NHS RESET
FOR THE FUTURE OF HEALTH AND CARE

NHS European Office

# International crisis-led healthcare innovation in response to the COVID-19 pandemic


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## About NHS Reset

COVID-19 has changed the NHS and social care, precipitating rapid transformation at a time of immense pressure and personal and professional challenge. One message from leaders and clinicians across the UK has been clear: we must build on the progress made to chart a new course. NHS Reset is an NHS Confederation campaign to help shape what the health and care system should look like in the aftermath of the pandemic.

Recognising the sacrifices and achievements of the COVID-19 period, it brings together NHS Confederation members and partners to look at how we rebuild local systems and reset the way we plan, commission, and deliver health and care. NHS Reset is part funded through sponsorship by Novartis Pharmaceuticals UK Limited.

Find out more at www.nhsconfed.org/NHSReset and join the conversation on social media using #NHSReset

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# Foreword

**Dr Layla McCay**

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We still have a long way to go before we reach the end the coronavirus pandemic and are able to fully comprehend the sheer levels of change it has sparked globally. We can, however, say that health services and industry have proven themselves capable of rising to the challenge of devising innovative solutions to meet evolving needs.

Healthcare systems and organisations around the world have been forced to adopt new digital healthcare technologies, strict infection control policies and creative ways of planning and deploying staff to meet the high and ever-growing healthcare demands. This change has been implemented at such pace that we are only just catching up with the consequences.

This widespread effort to respond to tragedy and trauma by changing the way health and care services are provided must be captured. This report aims to start this process. It outlines some of the crisis-led innovations that have helped us to respond to the immediate threats the pandemic has presented us with, and that will shape the future of health in the years to come.

This collation of innovations and ingenuity provides a structured look at some of the areas that were optimised to save and protect lives in the first wave of the pandemic. The authors come at this from a unique perspective – with backgrounds that include both academia and practical experience of healthcare delivery. They have been able to draw out not only why the key innovations matter, but also how necessity has driven the urgent development of more experimental and creative solutions. Systematic evaluation of these innovations will, of course, be crucial to understand their impact and outcomes, and what it would take to sustain and scale them.

The report is being published as part of our NHS Reset campaign, in which we have been engaging with health and care leaders, partner organisations and others to help shape the debate on the health and care system in the aftermath of the pandemic. The best practice and innovation strand, within which this report sits, enables us to reflect on the remarkable way systems have responded to the pandemic and start to consider how we embed and evaluate the positive changes we have seen to date. We are grateful to Dena Ettehad, Bilal Abou El Ela Bourquin and Matthew Harris for the helpful insights presented in this report.

# Key points

- The COVID-19 pandemic and associated lockdown measures have permeated close to all aspects of daily life, with immediate and profound effects on population health and its wider determinants. Across the globe there has been an explosion of innovation in response to the crisis, enabled by a sense of common purpose, the unfreezing of rigid organisational structures, processes and regulations, and huge increases in public expenditure.

- This report outlines some of the crisis-led innovations that have helped countries to cope during the first wave of COVID-19 infections and that may shape the 'new normal' in the years to come. It collates a number of innovations into six domains (stuff, staff, space, systems, surveillance and society), an adapted version of Farmer's 4 S's, which distils the elements that 'make all the difference in saving lives during an outbreak'.

- The acceleration of production has been a key enabler of innovation, notable in the production and mobilisation of personal protective equipment, ventilators, diagnostics, vaccines, medicines and infection control measures.

- Healthcare professionals have likened the initial waves of COVID-19 patients needing urgent medical attention to weathering a tsunami. Countries have employed pragmatic and creative approaches to augmenting capacity at considerable pace, including repurposing trains as hospital wards and working with hotel operators to repurpose rooms for quarantine operations.

- Across the globe, there has been increased innovation in healthcare staff recruitment and retention, redeployment and retraining, rostering and recognition. This has included initiatives based on 'reverse innovation', relaxed immigration policies and efforts to rapidly retrain and re-skill redeployed staff.

- Healthcare systems and services have adapted their models of care delivery. This has been supported by the adoption of telehealth and digital services. Testing robots, for example, are helping to limit staff exposure to infection and helping to conserve protective gear.

- Sustained creativity and innovation in the UK and internationally will be essential tools in helping to shape the 'next normal'. While innovation may have become a byword of the healthcare response to the pandemic, evaluation will be crucial to take stock of the impact on patients and healthcare staff and what should be taken forward.

