Solutions capabilities includes identifying the location of patients who have tested positive for COVID-19 as well as other patient, clinician and staff interactions and exposures to allow for infectious disease surveillance and automated monitoring for ‘hot-spots’ using local geo-mapping and more,” Holly Rimmasch, Chief Clinical Officer at Health Catalyst, said in a statement. “Data-informed surveillance and containment strategies can enhance COVID-19 detection, reduce transmission and help our nation’s hospitals and healthcare systems manage capacity and supplies to limit risk of system-overwhelm and improve patient, caregiver and community outcomes.”

Chatbot advice. Digital-payment company Flywire and AI-powered chatbot Ivy.ai are joining forces on a new COVID-19 chatbot that will let patients tap into information about the virus. The new tool is customizable for healthcare providers and can help assess COVID-19 risk in patients.

“The coronavirus pandemic is putting enormous strain on healthcare providers who are on the front line of treating and containing the virus,” said John Talaga, EVP and GM of Flywire’s healthcare division. “In addition to actively treating patients, doctors and nurses are overrun with calls from individuals about potential coronavirus symptoms. Flywire’s chatbot service is designed to help healthcare providers keep up with the high volume of requests they’re seeing. It’s one little way we can help our healthcare clients manage how they engage and support their patient population at this critical time.”

Resource hub. Virgin Pulse is launching a COVID-19 Hub that will include resources for helping its users deal with the pandemic. Users can tap into webinars, blog posts and links about staying healthy during this time. The hub’s curated content is centered on stress management, staying active, maintaining productivity, eating health and sleeping well.

“The mental, physical and financial toll COVID-19 is taking on employers, employees, families and the world at large cannot be understated,” Dave Osborne, CEO of Virgin Pulse, said in a statement. “Virgin Pulse, together with our partners, recognize that we must bring our collective resources to bear to help as many people as we can, as quickly as we can, and at the most critical time of their adjustment to this new world.”

Dashboard assessment. Athenahealth is adding two new dashboards to address the coronavirus. The first is one for high-risk populations. It can pinpoint areas with high-risk patients and let provider organizations know ahead of time. The second is a lab-testing dashboard that lets providers see a map of where tests are being ordered by other healthcare workers on the athenahealth network. The idea is to help clinicians track trends.

"As COVID-19 cases continue to grow across the country, it is critically important that our nation's leaders have current information to inform decisions on where to deploy hospital resources and bolster clinical infrastructure," Bob Segert, chairman and CEO of athenahealth, said in a statement. "Our COVID-19 dashboards enable users to track and predict which area hospitals may need more support based on the number of tests being performed and the number of people at risk of developing severe illness from COVID-19. By providing this data from our connected network, we aim to help providers on the frontlines battling the coronavirus and potentially slow the number of fatalities from this pandemic."

Apple health check. Apple launched a COVID-19 website and corresponding app. The new site, which serves as both a screening tool and information platform, was born out of a collaboration with Apple, the CDC, the White House Coronavirus Task Force and FEMA. Users are able to go onto the site and answer a list of questions including symptoms, risk factors and exposure. At the end of the survey, users are given a directive about possible next steps.

Siri give me guidance. In other Apple news, Siri has been updated to provide symptom-based guidance and, in some cases, telehealth-app download links to users seeking COVID-19 information from the virtual assistant.

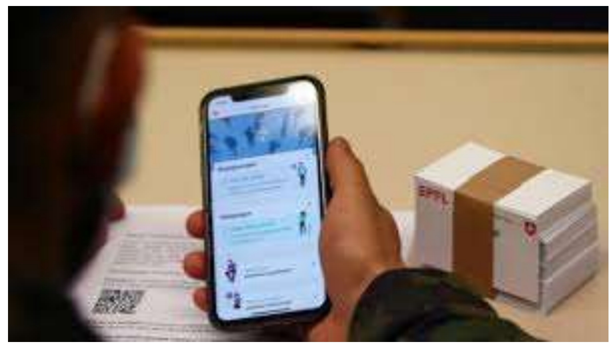
Now, when users ask Siri a question along the lines of "How do I know whether I have coronavirus?" or "I think I have coronavirus," the tool initiates a new conversation tree to determine the user's current symptoms. The user responds to each of these voice and text prompts with "yes," "no" or "not sure."

Wearable studies. Two major wearable studies kicked off this week. The first is the DETECT (Digital Engagement & Tracking for Early Control & Treatment) Study, headed by the Scripps Research Translational Institute. It combines heart-rate, activity and sleep data collected through a range of devices - such as Fitbits, Apple Watches, Garmins, Oura Rings or any others that can share data with Google Fit or Apple HealthKit - and pairs it with participant-submitted symptom reports.

The second is the UC San Francisco's TemPredict Study. This effort is inviting Oura Ring users to release their device-collected physiological data and complete daily surveys on their condition. It, too, looks to "identify patterns that could predict onset, progression, and recovery in future cases of COVID-19.

Birth control app turns to coronavirus. Birth control app Natural Cycles is now looking to address the coronavirus crisis with a new symptom tracker. Users of the app can enter their symptoms and then share them with their healthcare provider. The app allows users to also enter a positive or negative coronavirus test.

"The last few weeks we have been seeing changes in how our users use the app as the situation in the world is rapidly changing due to the new coronavirus," Natural Cycles co-founder and CEO Elina Berglund, said in a statement. "We asked ourselves how we can better help our users, as well as the medical community, and immediately dedicated internal resources to release our COVID-19 symptom trackers functionality to users everywhere on an expedited timeline."



Making a list. Chicago-based Intelligent Medical Objects is offering its customers two free COVID-19 Sets, designed to help with clinicians' workflow and management, specifically pertaining to the virus. The sets consists of a list of codes and patient groupings by issue or disease. The new addition, is pitched as a way to help providers document, track and analyze response to patient care. "The COVID-19 pandemic is an once-in-a-lifetime crisis for society. By providing up to the minute, clinically-accurate and specific terminology, mapped to the rapidly changing international standard codes, IMO is ensuring that governments and institutions have access to the right information as quickly as possible to fight the virus," Dr. Andrew S. Kanter, chief medical officer at IMO, said in a statement. "Leveraging specific value sets, we speed the process of grouping together patients who have various forms of COVID-19 disease and those who are suspected of or exposed to the disease."

Daily check. With a focus on the elderly population, My Day for Seniors on Alexa will now include COVID-19 screenings coming in the form of daily questionnaires. The system is able to communicate a possible case of COVID-10 back to a designated caregiver or family member.

"Now more than ever, advanced technology has the opportunity to provide support and engagement for people who would have been hard to reach even 5 years ago," Dr. Randall Williams, founder of My Day for Seniors, said in a statement. "My Day for Seniors is just one way we can help flatten the curve while providing support to seniors and peace of mind to loved ones."

Education focus. Patient engagement tool GetWellNetwork is adding free coronavirus management modules for health systems and provider organizations. The two modules focus on screening and testing, self-monitoring, self-quarantining, and symptoms monitoring. The company pitches these modules as a way to educate patients and share information with the broader community.

Speedy testing. Everlywell announced that it is working to develop a take-home coronavirus test that will be available soon. The company said it plans to offer the test at cost, with no profit to the company. The test will allow users to collect samples at home and then ship their sample to a lab.

The test results will then be available within 3 to 5 days online. The home test kit will include an overnight delivery label, a telemedicine consultation for those with positive results and the disease-sample collecting kit.

Test, assess. Direct-to-consumer virtual health company Ro is offering free COVID-19 triage telehealth assessment. After a user has completed the online assessment, Ro will connect them with a provider if it's deemed appropriate. The follow-up may be done through phone, or by text or video chat.

In a Medium post the company's CEO, Zachariah Reitano, said that the tool had been developed using guidelines from infectious-disease specialists, as well as those from the CDC and World Health Organization. Reitano said the new effort was created in part to help unburden hospitals and advise symptomatic patients about next steps.

Short term tele-fix. MeMD is launching a short-term telehealth business to address the needs of coronavirus patients. Companies can now purchase a 90-day virtual health package called Total Telehealth-Rapid Response.

"With telehealth, we can stem the flow of patients to crowded ERs, mitigate the spread of the virus and still ensure that people get the care they need," said Bill Goodwin, CEO of MeMD. "Short-term telehealth options make it possible for businesses to navigate a very uncertain time."

Alexa I need some advice. Voice-powered health tech company Orbita launched a new coronavirus-focused virtual assistant. The free tool is able to be integrated into other platforms, including scheduling and telemedicine applications. It comes equipped with a conversational question-and-answer format and screen tools based on CDC formats. Organizations also have the ability to integrate their custom content into the tech.

"We asked ourselves in recent weeks, 'What can we do to make a difference?,' and we quickly arrived at a logical decision for our company," Orbita CEO Bill Rogers said in a statement. "We're providing this COVID-19-specific chatbot free of charge to bring immediate support to organizations now scrambling to educate the public, provide rapid triage, and reduce infection risk, all within constraints of limited resources and rapidly changing circumstances."

One for providers, one for community. MobileSmith launched two COVID-19-focused new apps, one for staff members and one for community members. The staff-member app was designed to help health workers communicate. It also allows users to manage staff deployment, and provides video references.

The community app helps community responders access virtual or telehealth assessments and screening tools. It also provides information about COVID19.

Blood testing. Israeli blood-testing startup Sight Diagnostics announced that it is teaming up with Sheba Medical Center near Tel Aviv in order to provide blood testing for patients.

Sight's OLO blood analyzer will provide rapid complete blood count (CBC) results in a dedicated lab to process samples of COVID-19 patients who are being monitored and treated in a separate field hospital.

Baby advice. Prenatal-focused startup Babyscripts is teaming up with George Washington Medical Faculty Associates in order to answer expecting moms' specific COVID-19 questions. The team came up with a list of resources and recommendations relating to the virus that allowed Babyscripts app-users to tap into reference tools, such as FAQs. Babyscripts also announced that it would be launching a campaign for its health systems, which would allow providers to customize the COVID-19 information.