# Introduction

The novel coronavirus (SARS-CoV-2) represents a global health challenge of extraordinary proportions. First detected in China on 31 December 2019, the virus was acknowledged as a public health emergency by the World Health Organization (WHO) on 30 January 2020.[1] The disease was named COVID-19 on 11 February 2020 and declared a pandemic a month later, by which point case numbers had increased 13-fold.[2] As of 1 August 2020, as the first wave was coming to an end, the virus had spread to most countries across all continents except Antarctica, with 19,405,013 confirmed cases and 721,906 deaths.[3] Over half of the world's population had been placed under lockdown measures of varying stringency in a concerted effort to suppress viral spread, avoid overwhelming health services and ultimately protect lives.[4]

The pandemic and associated lockdown measures have permeated close to all aspects of daily life, with immediate and profound effects on population health and its wider determinants – from physical and mental health to social and economic wellbeing. Governments have responded to this unprecedented bio-psycho-social crisis with bold measures under time, knowledge and resource constraints, in an environment of mass uncertainty and fear. In an effort to suppress, if not mitigate against, the worst consequences of the pandemic, society at large has rallied its resources and ingenuity to devise creative solutions at speed. The crisis has presented unique conditions for innovation, namely: unity around a common purpose and an urgency to act; unfreezing of rigid organisational structures, processes and regulations; and huge increases in public expenditure.

This report seeks to outline some of the crisis-led innovations that helped countries to cope in the short to medium term during the first wave of COVID-19 infections and that may shape the 'new normal' in the years to come. We have collated some key innovations that have already been applied as well as some more experimental examples. We drew these from academic journal articles, company reports, news clippings, websites and our own clinical experience as junior doctors working in NHS trusts in London and Cambridge during the first wave. We did not employ a methodology such as a systematic review, as during a pandemic there is a high turn around of literature that is not

always peer reviewed and there is insufficient time for this high volume of work to be appropriately coded in search engines, meaning that many examples risk being missed.

We have categorised the examples into six domains, namely Farmer's four S's[5] (stuff, staff, space and systems), which according to the renowned medical anthropologist and physician 'make all the difference in saving lives during an outbreak'. We have also added two of our own: surveillance and society. The rationale behind this structure is that, during an outbreak, governments must optimise their stuff, staff, space, systems and surveillance to save lives, while society has to weather and adapt to the consequences. We differentiate between international examples of innovation and the UK's response to highlight the national contribution.

This paper has been written by external authors. As such, it does not necessarily represent the views of the NHS Confederation or its members. It was written between June and September 2020.

# Different types of innovation catalysed by the COVID-19 response

## Stuff: international innovation

COVID-19 is a deadly infectious respiratory disease disseminated through aerosols, droplets and fomites.[6] As such, patient management and infection control necessitates the use of personal protective equipment (PPE), disinfectants, mechanical ventilators, diagnostics, medicines and vaccines. The key theme of the innovation that has supported the optimisation of 'stuff' in this pandemic has been around accelerating production.

### Personal protective equipment

Globally, during this year there has been extensive media coverage of the shortage of PPE for front line healthcare professionals.[7] Furthermore, citizens have been increasingly encouraged to wear face masks in public, with over 100 countries making it compulsory.[8] Supplying PPE readily and at scale is an enormous manufacturing and logistical challenge, behind which lies opportunities for much-needed innovation.

On the manufacturing side, both organisations and individuals rose to this task. Providence, a healthcare organisation working across several American states, launched the 100 Million Mask Challenge, urging community volunteers to produce surgical face masks at pace[9] The American Hospital Association supported this effort by connecting manufacturers with hospitals and clinics in need.[10]

Redirecting their creative prowess, dozens of brands in the fashion industry mobilised their production facilities to address the global PPE shortage. European high-fashion designerscompeted with each other to exhibit corporate social responsibility. Dior repurposed its fragrance

production lines to produce hand sanitiser for French hospitals, while Chanel, Burberry and Louis Vuitton repurposed their factories for gown and face mask production.[11,12] In Asia, Fast Retailing (Japan) donated over 10 million masks to medical facilities in over 19 countries worldwide, while Taiwan's non-profit textile federation donated 15 million masks globally.[13,14]