“At times of crisis like this, access to accurate information is key for reducing anxiety and panic,” Juan Pablo Segura, president and cofounder of Babyscripts, said in a statement. “There’s a lot of conflicting information floating around on the internet, and pregnant women are especially vulnerable because they’re in a unique situation that complicates their normal responses to things like virus protection. Mobile health gives us the critical ability to communicate to these patients in real time and answer their questions.”

ALERT. OptimizeRx has integrated COVID-19 alerts into its health information network on EHRs. The system connects providers to CDC-specific information. The company is pitching this as a way to monitor the spread of the disease.

“As the number of new COVID-19 cases continues to grow daily, it is vital that providers have the most up-to-date information on the virus when treating patients,” William Febbo, OptimizeRx’s CEO, said in a statement. “Timely CDC messages within the OptimizeRx digital health platform at the point of care raises awareness at a critical time and location where health decisions are being made.”

Mapping the structure. Alphabet subsidiary DeepMind has released structural predictions for “understudied proteins” that are linked to COVID-19. Using the latest version of its AlphaFold system, an AI-enabled deep learning system, the company has been able to generate and release its findings.

“We emphasise that these structure predictions have not been experimentally verified, but hope they may contribute to the scientific community’s interrogation of how the virus functions, and serve as a hypothesis-generation platform for future experimental work in developing therapeutics,” the AlphaFold team wrote in a statement.

The statement went on to explain that understanding a protein’s structure is important for understanding its function. However, historically it takes months to acquire the proper data to come up with the structure, which is where computation models come into play.

Evaluate, educate. Healthcare providers will be able to tap into Bright.md’s new COVID-19 screening and evaluation tool. Patients can use the tool to get advice about where to go if they are presenting with COVID-19 symptoms. The tool is pitched as a way for providers to keep patients away from busy emergency rooms. It can be integrated into Bright.md’s virtual-care platform, the SmartExam.

"The COVID-19 scare will likely cause an overwhelming demand for hospital facilities and clinical resources, making it difficult to treat patients who need care the most," Dr. Ray Costantini, CEO and cofounder of Bright.md, said in a statement. "Crowded emergency departments also raise the risk of spreading viruses – whether it's COVID-19 or the common flu – to sick people at the facility, as well as to the larger community."

Take the survey. Georgian startup Rimidi announced that it is rolling out a new patient-reported outcome survey to help screen and track the spread of COVID-19. The new tool will integrate with EHRs, and its results can be analyzed by clinicians. The survey responses are compared to CDC guidelines about risk.

“One of the greatest challenges in China and across other countries that faced early COVID-19 outbreaks has been hospital-based transmission,” Dr. Lucienne Ide, founder of Rimidi, said in a statement. “With the app, we can help keep potentially infectious individuals from exposing other patients or staff in the healthcare system in waiting rooms, emergency rooms, or triage before they are identified and separated.”

Dealing with quarantine. As Israel's Sheba Medical Center prepared to take custody of the 12 Israeli passengers onboard the Diamond Princess, the cruise ship that was quarantined in Japan for several weeks because of the COVID-19 coronavirus, it worked with at least three vendors to bring telemedicine care to these patients.

Longtime remote-monitoring company Datos, whose platform the center used to develop a monitoring program and treatment protocols, and Tyto Care, a new partner who will provide the devices and a consumer-friendly user experience, will come together so patients conduct exams without medical staff present.

A third solution, from recent Teladoc acquisition InTouch Health, is a robotic telemedicine cart called Vici that is equipped with a camera, screen and medical equipment that can be sent into a quarantined patient area and controlled remotely by a doctor or nurse.

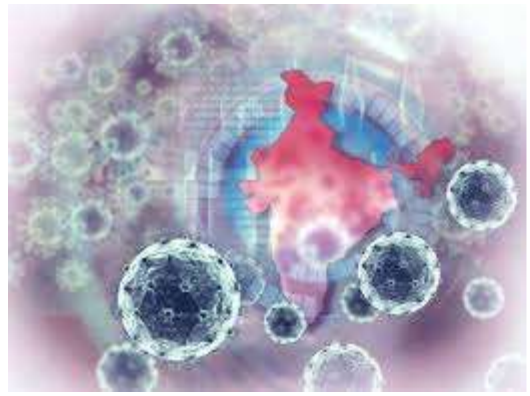
Diagnostic discoveries. Shanghai Public Health Clinical Center (SPHCC) and Yitu Healthcare, a Shanghai-based AI startup, officially launched the Intelligent Evaluation System of Chest CT for COVID-19.

The system enables intelligent diagnosis and quantitative evaluation of CT images of COVID-19 through image algorithms. It grades the severity of various pneumonia diseases of local lesions, diffuse lesions and whole-lung involvement. In addition, it accurately quantifies the cumulative pneumonia load of the disease through quantitative and omics analysis of key image features such as the morphology, range and density of the lesion.

Tracking the progression. Dr. Alex Liu, founder of the data science company RMDS Labs, is teaming up with researchers at Wuhan University to develop a new way of using AI and machine-learning programs to track the spread of the COVID-19 virus. The platform will also be looking at the future implications that the virus could have on the economy.

Accessing guidelines. MayaMD.AI released a tool that helps people who were exposed or potentially exposed to the coronavirus figure out their best course of action. It includes standardized guidelines that can be adjusted based on emerging best practices. The company noted that this tool could also be used for clinicians, healthcare workers, public workers and airline crews.

Assessing during intake. Carbon Health, a virtual and in-person primary-care network, launched a new integration into its workflow platform designed to help pinpoint the patients at risk for COVID-19. During the intake process, the system will prompt providers to ask questions surrounding travel history and symptoms.



Checking for contamination. The Chinese government released a new app intended to help citizens check whether they came into contact with the virus. App users are asked to register a phone number, name and ID number in order to see if they were in contact with someone infected, according to Chinese state media outlet Xinhua, which first reported the story.

Users are able to get the app by scanning a QR code through platforms like WeChat, Alipay and QQ. The app will then give them information on whether they came into "close contact" with the disease, which the government defines as being in close proximity with no protection to someone who has a confirmed or suspected case.

Tracking the spread. A team from Johns Hopkin's Center for System Science and Engineering released a new live dashboard that integrates information from the WHO and CDC to track the virus in real time. The dashboard includes information about cases by region and country, as well as the deaths. The information is displayed in a map and in corresponding charts.

Screening and supporting. InterSystems released a functionality allowing users of the latest editions of TrakCare to screen and support patients with COVID-19, as the fight against the spread of the outbreak intensifies.

The company said customers in China, the UK, the United Arab Emirates and other countries had already started using it.

The functionality is based on guidance from WHO and links to the Wuhan Coronavirus Global Cases app from the Johns Hopkins Center for Systems Science and Engineering in the US.

Partnering on solutions. Boston-based chatbot Buoy Health and digital epidemiology tool HealthMap have each been working on their own tools, but have come together in a data-sharing collaboration.

HealthMap has been focused on tracking the novel coronavirus from the onset, and has experience tracking the spread of diseases.

“There is all this information online and we can capture events ahead [of time using] what might be reported through these networks, social media, chat rooms … [Our] work is focused initially on early signs of a disease,” John Brownstein, who heads up HealthMap, told MobiHealthNews. “That is what we did with the coronavirus and found some signs on local news, chat rooms. ... We’ve been working with an international team to do some crowdsourcing of identification of keywords and metadata.”

Meanwhile, Buoy has a new feature providing patients with information about the condition. When people are using Buoy’s symptom tracker, it may also be listed as a possible condition for certain patients-based on travel history and other factors.

Buoy and HealthMap are sharing information coming into each platform to help assist patients at home as well as public health officials.

“Because we have a good sense of underlying risk we can push that information to Buoy, and that can help them fine tune their algorithm and fine tune their decision support tools,” Brownstein said. “But the reverse is also true – they are collecting symptom data from consumers that can point to signals for disease contamination.”

Giving guidance. At the beginning of February, Phreesia, a digital health company that focuses on the patient check-in space, launched a new screening module for its clients at no additional costs. The new tool is based on the CDC's guidelines and updates regularly based on these parameters.

Drones for surveillance. Bloomberg News reported that the Chinese government is using drones to ensure that its citizens are following public health safety guidelines. The drones, which come with loudspeaker capabilities, will zero in on individuals who aren’t following the recommendations, and an operator will give them instructions, such as, “go inside” or “put on a mask.”

The videos, which were posted by Global Times, a publication owned by the Chinese Communist Party's People's Daily newspaper, show the drones getting personal and calling out a person’s clothing or appearance in order to get their attention and then correct their behavior.

Curbing contamination. CNN reported that medical teams tapped robots to care for the first person diagnosed with the virus in the US. The robot was used to take vitals and communicate with the medical team outside of the isolation area. The CNN report specifies that the robot was used as a means of preventing the virus from being transmitted to the medical staff.

Check the guidance. Previously, athenahealth added a new update to its cloud-based software aimed at helping its clients screen and test their patients for COVID-2019.

As part of this effort, the company has implemented new diagnostic-testing orders and screening questions across its network of ambulatory and hospital customers.

"We pushed these updates directly into the workflows of 130,000 providers overnight – no downloads or installation required, and sincerely hope that our ability to respond quickly and provide the right resources will help our customers in their efforts to limit the spread of the 2019 novel coronavirus," athenahealth CEO Bob Segert said in a statement.

Among the new tools quickly developed and deployed: a set of new travel-related screening questions that appear within athenaClinicals workflows.

Testing kit. In late January Singapore-based Veredus Laboratories, a provider of innovative molecular diagnostic solutions, recently announced the development of VereCoV detection kit, a portable Lab-on-Chip application capable of detecting the Middle-East Respiratory Syndrome Coronavirus (MERS-CoV), Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) and COVID-2019 in a single test.

The VereCoV detection Kit is based on the VereChip technology, a Lab-on-Chip platform integrating two powerful molecular biological applications, Polymerase Chain Reaction (PCR) and microarray, that will be able to identify and differentiate MERS-CoV, SARS-CoV and COVID-2019 with high specificity and sensitivity.

Under development. A group of researchers led by Assistant Professor Shao Huilin at the Institute for **Health Innovation & Technology (iHealthtech)**, located at the National University of Singapore (NUS), is working on the development of a rapid COVID-19 detection kit based on the enVision technology platform, which they invented in 2018.

Traditional polymerase chain reaction-based (PCR) coronavirus detection kits take about a day to produce results, while the latest lab-on-chip detection kit currently in development by Veredus Laboratories can produce results in about two hours. enVision (enzyme-assisted nanocomplexes for visual identification of nucleic acids) can be designed to detect a wide range of diseases – from emerging infectious diseases (e.g. Zika and Ebola) and high-prevalence infections (e.g. hepatitis, dengue and malaria) to various types of cancers and genetic diseases. enVision takes between 30 minutes to one hour to detect the presence of diseases.

Curbing fake news. Facebook pledged to remove false claims and conspiracy theories about the disease posted on its social media platforms.

In **a recent blog post**, the company announced that it is working with a network of third-party fact-checkers to review information. If a piece of information is rated as false, the company pledges to limit its spread on Facebook and Instagram.

Facebook also noted that it would be providing aggregated and anonymized mobility data and population-density models to help researchers at Harvard and National Tsing Hua University in Taiwan create their forecasting modes.

Fever check. In the midst of the COVID-19 spread, Integrated Health Information Systems (IHiS), the national HIT agency in Singapore, has partnered with local healthcare AI startup KroniKare to pilot iThermo – an AI-powered temperature-screening solution that screens and identifies those having or showing symptoms of fever. iThermo is currently being piloted at IHiS headquarters in Serangoon North and St. Andrews Community Hospital (SACH) from February 10 onwards respectively in "live" operational environments.

Reimbursement for tests. The Centers for Medicare and Medicaid Services announced a new Healthcare Common Procedure Coding System code that will enable providers to bill the lab test for COVID-19. The code allows labs to bill for the specific test instead of using an unspecified code.

The system will be able to accept the code on April 1 for dates of service on or after February 4. HCPCS is a standardized coding system that Medicare and other health insurers use to submit claims for services provided to patients. [16]

Nationwide deployed QR code tracing system would be effective in case of second surge of COVID-19

A cybersecurity startup and a member company of the Born2Global Centre, swlDch suggests dynamic, unidirectional QR code technology that can encourage wider user adoption as well as protect user privacy.

How current QR code tracing works? How OTAC QR code tracing works?

Strict measures are eased as the number of COVID-19 cases is falling. However, concerns remain that further surges of cases may be on the horizon. Even countries with effective strategies have seen second wave spikes and clusters of cases. So when the World Health Organization says the virus may be here to stay, nations need to understand that they will experience new cases. The challenge is how to predict, track and handle them. It is crucial to keep test and trace momentum to manage the epidemic in a timely manner. Under this circumstance, many governments try to adopt contact-tracing app on a national scale. In the UK, a new NHS contact-tracing app will be in place. The app allows smartphones to track every other device they have come into contact with, exchanging anonymous IDs using Bluetooth signal. Once the case is confirmed, it then informs other users in close contact through the app.

South Korea is taking a slightly different approach. They focus on tracking visitors at high-risk facilities by adopting a QR Code based electronic registration system. This became compulsory because South Korean authorities have experienced considerable difficulties in their epidemiological investigation of the nightclub outbreak in May. Much of the information on handwritten visitor logs was found to be false or incomplete. From 10 June, visitors to those indoor venues such as nightclubs, Karaoke clubs, and gyms will be required to use an app that generates a one-time personalized QR code that can be scanned at the door. Utilizing QR code technology is basically a tokenization that helps to collect visitors' information and recall the information in case of an emergency.

However, this tokenization technology is likely to encounter a problem of limited coverage that is disrupting the national roll-out. Since it requires an active network connection for generating tokens, visitors who use entertainment venues located in the basement often experience serious latency during the code generation process. In addition, the more device connected to a network, the larger its attack surface grows, making easier for hackers to infiltrate the network. This can bring serious consequences like a breach of personal data. Some may question why individuals should bear the cost of mobile data for a service they are reluctant to use. On the other hand, the current system also causes technical challenges to QR code providers. They are required to be equipped with a great level of server capacity and computing resources in order to handle massive overhead from storing to encrypting/decrypting the tokens and information.

swIDch's OTAC (One Time Authentication Code) technology can be an alternative solution, tackling the network connection issue of the QR code tracking system. This patented algorithm of OTAC enables to generate dynamic QR code on visitors' smartphone even in off-the-network environment. Since OTAC does not require an active network connection, it can secure visitors information from hacking. In addition, it removes friction from user journeys by reducing heavy network traffic for generating tokens and server loads for persisting token details. In other words, system operators can save significant resources for processing tokens. As a result, the government can operate the system with larger coverage with less technical challenges.

The nationwide rollout is the key to efficiently operate the tracking system. Even though it is compulsory by the government, frictionless use of the system should be supported to encourage citizen's participation. swIDch believes that OTAC can increase adoption and use of the QR code tracking system by providing uninterrupted, safe, and easy use of the system. The company actively proposes the solution to other states typically in developing countries where a network connection is unstable. Inspired by UN's Sustainable Development Goals (SDGs), the company is willing to distribute its technology for free to any other country upon its requirement to tackle the global COVID-19 crisis together. [17]

Country Experiences

Best ICT Practices from East Asia

In the current crisis, certain East Asian nations and dependencies such as South Korea, Taiwan, Hong Kong, and Singapore have performed leaps and bounds ahead of the rest of the world. In large part, this has been due to their superior application of ICT across all dimensions of their public health response. ICT has helped these countries intervene more quickly and squelch emergent outbreaks. ICT has also aided these countries in performing safer, earlier and more frequent testing, strengthening information about where resources should be directed to combat the virus. Furthermore, ICT has played an irreplaceable part in the contact tracing efforts of these governments, while making the enforcement of quarantine for sick individuals and suspected carriers smoother and less labor intensive.

Finally, ICT has enabled more widespread public participation in disease containment efforts. By achieving nearly unblemished success while following very similar scripts to fighting the disease, these countries have realized a blueprint for pandemic suppression which other countries both today and in the future can and should follow to the best of their abilities in order to maintain the health and prosperity of their societies through this crisis and similar ones to come.

Rapid Intervention and Prevention

South Korea's rapid response to its first reported cases of COVID-19 was essential to moving the public health infrastructure into place to combat the pandemic within the country before the disease spread beyond the reach of containment measures. While simple good governance gave the country's early recognition of the disease weight in determining policy, ICT innovations also accelerated the speed at which this infrastructure could be mobilized. The South Korean government directed medical companies to begin developing potential testing kits for the coronavirus in late January, only a week after the country confirmed its first case.

Even before this, though, as early as January 16, the Korean biotechnology company Seegene had begun focusing on developing diagnostic techniques according to the information, which had been made publicly available at the time. Using AI and big data analytics, Seegene was able to optimize the chemical composition of its prototype tests according to the published genome of the virus by February 5, compressing a process, which normally takes 2-3 months to a matter of weeks.

Furthermore, the company was able to follow the insights yielded by this automated data analysis to begin producing its tests without even having a sample of the virus available for testing. The Korean CDC (KCDC) approved the test within less than a week of its initial development, paving the way for the mass production of tests before the virus had gained an untraceable foothold.

Taiwan took advantage of the lessons it had learned during the 2003 SARS outbreak to implement specific prevention strategies ahead of the arrival of the virus. The country was able to leverage ICT to almost entirely get ahead of its outbreak through pragmatic application of its existing data management systems for border control. On January 27, six days after its first reported case, Taiwan's National Health Insurance Administration (NHIA) took advantage of the interoperability of its patient identification systems with data from the National Immigration Agency (NIA) to compile a list of citizens and foreign residents alike, whether hospitalized or not, who had a travel history in affected areas within the past 14 days. Those identified through the new system were then directed via mobile phone notification to go into quarantine. By ICTs and Public Health in the Context of COVID-19 February 14, the system was made even more proactive through the introduction of the Entry Quarantine System, which used a mobile survey linked to a QR code to accelerate immigration clearance for individuals at low risk. Finally, by February 18, the government once again took advantage of the interoperability of its digitized records to automatically provide access to travel histories for all patients to every hospital, clinic, and pharmacy in the country. At every step of the development of this system, Taiwan modeled the successful mobilization of existing government data in the coordination of a preventative health response.

Safe and Frequent Testing

Without exception, the countries which have distinguished themselves by their responses to the coronavirus outbreak have done so by building high-volume testing regimes capable of handling the demands of an entire population before infection rates began accelerating out of control. One aspect of this is completing the development of testing kits early enough in the trajectory of the crisis to allow for mass production and delivery before symptoms begin manifesting themselves, but another part involves completing tests rapidly, reporting results quickly and directly to patients, and providing for the safety of health personnel throughout this process. ICT can lend a valuable hand to improving the safety, frequency and reporting efficiency of testing, as these countries have demonstrated.

South Korea has gained renown for its creative uses of ICT throughout the diagnostic process. First and foremost, South Korea was a pioneer in the implementation of automatic testing methods. These techniques, which involve a robot mixing the testing solution with multiple samples at once, have been shown to proceed up to four times faster than manual methods, in which a technician must pipette the testing solution into each individual test tube. By doing so, South Korea has eased testing bottlenecks, accelerated reporting of results, and shielded scarce medical personnel from potentially infectious sample. KCDC has also deployed a suite of additional ICT tools to mitigate risk and prioritize treatment according to the anticipated risk for each individual case. A number of image analysis tools currently in use, such as the VUNO Chest X-Ray AI Image Support Tool and JLK Inspection, are capable of classifying ICU patients by risk category according to AI analyses of chest X-rays which identify and highlight abnormal lesions within the chest cavity in as little as three seconds.