There were notable grassroots contributions to the PPE production drive and the so-called "citizen's supply chain", with creative individuals using 3D-printing software and repurposing acetate sheets from overhead projectors to produce hospital visors in their living rooms.[15] Alongside this, there was a wave of online video tutorials instructing viewers on how to make DIY face-masks using household materials and domestic sewing machines.[16,17]

On the logistics side, several countries have been resourceful in drafting their armed forces to manage and distribute supplies of PPE, recognising that they are best placed for dealing with major logistical challenges during disaster. For example, in an effort to optimise supply chains, the British Royal Air Force was deployed to collect PPE from overseas suppliers, with the British army distributing the supplies.[18,19]

Until this pandemic, a sizable proportion of the world's supply of PPE came from the USA, China and Germany. However, the shortages of these and other essential equipment highlighted the importance of reducing dependence on single sources for critical components. Post-pandemic there is likely to be a rethink of what components are strategic to a nation's survival, with increased emphasis on building self-sufficiency, resilience and efficiency into supply chains. Individual transactions may become less important than end-to-end value optimisations and organisations may invest more in just-in-time and just-in-case supply chains.

## Ventilators

COVID-19 can result in respiratory failure and necessitate mechanical ventilation in the most severe cases. At times during the pandemic, the demand for ventilators outstripped supply in many countries globally, with clinicians being forced to allocate their use based on comorbidities and, in some cases, demographic factors such as age.[20]

In a concerted effort to increase existing capacity and preparedness for a second wave of infections, governments called on industry to prioritise ventilator production. Several organisations mobilised rapidly, with companies such as Mercedes Formula One, Tesla and Dyson repurposing car and electronics manufacturing plants for ventilator production.[21–23]

COVID-19 has also served as a catalyst for open innovation. Examples include the American medical device company Medtronic, which shared its portable ventilator design specifications and code free of charge to all manufacturers worldwide under a free license for the duration of the COVID-19 pandemic.[24] Similarly, the Indian start-up AgVa Healthcare shared the designs of its portable ventilator that oxygenates room air and comes at a cost of approximately $2,000, a fraction of the price of many of its contenders. The software is installed via an app on the operator's smartphone, which acts as a simplified ventilator interface.[25] Other examples include Isinnova, an Italian start-up that used 3D printing to develop replacement ventilator valves when supplies at Chiari Hospital in Brescia were depleted. Isinnova risked facing legal action from the manufacturer of the original part, highlighting the tensions between open innovation and the protection of intellectual property rights.[26]

## Diagnostics

"Test, test, test", became the mantra of the World Health Organization's director general as early as 16 March 2020.[27] Early diagnosis facilitates timely self-isolation, contact tracing and epidemiological analysis, which is crucial in breaking the chain of transmission by reducing the basic reproduction (R) number below one. Countries such as Singapore, South Korea and Germany were able to de-escalate initial lockdown measures earlier than most, precisely because they ramped up testing rapidly.[28,29]

Naso- and oropharyngeal swabs are invasive sampling techniques widely used for SARS-CoV-2 detection.[30] In April, Chinese researchers at Guangzhou Institute of Respiratory Health developed an innovative, minimally invasive sampling technique relying on throat washings, with a significantly higher detection rate and greater ease of self-sampling than swabs.[31] By the end of the first wave of COVID-19 infections, more inventive, non-invasive diagnostics were also under development. Harvard and MIT were developing a novel test based on a face mask capable of producing a fluorescent signal when a person with the virus breathes, coughs, or sneezes.[32] The mask has a fast reading sensor that only needs to recognise a small part of the viral genetic sequence, emitting fluorescent signals within one to three hours. These signals are invisible to the naked eye; however, a $1 hand-held device can be used to scan the mask. Compared to traditional methods, this sensor may provide a faster, cheaper and non-invasive test.[33]

The drive to ramp-up testing through the creation of novel diagnostic methods has fomented significant technological innovation. The German company Bosch has developed the world's first fully automated

molecular diagnostic test that is able to detect SARS-CoV-2 and nine other respiratory viruses within two-and-a-half hours.[34] The Canadian firm Sona Nanotech developed a quick-response antigen test based on lateral flow and gold nanorod technologies to generate binary test results (positive / negative), in up to 15 minutes at a cost of less than $50 per test.[35] These easy-to-use point-of-care tests could be suitable for home testing and monitoring, as they do not require expert interpretation. They could also be used both prior to entering closed spaces (such as in airports) as well as to facilitate timely release from quarantine.