In addition to boosting the capacity of the testing process, successful countries have also applied ICT to direct more potentially infectious people toward testing. Upon entry into South Korea, new visitors are required to download an app on their smartphones which walks them through a set of potential symptoms and guides them to testing sites in case of a potential match. More interactive self-diagnosis symptoms have been put in use elsewhere, such as the Tencent Health portal on WeChat, which allows users to look up nearby positive cases, learn about potential symptoms, and review information on self-protection, and a chatbot launched by the Government of Singapore allowing users to learn about the disease and what resources the government has made available to combat it.

Contact Tracing and Quarantine Enforcement

Taiwan, South Korea and Singapore have all set themselves apart by the efficiency and thoroughness of their contact tracing and quarantine measures, made possible through the judicious use of ICT. The most effective uses of technology for the tracking of infection statuses, the movements of the infected, and chains of contact have three basic traits in common: near-universal or mandatory adoption, a strong public digital infrastructure on the back end, and seamless data sharing and interoperability between publicly and privately stored data.

Singapore has demonstrated both how ICT can be used to direct exposed individuals into home isolation and how to use e-health tools to improve contact tracing. As early as February 10, Singapore developed and introduced a texting and web-based platform through which individuals under home quarantine could report their location to the government. Several weeks later, by February 27, the country began combining data from serological testing with contact tracing efforts to build a sophisticated map of transmission linkages through the population, improving the efficiency and efficacy of home quarantines, an initiative which would not be possible without the capacity to seamlessly track patients through digital health records.

Singapore has gained even more publicity for its TraceTogether app, which directly applies mobile technology to decentralize contact tracing with the aid of these digitized testing records. TraceTogether uses Bluetooth to ping other users of the app within a specific physical radius of the user's mobile device. If a user is later reported to have tested positive for COVID-19, all users who have recently come within close physical proximity of that user are sent a notification and directed to take the appropriate preventive measures. TraceTogether has been successfully replicated in numerous other countries, including India, and Apple and Google recently announced joint efforts to improve upon this approach by integrating Bluetooth contact tracing into their own mobile operating systems.

In Taiwan, individuals who test positive and are placed in mandatory home quarantine are kept there with the help of their phones. All who are placed under quarantine have their location monitored via the location data on their phone, and are required to stay within a "digital fence" encompassing the bounds of their property. If their location as reported by their device moves beyond this fence, or stops being received, then automatic alerts are sent and police are dispatched to investigate whether quarantine was broken. In one case, a man whose phone battery died overnight woke up to the sound of two police officers knocking on his door, dispatched to determine whether he had left his house or not. South Korea has adopted a similar app, which sends location alerts to a designated case officer for each individual under enforced isolation. Hong Kong takes the “digital fence” approach one-step further by pairing an app, which all new arrivals must download with a wearable device, which reports location data back to authorities.

Public Participation

Finally, the most successful countries have used ICT to interactively engage with the public during the outbreak. The most successful ICT tools are used not just to notify or to compel action, but to build avenues for decentralized action and contribution of time, information, and other resources by the general public. Relevant human resources are as scarce a resource as face masks in a global outbreak, and these tools allow citizens to start closing the vast gap between what is needed and what can be provided on all fronts.

In this case, Taiwan has provided the model on how to promote mass voluntary civic engagement. Avoiding the twin extremes of a laissez-faire, opt-in approach which is sunk by low rates of adoption and follow-through and an authoritarian approach which foments mistrust and boxes out the potential contributions of civil society, Taiwan has built an overlapping network of databases shared directly between government and activists and coordinated through the open democracy portal vTaiwan in order to direct the production and distribution of all relevant resources and information. Over half of Taiwan’s population participates in vTaiwan, which by coordinating public-private partnerships, “hacktivism,” and mass collective action, has been responsible for the implementation of 124 separate health policy interventions according to a study by the Stanford University School of Medicine. One tool developed through this creative approach mapped facemask supply and demand, as reported by producers, medical personnel and ordinary citizens alike, in order to direct new shipments to where they were most needed. In another example, activists worked directly with the digital ministry to build a participatory tool for symptom report sharing, verification, and location history analysis to notify individuals who had likely been exposed.

Through this unique e-government approach, despite having had its access to WHO data on the coronavirus blocked due to its dubious international status, Taiwan was able to accomplish similar scale and coverage as similar efforts in more authoritarian states without compromising user privacy. Taiwan further built up transparency and public trust through the use of ICT through measures such as livestreaming meetings tied to the health crisis response, which additionally avoided the coordination and misallocation challenges, which have plagued countries with a less sophisticated digital response while highlighting challenges the government had encountered which a decentralized approach could help solve. By limiting the use of ICT for force and compulsion only where absolutely necessary, and applying an approach to data and information which emphasizes transparency and collaboration, Taiwan has built its capacity for a truly public health response which is flexible, creative, and most importantly, exportable. [1]

How countries are using technology to fight coronavirus

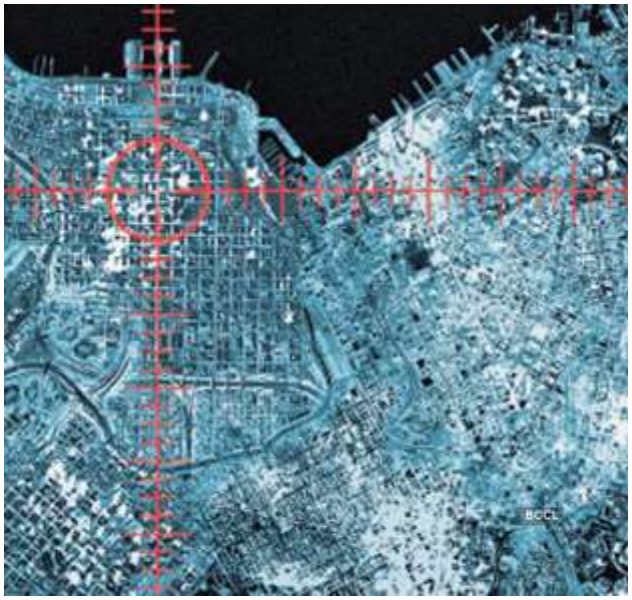
The technologies being used against the pandemic are raising questions about excessive surveillance.

The rapid spread of Covid-19 has forced countries to use every trick in the book to contain the disease. Some countries, like South Korea and Singapore, have done a better job than, say, Italy and Spain.

Asian countries have used a range of technologies in their fight against the pandemic, raising questions about excessive surveillance and the violation of citizens’ privacy. Here is a snapshot of some of the tech tools being deployed in different countries.

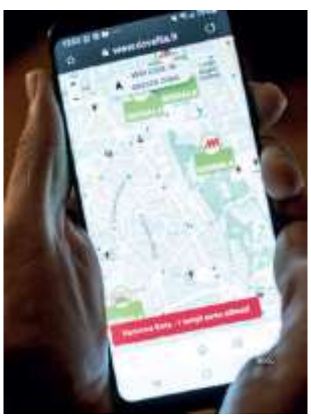
Location Tracking

Possibly the most commonly used technology by governments, tracking people’s whereabouts through the location information provided by their phones has been crucial to identifying where an infected person went before being quarantined and how many people were in close proximity to the patient. Israel has allowed its internal security agency the use of its citizens’ location data for 30 days. South Korea, China and Taiwan have also used location-tracking wide -tracking widely to limit the transmission of the virus. However, in Europe, which has stricter laws on data protection, Germany and Italy are using anonymized location data to identify public spaces where people are gathering in groups by defying lockdowns.



Mobile Apps

A startup in the UK recently launched an app for people to self-report their symptoms. C-19 Covid Symptom Tracker, which was downloaded 7.5 lakh times in three days, helps identify high-risk areas, among other things. South Korea has an app called Corona 100m that has mapped the locations of Covid-19 patients and alerts users if they come within 100 meters of an infected person.



India is also set to launch an app that will tell users if they came in contact with someone who later tested positive for Covid-19, as reported by ET on March 26. The app will be based on location data obtained from the infected person's smartphone. It will also use short-distance Bluetooth signals between phones, like Singapore's TraceTogether app, which helps authorities trace contacts of a patient.

In China, apps developed by Alibaba and Tencent give people a colour code based their health condition and travel history. This code, decided by a big data-driven algorithm, will determine whether a person gains entry into a mall or a subway station, or can travel between cities.

CCTVs

When a family of three in Kerala's Pathanamthitta district tested positive for Covid-19 after returning from Italy, local authorities realized the family had visited several places and met many people for a week before they were quarantined. Reviewing CCTV footage from the areas they had been to was one of the methods the local administration used to track down 900 people the family could have potentially infected. South Korea and Singapore, too, have used CCTVs extend extensively in contact tracing.

Smart Imaging

In an effort to enable contactless and rapid temperature detection, China is using AI-powered thermal cameras to identify those in a crowd who have a fever. The country is also deploying facial-recognition systems to identify those not wearing masks.

Robots & Drones

In early March, a new isolation ward was opened in Wuhan, the Chinese city where the coronavirus outbreak started. What's interesting about this ward is that it is entirely manned by robots that take patients' temperature, give them food and drugs, and disinfect the ward. China has also used robots in quarantine facilities, and so has Singapore to clean hospitals. The use of robots spares healthcare workers the risk of contracting the virus. In some parts of China, the police have used drones fitted with cameras and loudspeakers to disperse crowds and direct individuals in the streets to return home. [18]

South Korea

The world is facing an unprecedented economic, social and political crisis with the spread of COVID-19. The Republic of Korea is no exception. Korea had surge coronavirus infections that started spreading at the local and community level.

The number of new coronavirus cases increased exponentially, peaking at 909 new infections on February 29. But new case have dropped significantly. Korea was able to successfully flatten the curve on COVID-19 in only 20 days without enforcing extreme draconian measures that restrict freedom and movement of people.

Korea's Secret to Success? ICT

COVID-19 Digital Response played a vital role in Korea according to the official Korean Government publication, Flattening the curve on COVID-19, which presents the actual response measures of Korean government against COVID-19 using the latest ICTs, including:

- Mobile devices were used to support early testing and contact tracing.
- Advanced ICTs were particularly useful in spreading key emergency information and helping to maintain extensive social distancing.
- Updated information and testing results were published on national and local government websites.
- The government provided free smartphone apps that flagged infection hotspots with text alerts on testing and local cases.

The new report also discusses how we can fight smarter against an invisible micro-pathogen. We hope the information and experience of Korea may provide a valuable solution to help your country and community combat COVID-19.

How Korea is using innovative technology and AI to flatten the curve

Here are some of the top reasons for success:

1) Fast-developed testing kit

An important part of the Republic of Korea's strategy since the outbreak of the coronavirus has been widespread testing.

Thanks to artificial intelligence (AI), the development of a coronavirus testing kit happened fast in the country. Life sciences company Seegene came up with a coronavirus testing kit in under just three weeks

"To develop a test in such a short time would not have been possible without AI," said Tai-Myoung

Chung, Professor in the Department of Interaction Science at Sungkyunkwan University (SKKU)."

The testing kit, which would normally have taken two to three months to develop, was approved by the authorities within less than a week of its application, and also certified in the European Union.

Just a few weeks later, when an enormous cluster of Coronavirus cases emerged in the city of Daegu, it was ready for testing.

The number of coronavirus cases in the Republic of Korea peaked on 29 February, recording a total of 909 infections.

"Currently we have a total of 118 testing stations available nationwide, and have a testing capacity of 15,000 per day on average – with a maximum of 20,000 per day," said Lee.

"It began with only lab testing, which later on expanded to local governments and also to the primary medical laboratories and hospitals," said Dr Lee.

Widespread testing in the Republic of Korea is targeted mainly at the high-risk groups, i.e. those with underlying diseases, the elderly, people who share homes, or live in crowded areas, and passengers at arrival points emanating from countries with cases of the coronavirus or other infectious diseases in the past such as SARS or MERS.

2) Smart quarantine information system

Dr Lee told the webinar audience that a quarantine information system was put in place after the MERS outbreak in 2015.

"Even before this COVID-19 outbreak, inbound travelers entering the Republic of Korea have been required to be checked for fever and to also to fill out a health questionnaire," explains Dr Lee.

Inbound passengers with symptoms or having travelled to or from a risk country are placed in quarantine.

"Information about the inbound traveler from the Ministry of Justice, the Ministry of Foreign Affairs, airline companies and major telephone telecommunication companies are collected by KCDC's quarantine information system," says Dr Lee.

This enables frontline health workers to have a full record of the patient's history of movements to help them quickly identify and isolate or treat the suspected coronavirus patient in a timely manner.

In-bound travelers are required to download a self-health check mobile app to their smartphone and submit their health conditions on this app during their 14-day incubation period, explains Lee.

With the collaboration of telecom companies, they also receive texts messages and receive guidance on how to report any coronavirus symptoms they might have developed while in quarantine.

3) Mobile phone technology data for contact tracing

As well as interviewing, officials are using location data from mobile phones, credit-card transaction records and CCTV footage to trace and test people who might have recently come into contact with an infected person.

In many places, detailed maps are published showing precise movements of infected people, encouraging others who thought they might have been in contact with an infected person to seek out testing.

4) AI for improving diagnosis efficiency and patient classification

Lee explained that as part of the risk-mitigation strategy, KCDC established a system, which categorized confirmed cases into four categories: mild, moderate, severe and very severe.

"Each category receives a different treatment and is admitted to a different facility according to the severity of the case," said Dr Lee.

Professor Chung gave examples of AI-based tools that are being used in the country to enable the quick diagnosis and classification of patients.

For example, VUNO's Chest X-Ray AI Image Support Decision Tool – an algorithm for identifying abnormal findings on chest x-rays – classifies intensive care patients by using X-ray images and can examine the lung within just three seconds.

JLK inspection, though numerous studies have developed an all-in-one medical platform called AiHub for disease diagnosis, which, it says, uses world class AI and big data technology from various imaging devices. It can examine lung disease within seconds using an AI technique that is being used in hospitals.

The company has also produced an AI-based, hand-held chest X-ray camera, which can scan the chest in just three seconds and give a heatmap visualization of abnormal lesion.

5) Mobile apps for information sharing

Many mobile apps have been very quickly developed in the country since the outbreak of the virus.

They have proved useful for information sharing to advise and inform the public. "This would be a huge task for already stretched health-care staff and volunteers," claimed Professor Chung, saying that they can be developed quickly within a few days to a week.

For example, one mobile app has been developed to direct those who develop symptoms to the nearest available testing station. Another can indicate the nearest point of purchase for available masks.

A public chat robot using AI techniques is being used to inform on ways of responding to coronavirus, and another AI-based voice robot automatically calls people who need attention, explained Professor Chung.

6) Daegu: Making use of a smart city hub

Daegu City, where the majority of the Republic of Korea's cases of COVID-19 have occurred so far, is currently in the process of being transformed into a smart city (set to be completed in 2021).

The epidemiological investigation during the outbreak was able to use the data hub of the smart city, particularly for tracing patient routes, which Chung says is "critical to developing a new medicine as quickly as possible." [19]

ICT Helps Social Distancing

Korean government implements number of ICT measures to enhance social distancing. The CBS (cellular broadcasting service) transmits emergency alert text messages on natural or manmade disasters to cell phones through mobile telecom carriers in Korea. It is an effective tool that could help disaster response.

Since the coronavirus outbreak, Korean government opened a website to provide information about companies providing solutions for remote working and education and their products.

In addition, the government has temporarily permitted doctors to perform telemedicine from the end of February as part of preventive measures to avoid group contagion in vulnerable facilities including medical institutions and nursing homes.

ICT Locates COVID-19 with Speedy Testing

The test-kits for COVID-19 quickly became widely available and played a major role in eliminating uncertainties in the early stages of the viral spread. In Korea, five diagnostic reagent companies have obtained emergency use approval as of now and are producing RT-PCR reagents.

Artificial Intelligence (AI) plays a significant role in supporting researchers and healthcare professionals in the diagnosis and screening of patients with severe symptoms, as well as developing appropriate responses based on a thorough analysis of the situation on the COVID-19 spread.

In addition, famous "Walk-Thru" testing station allows quick collection of samples as subjects walk through the station with minimal contact.

ICT Quickly Traces COVID-19

A COVID-19 diagnostic kit was developed by a Korean biotech company using ICT, such as AI and high-performance computing. It quickly became widely available and played a major role in eliminating uncertainties in the early stages of the viral spread.

One of the reasons behind Korea's rapid development of diagnostic kits is because companies invest in fostering an R&D environment based on ICT such as big data and AI, which allowed the use of research resources available on global online platforms of the WHO and other international organizations.

In addition, artificial intelligence can quickly learn, recognize, and analyze large-scale data based on high-performance computing resources, enabling more accurate analysis and decision-making. A walk-thru testing station allows quick collection of samples as subjects walk through the station with minimal contact.

ICT Facilitates COVID-19 Treatment

The use of AI for COVID-19 research is expected to reduce the time required to develop medicine, as AI can learn and make deductions based on the virus and other medical data.

One Company, which develops new medicine and relevant platforms through the use of AI, used deep learning algorithms to predict the interaction of drug and protein, and propose candidate medicine for the coronavirus.

Another Company and its researchers used pre-trained deep learning-based drug-target interaction model called Molecule Transformer-Drug Target Interaction (MT-DTI) to identify commercially available drugs that could act on viral proteins of SARS-CoV-2.

An AI-driven drug discovery start-up using bioinformatics and pharmacogenomics for incurable and rare diseases, has been developing platforms to find candidate substances to treat COVID-19 more efficiently.

ICT Flattens the Curve on COVID-19

Key information such as the accumulated count by region and number of tests performed is summarized and provided as visualization data on the main page of the website.

Information on providing overseas travel history, finding COVID-19 screening centers, early-detecting of patients, using epidemiologic surveys and isolating the close contacts of a patient are also provided accordingly.

Real-time data of publicly-distributed facemasks is provided to people through mobile applications and web services, reducing confusion and inconvenience while raising distribution efficiency.

COVID-19 Information is a Public Good

We should together make best efforts to turn the crisis into opportunity and make the best use of the cutting-edge COVID-19 Digital Responses in the fight against the coronavirus. We should also work together by making every information gathered on COVID-19 readily available to all.

Any information on fight against COVID-19 is a public good, and it should be provided quickly to everyone in need and in their fight against COVID-19, as they must act and response most quick and swift manner. In this pandemic we are all connected, any wisdom and experience must be also shared quickly and fairly.

We hope this study will be a small but meaningful policy guides for the international community and especially those developing countries by sharing Korea's experiences and countermeasures against COVID-19 over the past three months. COVID-19 countermeasures taken by the Korean government will not be conclusive nor the Korean case cannot be a universal key for all countries' fight against COVID-19. [19]

China

The similarities in facts and fiction aren't generally as obvious as in the case of 2011 Hollywood film Contagion, which today appears to be hauntingly prescient —almost like a chronicle of a pandemic foretold. Mass quarantines, food scarcity, endless queues and ghost towns due to a virus outbreak in the film make you feel as if we are living in a time that was well scripted several years ago. What is different, though, is the availability and use of sophisticated technologies that can, and in a lot of ways are, proving to be critical in combating the Novel Coronavirus and reclaiming our spaces.