In the interim, between the easing of lockdown measures and the availability of widespread vaccination, new testing protocols, based on rapid and robust methods, are being developed to facilitate the re-opening of economies and the resumption of nearer to normal daily life while still protecting population health.

## Vaccines

A proven vaccine is desperately needed to protect people from SARS-CoV-2 while allowing society and the economy to resume normal activity.

The pandemic has set off a global race for an effective vaccine with multiple research groups, many of them backed by the non-profit Coalition for Epidemic Preparedness Innovations (CEPI), responding to the call for prompt innovation.[36] As of 1 July 2020, 132 were undergoing pre-clinical evaluation and 17 candidate vaccines were undergoing clinical evaluation.[37]

In addition to novel vaccines, repurposing is a well-known means of fast and frugal innovation, and thus a promising approach to tackle COVID-19. Several vaccine candidates were previously used for other viruses and even bacteria like Mycobacterium tuberculosis. In an effort to encourage debate on accelerating vaccine development, several scientists have agitated for 'human challenge trials', whereby healthy volunteers are given the candidate vaccine and then intentionally infected with the coronavirus.[38] This contentious yet innovative trial model has attracted over tens of thousands of volunteers in more than 100 countries worldwide.[39] It raises an interesting ethical dilemma: can we obtain informed consent from participants when the risks posed are not yet fully elucidated? The WHO has published a document on this topic outlining the key criteria for the ethical acceptability of COVID-19 human challenge studies.[40]

## Medicines

As well as vaccines, researchers and manufacturers moved potential therapeutics into clinical trials at pace to find treatment candidates that

lower COVID-19-associated morbidity and mortality. As of 1 July 2020, Dexamethasone was the only drug proven to be safe and effective in the management of patients severely ill with COVID-19, with preliminary data from the RECOVERY trial demonstrating mortality reductions of one fifth for those requiring oxygen and approximately one third for those not requiring oxygen.[41] Gilead's experimental antiviral Remdesivir was granted an emergency-use authorisation by the US Food and Drug Administration after promising results in a randomised, placebo-controlled trial of 1,063 patients hospitalised with severe COVID-19.[42,43]

Several other repurposed treatments were used off-label, on a compassionate-use basis or as part of randomised clinical trials. The relaxation of stringent regulatory processes enabled compounds to be donated and trialled more swiftly. The Gates Foundation asked several drug companies to provide access to their pipeline of developed antiviral drugs so as to enable researchers funded by the Therapeutics Accelerator to screen compounds, deciding which ones should enter human trials first.[44,45] This is testament to the fact that a sense of urgency, clarity of vision and a unified purpose can facilitate rapid, open innovation.

## Infection control

Tests, vaccines and medicines, while essential, are not the sole means of combating this virus. While we eagerly await the discovery of new or the repurposing of existing vaccines and medications, there are renewed efforts to reduce the infectious particles on our persons and in our surroundings. The demand for sanitising products sky-rocketed during this pandemic, incentivizing existing companies to scale production and alluring others into the market. In an innovative repurposing of factory facilities, several distilleries switched production from drinkable to sanitising alcohol.[46,47]

The need for thorough, rapid and in some instances large-scale sanitisation has served to accelerate our transition towards increasing reliance on robot technology. A 2017 report by the global consultancy firm McKinsey predicted that up to one-third of US workers would be replaced by automation by 2030.[48] The COVID-19 pandemic is seemingly expediting this transition. Instead of manual disinfection, which requires workforce mobilisation and potentially unacceptable exposure of cleaning personnel, several countries are relying on robots to dispense sanitisers and clean shared spaces, in a move that’s proving fast and cost-effective.

In South Korea, robots have been used to distribute hand sanitiser, while Walmart, America's biggest retailer, has used robots to scrub floors.[49] UVD Robots, the Danish manufacture of ultraviolet-light-disinfection robots, has shipped hundreds of machines to hospitals in China and Europe.[50]

However, many countries have not yet adopted these technologies. While the Singaporean government has deployed Spot (the Robo-dog) as well as aerial drones to public parks to encourage social distancing.[51] In several countries, aerial drones are also transporting medical samples, spraying disinfectant and delivering food and medicine.

## Stuff: the UK response

In optimising the 'stuff' required to tackle the COVID-19 pandemic, the UK leveraged new ways of working that not only accelerated production, but also boosted innovation in new areas of discovery, such as diagnostics and vaccine development.