Like Black Deaths in Europe during the medieval ages or the Spanish Flu outbreak in 1918, COVID-19 has exposed human fragility, along with the downside of an interconnected world. The only reprieve, thanks to technological advancements, is that we are more equipped than any era in the history to respond to a pandemic.

During the time of SARS (Severe Acute Respiratory Syndrome) outbreak in 2002, it took scientists more than a year to decode the genome of the virus, whereas thanks to tech advancements, the Coronavirus genome was identified within a month.

With despair lingering and the world in disarray, had it not been for effective and advanced technology solutions, we would have been staring at an unmanageable crisis. China illustrates this case. By mustering resources at its disposal and deploying the latest technology, the country has mitigated the effects of the virus to a significant extent and profiled people at risk. Today, several affected countries are looking at the Chinese model of best use of technology to save their populations in this race against time. [20]

The coronavirus is testing China's disaster preparedness and response, from public health systems to information sharing. Yet China has a key advantage in this fight: its technology infrastructure.

As the coronavirus spreads, so too are innovations to combat it. Not only is technology making life in quarantine more livable for millions of people, but it is also helping to fight the virus.

The Code

Within the first few weeks of the virus, China had sequenced the genome. By posting that sequencing online, it trigged a ripple effect in research labs across the world, with a surge in orders for synthetic samples of the virus to build copies of it from scratch. This allowed new treatments to be trialed – even experiments that failed offered vital clues in guiding researchers on where they should focus. [21]

Satellite monitoring

While dozens of makeshift hospitals were being constructed at breakneck pace, their progress was continuously being monitored using GaoFen, a constellation of high-resolution earth observation satellites. Zhuhai-1 hyperspectral imaging satellite and ESA's Sentinel-1 also helped in non-stop monitoring of hospital construction. The Wuhan University actively collected and analyzed multiple data sources and identified which site would be best suitable for the hospital.

TFSTAR, a second generation AI satellite designed by the Satellite Technology Research Center of University of Electronic Science and Technology of China (UESTC) and ADA-Space, is capable of powerful analytics and processing, which enables it to sift through the data. By combining TFSTAR's data processing capability with geocoding, a health visualization of COVID-19 was created on which people could see the geographical reach of the virus and could find out the distance between them and active infection. [20]

The Skies

Drones are being dispatched to respond to the outbreak, across the country. From patrolling walkways with loudspeakers warning residents to wear masks, to hovering over streets with QR code placards that drivers can scan with their phones to register health information; the drones allow authorities to get information out faster while also keeping a safe distance while performing their duties. Agricultural drones are also spraying disinfectants in remote areas, while others have been used to deliver crucial medical supplies. [21]

Drones used to spray disinfectant on city streets are 5 times more efficient than manual spraying.

Positioning technologies

It is known that positioning technologies play a crucial role during the time of crisis and disasters. Government agencies and first responders on the ground require precise positions to accurately assess the situation, pinpoint the most risky areas and carry out relief and rehabilitation efforts accordingly. In the case of epidemics and outbreaks too, GNSS comes in quite handy. In China, BeiDou, the country's own GNSS constellation, helped track patients and affected places, thus containing the virus, apart from analyzing the pattern of the outbreak. With the help of reliable data and precise mapping and imagery, China could build thousands of new makeshift hospitals across the country.

BeiDou is being used by decision-makers for transportation planning. Logistics companies are using GNSS terminals to help ply essential relief goods faster. BeiDou also has a RDSS (Radio Determination Satellite Service) that is relaying information real-time. According to reports, the Chinese government was able to hasten the construction of two new hospitals in Wuhan mainly due to BeiDou.

In Ruichang, Jiangxi province, the police forces are using BeiDou-enabled drones for monitoring congested public areas. The Chinese Ministry of

Transportation was able to swiftly send emergency messages to over 6 million connected vehicles using BeiDou. The Chinese e-commerce giant JD also delivered medical equipment in remote hospital areas in Wuhan with the help of robots based on BeiDou. [20]

Drones

In some of the severely affected areas, where humans were at a risk of catching the virus, drones came to the rescue. Drones were transporting both medical equipment and patient samples, saving time and enhancing the speed of deliveries, while preventing contamination of medical samples.

Drones were also flying with QR code placards that could be scanned to register health information. Agricultural drones were spraying disinfectants in the countryside. Drones powered with facial recognition were also being used to broadcast warnings to the citizens to not step out of their homes, and chide them for not wearing face masks.

Antwork, a group company of Japanese dronemaker Terra Drone, carried medical samples and other essential materials in Xinchang when the city was grappling with the virus. [20]

The Phones

Smartphones are playing a critical role in reducing exposure. Delivery apps offer contactless delivery, whereby drivers drop food off at a specific point – including a card stating the temperature of everyone involved in cooking and delivering the food. Another offers users maps marking residential communities with confirmed cases and their proximity to them. Meanwhile, mobile payment apps are reducing transmission along paper money, which can carry viruses for up to 17 days. With the world's highest penetration of e-wallets and two of the world's largest mobile pay, Chinese fin-tech is helping to slow the coronavirus spread. [21]

Autonomous vehicles

At a time of severe crunch of healthcare professionals and the risk of people-to-people contact, autonomous vehicles are proving to be of great utility in delivering essential goods like medicines and food items. Apollo, which is Baidu's autonomous vehicle platform, has joined hands with self-driving startup Neolix to deliver supplies and food to a big hospital in Beijing. Baidu Apollo has also made its micro-car kits and autonomous driving Cloud services available for free to companies fighting the virus.

Idriverplus, a Chinese self-driving company that operates electric street cleaning vehicles, is also a part of the mission. The company's flagship vehicles are being used to disinfect hospitals. [20]

Mobile tracking/mass surveillance

China is not known to be a country that abides by individual data privacy as an inalienable right. In order to effectively fight the virus, it has created a massive surveillance system. The Chinese government is gathering people's smartphone location data, body temperatures, travel history and other details in a centralized database, in which the data is being analyzed using Big Data and Machine Learning.

Thousands of facial recognition-powered CCTV cameras have also been installed at almost every quarantine center and only those who have been assigned the green color code are allowed to drive on the roads. WeChat, the popular instant messaging app that also has a digital wallet, is being used to collect data.

Using this data, the government can find out the number of people with whom an infected person was in close contact and order them to self-isolate themselves. For instance, if in the past ten days, an infected person bought biscuits from a grocery store using WeChat money or AliPay, the cashier at the store who was in contact with him, will be ordered to quarantine himself. [20]

The Infodemic

As the virus began making headlines globally, false information also spread, it was labeled an 'infodemic' by the WHO. Yet while technology has facilitated misinformation, it is also helping to curb it. In China, a massive online mobilization of experts, universities, organizations (including UNDP), celebrities and even A.I. news anchors are battling the infodemic, urging everyone to "spread the word, not the virus." For instance, sharing how to wear masks, and encouraging youth to share facts with the elderly and promoting social distancing.

Netizens participating in UNDP's the Spread the Word, Not the Virus campaign in over 30 different languages and dialects. [21]

Business continuity

A major challenge during the virus is being able to work. Several tech companies are offering free online collaborative tools. Other businesses have quickly adopted work-from-home policies, using online meeting software, collaboration platforms and LBS technology to clock in and ensure employees stay home. At UNDP, the use of Zoom teleconferencing and ERP Platforms have allowed us to keep working. [21]

Education and parents' sanity

After weeks of schools being closed, possibly the biggest challenge for parents is keeping children occupied and continuing their schoolwork. To enable this, many Chinese schools have rolled out online learning platforms, where students take courses and teachers give lectures from home, via live-streaming platforms. [21]

Students utilizing technology to study at home.

E-Medical and psychological care

From hypertension to arthritis, people still have many other medical needs. Online doctors and express deliveries of medicine are on the rise, as people avoid hospitals. Many institutions also offer online psychological counseling services – often for free – to counter the stress of social distancing. [21]

Health sensors and apps

Utilizing its sophisticated and expansive surveillance network for public good, the Chinese government joined hands with tech giants Alibaba and Tencent to develop a color-coded health rating system that is tracking millions of people daily. The smartphone app was first deployed in Hangzhou in collaboration with from Alibaba. It assigns three colors to people — green, yellow and red — on the basis of their travel and medical histories. In the industrial hub of Shenzhen, a similar software was created by Tencent.

Whether a person should be quarantined or allowed in public spaces was decided based on the color code. Citizens had to log into the app using pay wallet services like Alibaba's Alipay, Ant's wallet, etc. Only those people who were assigned a green color code could be allowed in public spheres after using the designated QR code at metro stations, offices and other public places. There were checkpoints at most public places where the code and a person's body temperature was checked. More than 200 Chinese cities were using this system. [20]

Robotics

From preparing meals at hospitals, doubling up as waiters in restaurants, spraying disinfectants to vending rice and dispensing hand sanitizers, robots were on the frontline to prevent the spread of Coronavirus. In many hospitals, robots were also performing diagnosis and conducting thermal imaging. Shenzhen-based company Multicopter is using robots to transport medical samples.

A hospital in Wuhan, the epicenter of the outbreak, was being staffed entirely by robots. Wuchang Hospital, China Mobile and Cloud Minds, a manufacturer of Cloud-based robotics systems, came together for this project aimed at making the hospital facility completely smart and digital. Most of the devices in the hospital are IoT enabled and services are carried out by robots. The initial screening of the patients is done by 5G-enabled thermometers that send instant updates. Also, there are rings and bracelets that are connected to the CloudMinds AI platform so that it can monitor all changes in the body.

As per a Reuters report, a small robot called Little Peanut was delivering food to passengers on a flight from Singapore to Hangzhou, China who were being held under quarantine in a hotel.