To increase existing capacity for a potential second wave of infections, the UK government, as others around the world, called on industry to prioritise ventilator production. In the UK, this was met with several novel collaborations between the private sector and academia. Examples include the Mercedes Formula One team collaborating with University College London to reverse engineer a continuous positive airway pressure machine in less than one hundred hours.[52] Meanwhile, in less than a fortnight, a collaboration between scientists, clinicians and manufacturers at the University of Oxford, King's College London and Smith+Nephew developed OxVent, a rapidly deployable open-source ventilator comprising 90 per cent repurposed off-the-shelf parts.[53] Once approved by the Medicines and Healthcare products Regulatory Agency, OxVent could be available for use abroad at a cost of under £1,000 per unit, in stark contrast to the length of time and the associated costs of such an endeavour in pre-pandemic times. This serves as a good example of fast and frugal innovation.[54]

In diagnostics, researchers at the University of Cambridge developed the pioneering COVID-19 Sounds App which relies on machine learning algorithms trained on crowdsourced datasets to detect whether a person is suffering from COVID-19 based on the sound of their voice, breathing and coughs.[55] This ground-breaking software has the potential to aid telephone triage of patients, potentially sorting mild cases who can self-care at home, from those requiring hospital admission. Similarly, ingenious solutions include training 'COVID-19 dogs' to detect coronavirus from human odour. Researchers at the London School of Hygiene and Tropical Medicine are collaborated with Medical Detection Dogs charity and Durham University in a trial assessing whether dogs who can detect certain cancers will also be able to detect coronavirus in asymptomatic carriers.[56]

As with ventilator production, ramping up of testing has been achieved often through new collaborations between industry and academia.

AstraZeneca, GlaxoSmithKline and the University of Cambridge are reducing the turn-around time from swab to result (from 24 to for hours) for existing polymerase chain reaction (PCR) tests through an innovative method of viral inactivation.[57] The UK diagnostics firm Intelligent Fingerprinting and Imperial College London trialled a fingerprint test that collects fingerprint sweat, which is read by a portable analysis unit, using highly sensitive lateral flow technology and fluorescence measurement techniques to provide results within a 10-minute timeframe.[58]

The UK has lead the way on vaccine and treatment development for COVID-19. The foremost candidate for a COVID-19 vaccinethat can be rolled out at scale is the University of Oxford/AstraZeneca's vaccine. Additionally, as of 1 July 2020, Dexamethasone was the only drug that has been proven to be safe and effective in the management of patients severely ill with COVID-19, with preliminary data from the RECOVERY trial demonstrating mortality reductions of one-fifth for those requiring oxygen and approximately one-third for those not requiring oxygen.[59] Conducted by researchers at Oxford University, the Randomised Evaluation of COVID-19 Therapy (RECOVERY) trial involved all major hospitals in the UK on an unprecedented scale and as many as 3,500 doctors, nurses and research staff, including consultants, junior doctors.

## Space: international innovation

Healthcare professionals have likened the initial waves of COVID-19 patients needing urgent medical attention to weathering a tsunami. Creating and conserving space within hospitals, and intensive care units, in particular, has thus been a priority for governments throughout this pandemic.

Countries have employed pragmatic and creative approaches to augmenting capacity. In ten days, the Chinese built Wuhan's LeiShenShan and Huoshenshan hospitals, a logistical feat that was celebrated for its speed yet criticised for structural, safety and labour concerns.[60] In India and Pakistan, trains were repurposed as hospital wards for COVID-19 patients.[61] Moreover, many hotel operators have coordinated with healthcare organisations to repurpose their room capacity for quarantine operations. In an effort to conserve bed capacity and mitigate against nosocomial infection, some healthcare providers are only admitting patients who strictly need hospital care, expediting discharge of existing patients, postponing non-urgent procedures and segregating non-COVID patients from incoming suspected and confirmed cases.

# Space: the UK response

In a similar vein to other countries, the UK repurposed several conference centres into 'Nightingale' field hospitals in a matter of weeks and increased its capacity by a further 8,000 beds by commissioning private hospitals at cost.[62] Many hospital trusts in the UK divided their hospital space into Red (COVID-19 swab positive), Amber (COVID-19 swab result awaiting), and Green (COVID-19 swab negative). Other trusts opted to segregate entire hospitals into Clean (COVID-19-free) and Dirty (COVID-19 cases), transferring patients as appropriate. In addition, the 'Hospital at Home' model whereby people receive hospital-level care in the comfort of their own homes has become more widespread.[63]

# Staff: international innovation

A sizable workforce composed of skilled and motivated staff is needed to man the space and use the 'stuff' required to manage the COVID-19 pandemic. In light of this, there has been increased emphasis and thus innovation in what we term the **6 R's** – adequate staff recruitment and retention, redeployment and retraining, rostering and recognition.

Some have proposed staff recruitment and training initiatives based on 'reverse innovation', most notably the implementation of a large-scale emergency programme to train community health workers to support people in their homes; a model which has provided effective health and social care support at scale in Brazil, Pakistan, Ethiopia and other nations.60 In an effort to retain key skills, some countries, including the USA, relaxed their immigration policies to encourage migration of such personnel.[64]

In light of the fact that certain specialties (including intensive care, infectious diseases and respiratory medicine) have been more severely impacted than others, some workforce managers have **redeployed** multidisciplinary staff (doctors, nurses, physiotherapists) from other medical and surgical specialties. To ensure consistent and safe practice, there has been a concerted effort to rapidly retrain and re-skill redeployed staff, with cross-country, cross-sectoral and cross-institutional collaboration to achieve this. For example, the Department of Anaesthesia and Intensive Care at the University of Hong Kong, sponsored by an unlimited educational grant from the ventilator manufacturer MAQUET, has been delivering its Basic Assessment and Support in Intensive Care (BASIC) course in blended-learning format to train doctors from as far and wide as Pakistan, South Africa and Fiji to care for critically-ill, ventilated patients.[65]

**Rostering** hospital staff during the COVID-19 crisis has been a challenge, especially since a great proportion of them may be ill or self-isolating at any one time. Staff rostering systems have had to adapt to this by becoming more dynamic, responsive and responsible.[66] On the one hand, they must ensure that the right numbers of staff are present in the right areas at the right times. On the other, it is prudent to protect staff from unwarranted exposure to infection, shield vulnerable staff members, prevent staff burn-out and account for unexpected sickness. Services such as surgery, which may be less busy than usual, have operated a 'skeleton service' with several staff members on standby at home. Thereby creating a pool of supernumerary staff members who can remain at home protected from the risk of viral infection yet can be readily deployed should the need arise.

The public's **recognition** of the work of health professionals has increased substantially over the course of this pandemic. The Clap for Carers initiatives around the world demonstrated public solidarity with healthcare staff, serving to boost morale to some extent. In a wellbeing drive, many hospitals have set up psychological support groups and helplines as well as creating staff 'rest and recharge areas'. A creative example being Project Wingman's "tea and empathy" scheme, whereby airline crew from across the industry are coming together to support the wellbeing of frontline staff in the UK and US during the COVID-19 outbreak.[67]

This pandemic has made organisations less reliant on traditional structures, forcing them to rethink how to organise a distributed health workforce. Organisations are moving from lines and silos to networks and teamwork. Working towards a common purpose, with a unified mission and sense of urgency, they are better positioned to problem-solve quickly and are learning to give more weight to expertise than rank.

## Staff: the UK response

In the UK, as in other countries' experience, there was an early drive to **recruit and retain** more healthcare workers. Within weeks of the pandemic, final-year medical and nursing students were given early registration for their imminent enlisting to the workforce.[68,69] Recently-retired healthcare professionals were encouraged to return to medical practice to support the workforce; those nearing retirement age were asked to consider staying until the end of the COVID-19 crisis.[70,71] In what has been a drastic shift away from a bureaucratic system, educational adjustments were made to relax the stringency of annual appraisals for existing staff, while those returning from retirement have been given temporary registration.[72] Furthermore, many international governments called for volunteers to support the health services, with over 750,000

signing up in the UK.[73] The British Home Office extended visas for overseas healthcare professionals to enable them to continue their work.[74]

In light of the fact that certain specialties (including intensive care, infectious diseases and respiratory medicine) have been more severely impacted than others, workforce managers have redeployed multidisciplinary staff (doctors, nurses, physiotherapists) from other medical and surgical specialties.[75] Institutions such as the National Institute of Health Research in the UK mandated that clinicians currently engaged in academia resume their clinical practice. Furthermore, vast numbers of NHS dental professionals have been redeployed to hospitals to support their medical colleagues.[76] While healthcare professionals should never work outside their competence, professional indemnity has also been relaxed, with the UK's General Medical Council covering professionals for practice in areas outside their usual field of expertise in these unprecedented times.[77]