CloudMinds alone has deployed 100 robots in the country's hospitals. A few modified robots like Cloud Ginger (aka XR-1) and the Smart Transportation Robot carry food and medicine to patients from healthcare providers without any human contact. [20]

Robot nurses and AI Diagnoses

Robots are also used in many Chinese hospitals to deliver food, medicine and other supplies to patients; to disinfect hospitals and other public areas; to check patients temperatures; and to answer common questions. Coronavirus is being diagnosed using AI, which can read thousands of CT scans in 20 seconds with an accuracy rate of 96%. [21]

Robots are being used in hospitals in Wuhan to assist patients with questions, reducing the possibility of human contamination.

Connecting people

Compulsory quarantine has disrupted daily life and curtailed social interaction for nearly one fifth of the global population. This is leading millions to meet online instead. Families dine together with relatives in distant cities, raising a glass to each other on camera. Even weddings have been held in Virtual Reality. [21]

Big Data dashboards

Transparent and accessible public data has facilitated the development of dashboards to track the spread of virus. This time around, these dashboards are not only made by UN organizations like WHO, but also smaller organizations and enterprises that have contributed to their needs. Users can access these real time updates easily through their familiar Apps.

While the use of technology can at times present its own challenges, and fuel debates about privacy and public good; in the fight against the coronavirus, it is playing a critical role in offering treatment, information, support, food, schooling and greater safety for many. [21]

Big Data and facial recognition

Access to public information has led to the creation of dashboards that are continuously monitoring the virus. Several organizations are developing dashboards using Big Data. Face recognition and infrared temperature detection techniques have been installed in all leading cities. Chinese AI companies like SenseTime and Hanwang Technology have claimed to come up with a special facial recognition technology that can accurately recognize people even if they are masked.

Smartphone apps are also being used to keep a tab on people's movements and ascertain whether or not they have been in contact with an infected person. Al Jazeera reported that telecom company China Mobile sent text messages to state media agencies, informing them about the people who have been infected. The messages included all the details about the people's travel history. CCTV cameras have also been installed at most locations to ensure that those who are quarantined don't step out. [20]

Artificial Intelligence

With the help of data analytics and predictive models, medical professionals are able to understand more about a lot of diseases. Baidu, the Chinese Internet giant, has made its Lineatrfold algorithm available to teams that are fighting the outbreak, according to the MIT Technology Review. Unlike Ebola, HIV and Influenza, COVID-19 has only a single strand RNA, so it is able to rapidly mutate. The algorithm is a lot faster than other algorithms that help predict the structure of a virus.

Baidu has also made tools to effectively screen large populations and an AI-powered infrared system that can detect change in a person's body temperature. It was being used in Beijing's Qinghe Railway Station to identify passengers who were potentially infected. The system can examine up to 200 people in one minute without disrupting passenger flow.

Alibaba has developed a Cloud-based Coronavirus diagnosis tool that the company claims is more than 96% accurate and takes less than 20 seconds to work. The tool uses AI to detect traces of the virus. Alibaba says that it has been used on more than 5,000 patients throughout China. [20]

How Can AI Technology Help Fight The Pandemic COVID-19?

The outbreak of the Coronavirus or the COVID-19 seems to be a major concern for many. While there are reasons to panic, however, here are ways in which technology can help fight the pandemic.

Ever since coronavirus (COVID-19) broke out in Wuhan, China, it has spread to 100 other countries at least. China has leaned on the strong technology sector and has adopted Artificial Intelligence (AI), data science and technology to track and fight the pandemic. Tech leaders like Alibaba, Baidu and Huawei have integrated several healthcare initiatives.

Here's listing 5 ways technology can help in fighting and managing COVID-19.

Using AI To Identify, Track And Forecast Outbreaks

AI can learn to detect an outbreak; also the better one can track the virus, the better chances of fighting it. AI can detect an outbreak by analyzing news reports, social media platforms, and government platforms. Canadian startup BlueDot's is working relentlessly to warn people of the threat days before the WHO issued its public warnings.

Using AI To Help Diagnose The Virus

Infervision, an AI company had launched a coronavirus AI solution that helps front line healthcare workers detect and monitor the disease efficiently. This remedy also improves CT diagnosis speed. Alibaba, Chinese e-commerce giant has built an AI-powered diagnosis system, which is 96 percent accurate in diagnosing the virus in seconds.

Using Drones To Deliver Medical Supplies

Drone delivery is being considered as one of the safest and fastest ways to get medical supplies whenever they need to go during a disease outbreak. There are examples like Terra Drones that are using their unmanned aerial vehicles, in order to transport medical samples and quarantine material with minimal risk. Also, drones are being used to patrol public spaces, track non-compliance to quarantine mandates.

Using Chatbots To Share Information

Using chatbots effectively is a very prudent way to deal with the pandemic. For instance, Tencent operates WeChat, where people can access free online health consultation services via it. Also, the travel and tourism sector has immensely benefited from the use of chatbots.

Using AI To Identify Infected Individuals

At a time when many people have tested positive, China's sophisticated surveillance system had used facial recognition technology and temperature detection software from SenseTime, in order to identify that have developed a fever, and are more likely to have the virus.

Similarly, technological advances like 'Smart Helmets' that are being used by officials in Sichuan province to identify people with fevers. Also, the Chinese Government has developed a monitoring system called Health Code, that uses big data to identify and assess the risk of each individual based on their travel history. [22]

Switzerland

As the coronavirus (Covid-19) pandemic spreads, in Switzerland and elsewhere, technologies are multiplying in an attempt to curb this disease, or at least to help patients and healthcare workers. Among them, digital technology has its card to play: chatbots, robots, telemedicine and big data are being deployed to help gather information, reassure the population, treat patients, make a diagnosis or even prepare future vaccines. A non-exhaustive overview of the technologies currently in use, the list of which is growing day by day.

Covid-19 is the first major epidemic of our century. It represents an excellent opportunity for the many digital health companies and technologies to see what they can do to help counter this threat. It is also an opportunity to rethink the doctor-patient relationship. "The coronavirus, although it weighs negatively on our lives, represents an opportunity to rethink the whole model of how we see our patients, certainly using technology" said Dr Shafi Ahmed, a British physician and pioneer of virtual reality surgery, in an interview with Mobihealthnews.

In China, technology giants responded to the pandemic by deploying autonomous vehicles to supply medical personnel, equipping drones with thermal imaging cameras to improve virus detection, and lending their computing power to help develop a vaccine. Alibaba announced that it has developed a new diagnostic tool based on artificial intelligence. According to the Chinese giant, its algorithm is capable of detecting infections with an accuracy rate of up to 96%, all in about 20 seconds.

Baidu, the Chinese equivalent of Google, has developed an artificial intelligence model to detect people who are not wearing protective masks. Another problem with masks is that when half the face is hidden, traditional facial recognition solutions no longer work properly. As a result, citizens are forced to remove their masks to pay for shopping or to gain access to a building, which poses hygiene problems. SenseTime, a Hong Kong company specializing in automatic crowd surveillance, has developed an identification system that works despite the use of a protective mask.

Robots and chatbots on the forefront

In Kaifu district (Hunan province), robots measure body temperature, record data and disinfect the hands of employees in the morning when they arrive at work. This improves the efficiency of controls and reduces labour costs. The United States is not lagging behind in the deployment of digital solutions. The first person diagnosed in the United States was thus treated by a few healthcare professionals, but also by a robot, according to CNN Health. This robot, equipped with a stethoscope, takes the vital signs of the man and communicates with him on a large screen.

Chatbots are also widely used in the USA. These conversational robots can reassure people and help them to get treatment, while keeping them away from emergency care centres. Seattle-based start-up 98point6 offers virtual tours via its application. Patients start chatting with an artificial intelligence before being transferred to a doctor who continues the conversation via SMS. At the end of January this year, Bright.md, a Portland-based start-up, put its own coronavirus screening system into operation. Its product uses AI to conduct remote interviews with patients. When Bright.md's application reports a possible case of coronavirus, the software automatically arranges a video interview with a doctor.

In Israel, the Sheba Medical Center applied telemedicine to 12 quarantined patients. Remote monitoring of treatment protocols, medical examinations without the presence of medical staff and a robot remotely controlled by doctors (with screen, camera and medical equipment) were deployed on site.

In France, which has just announced the closure of its schools, the Doctolib site specializing in making medical appointments provides free teleconsultation for all doctors in the country for the duration of the epidemic. In Switzerland, Unisanté (CHUV) in Lausanne has put a test online to assess the risk of being a carrier of the virus. It is available on www.coronacheck.ch.

Digital epidemiology is developing

Digital technology also makes it possible to play a key role in providing information and thus in anticipating the disease. This is what is known as digital epidemiology, which consists of collecting, analyzing and sorting the huge masses of data produced on the Internet. This technique is currently made simpler thanks to hyper-connected populations. "The data exists, but public health agencies have to chase it down, which takes time. Digital epidemiology offers tools that make them more responsive" said Marcel Salathé, professor of digital epidemiology at the Ecole Polytechnique Fédérale de Lausanne, in an interview with the newspaper Le Temps.

The European Centre for Disease Prevention and Control, based in Sweden, uses the internet and social networks to monitor disease outbreaks. As part of the Epidemic Intelligence project, data specialists and medical epidemiologists are analyzing the internet, the media and social networks in search of new cases. But their task is enormous. For the coronavirus, for example, millions of tweets are analyzed every day.

In the same vein, Harvard University has developed HealthMap. This interactive map provides surveillance of the epidemic. On a world map, each point corresponds to clinical cases, political decisions or press articles. These initiatives, which are multiplying, give a fairly precise and above all very rapid idea of the progression of the virus. Digital technology makes it possible to avoid the slowness of the usual processes, during which medical information is sent from the field to health agencies before being communicated to the general public.

Finally, the Health Tech Hub, based in Copenhagen, uses the broadcast and sharing power of digital. It has just launched a worldwide call for solutions. The idea is to identify the best available solutions and to share them online after validation.

A "synthetic" copy of the virus

Researchers at a lab at the University of North Carolina are going even further than identifying and informing: they are trying to create a copy of the virus. To do so, they are using only computer readings of the gene sequence put online by Chinese laboratories last January. Creating a "synthetic" virus gives researchers powerful tools to study treatments, vaccines and how mutations could make the virus more dangerous. [23]

Taiwan

Response to COVID-19 in TaiwanBig Data Analytics, New Technology, and Proactive Testing

Taiwan is 81 miles off the coast of mainland China and was expected to have the second highest number of cases of coronavirus disease 2019 (COVID-19) due to its proximity to and number of flights between China.1 The country has 23 million citizens of which 850 000 reside in and 404 000 work in China.2,3 In 2019, 2.71 million visitors from the mainland traveled to Taiwan.4 As such, Taiwan has been on constant alert and ready to act on epidemics arising from China ever since the severe acute respiratory syndrome (SARS) epidemic in 2003. Given the continual spread of COVID-19 around the world, understanding the action items that were implemented quickly in Taiwan and assessing the effectiveness of these actions in preventing a large-scale epidemic may be instructive for other countries.

COVID-19 occurred just before the Lunar New Year during which time millions of Chinese and Taiwanese were expected to travel for the holidays. Taiwan quickly mobilized and instituted specific approaches for case identification, containment, and resource allocation to protect the public health. Taiwan leveraged its national health insurance database and integrated it with its immigration and customs database to begin the creation of big data for analytics; it generated real-time alerts during a clinical visit based on travel history and clinical symptoms to aid case identification. It also used new technology, including QR code scanning and online reporting of travel history and health symptoms to classify travelers' infectious risks based on flight origin and travel history in the past 14 days. Persons with low risk (no travel to level 3 alert areas) were sent a health declaration border pass via SMS (short message service) messaging to their phones for faster immigration clearance; those with higher risk (recent travel to level 3 alert areas) were quarantined at home and tracked through their mobile phone to ensure that they remained at home during the incubation period.

Moreover, Taiwan enhanced COVID-19 case finding by proactively seeking out patients with severe respiratory symptoms (based on information from the National Health Insurance [NHI] database) who had tested negative for influenza and retested them for COVID-19; 1 was found of 113 cases. The toll-free number 1922 served as a hotline for citizens to report suspicious symptoms or cases in themselves or others; as the disease progressed, this hotline has reached full capacity, so each major city was asked to create its own hotline as an alternative. It is not known how often this hotline has been used. The government addressed the issue of disease stigma and compassion for those affected by providing food, frequent health checks, and encouragement for those under quarantine. This rapid response included hundreds of action items (eTable in the Supplement).

Recognizing the Crisis

In 2004, the year after the SARS outbreak, the Taiwan government established the National Health Command Center (NHCC). The NHCC is part of a disaster management center that focuses on large-outbreak response and acts as the operational command point for direct communications among central, regional, and local authorities. The NHCC unified a central command system that includes the Central Epidemic Command Center (CECC), the Biological Pathogen Disaster Command Center, the Counter-Bioterrorism Command Center, and the Central Medical Emergency Operations Center.

On December 31, 2019, when the World Health Organization was notified of pneumonia of unknown cause in Wuhan, China, Taiwanese officials began to board planes and assess passengers on direct flights from Wuhan for fever and pneumonia symptoms before passengers could deplane. As early as January 5, 2020, notification was expanded to include any individual who had traveled to Wuhan in the past 14 days and had a fever or symptoms of upper respiratory tract infection at the point of entry; suspected cases were screened for 26 viruses including SARS and Middle East respiratory syndrome (MERS). Passengers displaying symptoms of fever and coughing were quarantined at home and assessed whether medical attention at a hospital was necessary. On January 20, while sporadic cases were reported from China, the Taiwan Centers for Disease Control (CDC) officially activated the CECC for severe special infectious pneumonia under NHCC, with the minister of health and welfare as the designated commander. The CECC coordinated efforts by various ministries, including the ministries of transportation, economics, labor, and education and the Environmental Protection Administration, among others, in a comprehensive effort to counteract the emerging public health crisis.

Managing the Crisis

For the past 5 weeks (January 20-February 24), the CECC has rapidly produced and implemented a list of at least 124 action items (eTable in the Supplement) including border control from the air and sea, case identification (using new data and technology), quarantine of suspicious cases, proactive case finding, resource allocation (assessing and managing capacity), reassurance and education of the public while fighting misinformation, negotiation with other countries and regions, formulation of policies toward schools and childcare, and relief to businesses.

Border Control, Case Identification, and Containment

On January 27, the National Health Insurance Administration (NHIA) and the National Immigration Agency integrated patients' past 14-day travel history with their NHI identification card data from the NHIA; this was accomplished in 1 day. Taiwan citizens' household registration system and the foreigners' entry card allowed the government to track individuals at high risk because of recent travel history in affected areas. Those identified as high risk (under home quarantine) were monitored electronically through their mobile phones. On January 30, the NHIA database was expanded to cover the past 14-day travel history for patients from China, Hong Kong, and Macau. On February 14, the Entry Quarantine System was launched, so travelers can complete the health declaration form by scanning a QR code that leads to an online form, either prior to departure from or upon arrival at a Taiwan airport. A mobile health declaration pass was then sent via SMS to phones using a local telecom operator, which allowed for faster immigration clearance for those with minimal risk. This system was created within a 72-hour period. On February 18, the government announced that all hospitals, clinics, and pharmacies in Taiwan would have access to patients' travel histories.

Resource Allocation: Logistics and Operations

The CECC took an active role in resource allocation, including setting the price of masks and using government funds and military personnel to increase mask production. On January 20, the Taiwan CDC announced that the government had under its control a stockpile of 44 million surgical masks, 1.9 million N95 masks, and 1100 negative-pressure isolation rooms.

Communications and Politics

Reassure and Educate the Public, While Fighting Misinformation

In addition to daily press briefings by the minister of health and welfare the CECC, the vice president of Taiwan, a prominent epidemiologist, gave regular public service announcements broadcast from the office of the president and made available via the internet. These announcements included when and where to wear a mask, the importance of handwashing, and the danger of hoarding masks to prevent them from becoming unavailable to frontline health workers. The CECC also made plans to assist schools, businesses, and furloughed workers (eTable in the Supplement).

Taiwan's Outcomes so Far (as of February 24)

Interim Outcomes

The CECC has communicated to the public in a clear and compassionate manner. Based on a poll of 1079 randomly selected people conducted by the Taiwan Public Opinion Foundation on February 17 and 18, the minister of health and welfare received approval ratings of more than 80% for his handling of the crisis, and the president and the premier received an overall approval rating of close to 70%. As of February 24, Taiwan has 30 cases of COVID-19. These cases represent the 10th-highest case number among countries affected thus far, but far fewer than the initial models predicting that Taiwan would have the second-highest importation risk.

Challenges

First, real-time public communications were mostly in Mandarin Chinese and sign language. Other than the Taiwan CDC website, there was not enough communication in different languages to non-Taiwanese citizens traveling or residing in Taiwan. Second, while its attention was focused on air travel, Taiwan permitted the docking of the Diamond Princess cruise ship and allowed passengers to disembark in Keelung, near New Taipei City, on January 31, before the ship left for Japan. The ship was subsequently found to have numerous confirmed infections onboard. This created a temporary public panic with concern about community spread. The government published the 50 locations where the cruise ship travelers may have visited and asked citizens who may have been in contact with the tour group to conduct symptom monitoring and self-quarantine if necessary. None were confirmed to have COVID-19 after 14 days had passed. Third, whether the intensive nature of these policies can be maintained until the end of the epidemic and continue to be well received by the public is unclear.

Conclusions

Taiwan's government learned from its 2003 SARS experience and established a public health response mechanism for enabling rapid actions for the next crisis. Well-trained and experienced teams of officials were quick to recognize the crisis and activated emergency management structures to address the emerging outbreak.

In a crisis, governments often make difficult decisions under uncertainty and time constraints. These decisions must be both culturally appropriate and sensitive to the population. Through early recognition of the crisis, daily briefings to the public, and simple health messaging, the government was able to reassure the public by delivering timely, accurate, and transparent information regarding the evolving epidemic. Taiwan is an example of how a society can respond quickly to a crisis and protect the interests of its citizens. [24]

Discussion and Conclusions

This article provides an in-depth views of ICT interventions by providing (a) the type of ICT solutions that are deployed during the COVID-19 pandemic, (b) the way ICTs are being used to provide the health services, (c) the types of services or supports that are received from digital innovations, (d) explore the strengths, weakness, threats and opportunities of ICT interventions to combat with COVID-19 pandemic and to mitigate future pandemics. The outcomes of this research will greatly contribute to the practitioners, government, policy makers, doctors and individuals to aware about the ICT tools and their roles during the pandemic situations. The government of developing or infected countries may take necessary initiative to develop the affordable useful ICT-based system to provide health service and aware people to reduce the pandemic spread of COVID-19.

The outcome of this research provides implications for the potential future researches. First, investigate the critical success factors of ICT interventions during the pandemic situation in context of developing and developed countries. Second, explore the impact of ICTs on reducing and combating the COVID-19 pandemic. Third, mitigate the weaknesses and threats of ICT interventions. Finally, further research and development may focus to explore and achieve the opportunities (revealed through the SWOT analysis) to ensure the optimum benefits ICT interventions during the future pandemics.

This article has a few limitations as well. First, some related contents may be omitted due to use the specific keywords to search related content in the online review study. Second, only TACAS was conducted with inadequate number of participants and the remote sessions were conducted online due to the vulnerable situation.

Further studies and articles could be conducted through other methods like survey, interviews and the likes; similarly, data could be collected from a wider group of participants. Finally, it might be possible that the materials which have been used for the research may have some biases in their reporting.

However, to the best of our knowledge, no academic research or studies is conducted focusing to the ICT interventions in the COVID-19 pandemic; thus, the outcome of this article would contribute as an eye opener to the researcher, practitioners and government to take necessary further initiatives to deploy and develop such ICT or digital interventions to combat with the pandemic spread of novel Coronavirus.

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