As per the international trend, the UK public's recognition of the work of health professionals has increased substantially over the course of this pandemic. The UK Clap for Carers initiative, the videos and messages of support, the motivational posters, the business discounts and concessions for healthcare workers, as well as the countless generous donations by individuals and organisations, have all demonstrated public solidarity with healthcare staff, serving to boost staff morale to some extent.[78] Staff in the UK have also benefited from wellbeing initiatives, such as the British Airways lounge created to allow healthcare staff to replenish and unwind at Northwick Park Hospital, one of the first UK hospitals designated to take COVID-19 patients. Similarly, staff from easyJet, Virgin, Norwegian and SAS airlines also opened first-class lounges in Whittington and North Middlesex hospitals in London.[79]

## **Systems and services:** international innovation

At every level and in every aspect of healthcare around the world, health services and industry have proven themselves capable of rising to the challenge of devising innovative solutions to the problems posed. At times, completely altering how they deliver care.

**Community** paramedics have been increasingly treating patients in their homes, in some cases with virtual assistance from physicians for the management of more complex conditions. A good example of one of these so-called mobile integrated health care programmes is Houston's Project ETHAN (Emergency Telehealth and Navigation), which proved successful in reducing the need for emergency department transfer.[80] Avera Health,

a regional health system based in the USA, sent mobile home healthcare units to assess patients and test for SARS-CoV-2, thereby averting the need for emergency department attendance.[81] Those requiring hospitalisation were then sent directly to an inpatient bed, effectively bypassing crowded emergency departments, hence protecting healthcare workers and other patients.

This innovation has been supported by telehealth, which uses electronic information and telecommunications technology (the internet, telephone communication and videoconferencing) to enable long-distance clinical care. The COVID-19 pandemic has accelerated its adoption across settings, as healthcare providers seek to protect both patients and staff from virus transmission and nosocomial infection. There has been a move away from face-to-face visits to virtual consultations, whereby patients communicate with doctors at scheduled times or on demand using their phones, tablets and computers. This system has enabled patients to stay at home while doctors, who are self-isolating, can continue working from home. This does however raise the ever pervasive issue of equality of access; it must not be assumed that a new 'digitised' service will be accesible to everyone, equally. Not everyone has access to the internet, smartphones or computers; some do not have the confidence, ability or interest to engage with digital software and applications. As such, some sections of the population – such as individuals with a disability, low-income households and older people – are at particular risk of becoming digitally excluded.

As the pandemic has forced societies to reconsider the need for routine human interactions in a **secondary care** setting, it has created an unprecedented opportunity for testing robots. Spot, the Robo-dog developed by Boston Dynamics, has been working in Boston's Brigham and Women's Hospital triage tents as an avatar for hospital workers, who remotely operate the robot and speak to patients through the iPad mounted on Spot, thereby limiting staff exposure to infection and helping to conserve protective gear.[82]

Another solution is Teladoc Health's electronic intensive care unit (e-ICU) monitoring programme. It is available in several hospitals throughout the United States and is an example of how the monitoring of up to 100 patients can be outsourced to nurses and physicians working remotely.[83] Since the outbreak of COVID-19, we have heard many heart wrenching testimonies from friends and relatives who have been prohibited from visiting loved ones in hospital. In an effort to overcome this, healthcare providers are relying increasingly on tablets and smartphones to enable contact between patients and loved ones.

The downsides of telehealth and other virtual solutions are that it does not yet allow for physical examination of patients, which is the bedrock of patient assessment, leaving physicians concerned by the prospects of missing vital presenting signs. Meanwhile, from the patient's perspective, telehealth does not allow for the oft-healing 'physician's touch' and it not an option for those not digitally connected for lack of financial means or know-how, thereby potentially perpetuating inequalities in access to healthcare.[84] To optimise video-based consultations, there is a growing need to train medical students and clinicians in "webside manner"; this creates a potential opportunity for collaboration with arts and broadcasting services.[85]

The pandemic has accelerated the transition of organisations to agility – defined as the ability to reconfigure strategy, structure, processes, people and technology quickly toward value-creating and value-protecting opportunities. There is likely to be a paradigm shift in organisations thinking about ecosystems (how all components fit together) rather than separate units. Healthcare organisations with healthy ecosystems of suppliers, partners, vendors and committed clients can develop better ways to collaborate during and after this pandemic because these relationships are trust-based.

## **Systems and services:** the UK response

As gatekeepers of the UK health service, **primary care** providers were among the first to be affected by the COVID-19 pandemic. They reorganised at pace out of a necessity to streamline COVID-19 care and to avoid propagating the virus to staff and patients alike. There has been a rapid move away from face-to-face consultations towards increased adoption of telephone, video or online consultations for remote patient triage, as well as management of routine reviews and non-urgent presentations.[86]

General practices in the UK have instituted so-called 'hot' and 'cold' clinics whereby patients with suspected COVID-19 are seen in 'hot' clinics by professionals wearing adequate personal protective equipment, while those presenting with other conditions are reviewed in 'cold' clinics by more vulnerable staff members who require some element of shielding.[87] Some practices are trialling camera technology (e.g. Lifelight First software) to monitor patients' vital signs (blood pressure, pulse, respiratory rate) in a contactless manner.[88] Non-urgent activity at general dental practices was paused at the start of the pandemic, with redirecting of dental care professionals and PPE to hospitals.[89]

In **pre-hospital care**, telephone services such as NHS 111 have assumed a greater role in patient triage. Patients with mild COVID-19 symptoms are instructed to self-isolate and given safety-netting advice, whereas those with more severe symptoms are sent an ambulance for prompt assessment. For patients with non-COVID-19 symptoms, telephone triage provides information on which local service to use.

In **secondary care**, in an effort to conserve capacity for COVID-19 care, NHS England and NHS Improvement has published over 50 specialty-specific guidelines for the management of non-COVID-19 patients during the pandemic.[90] Surgical specialties, in particular, are operating new models of care with a reduced service and new standard operating procedures. Non-urgent elective procedures were postponedtemporarily and greater emphasis placed on conservative management of patients in the first instance.[91] This gained particular traction in light of emerging evidence that contracting COVID-19 in the perioperative phase can increase mortality.[92]

With an imbalance in workload, there has, at times, been a need to redeploy staff to those services and specialties under greatest pressure. Command and control centres were established in most hospitals to monitor the number of confirmed and suspected COVID-19 cases on different wards and allocate staff (sometimes daily) to where they are most needed.

Telehealth has proven particularly useful in forward triage and thus in preventing inappropriate attendance at emergency departments and ensuring that face-to-face consultations are reserved for those patients in greatest need of physical assessment. Telehealth appointments surged, prompting a 'black swan' moment for the adoption of digital technologies that enable remote consulting, such as Livi, which provides remote consultations to the NHS and Nye health.[93]

Worsening **mental health** during the pandemic has been driven by social isolation, anxiety about job and financial losses, housing insecurity and quality, loss of coping mechanisms and reduced access to mental health services.[94] There are growing concerns over a drastic rise in the number of people with mental health problems in the coming months and possibly years. Seeking to mitigate against this, the NHS has established an urgent 24/7 mental health telephone support line to provide advice and triage patients needing urgent psychological care.[95] Moreover, mental health start-ups (such as Braive and Moment Pebble) offer programmes to help people cope with the stresses of social isolation and the continuous barrage of anxiety inducing news that they are exposed to on a daily basis.[96]

Beyond patients and hospitals, amid the developments at individual patient and hospital level, there were severaltemporary changes to the wider NHS structure, including the suspension of routine quality inspections, the replacement of existing payment systems, centralising of NHS commissioning, as well as the suspension of NHS competition rules.[97]

## **Surveillance:** international innovation

During the early stages, epidemiologists rushed to model the COVID-19 pandemic, using computer models to forecast viral transmissibility and severity, and simulate the role of non-pharmaceutical interventions to reduce mortality and healthcare demand.[98] With the resumption of near-normal social and economic activity, many governments initiated tracking and tracing strategies, with the intention to test thousands of people daily, track viral spread and ultimately trace and alert exposed individuals. These strategies enable selective isolation of confirmed and suspected cases, thereby sustaining epidemic suppression during lockdown de-escalation.

### Computer models

Numerous models that predict health, social and economic impacts have been developed to inform policymaking at national and international levels. Researchers in Hong Kong, led by Professor Gabriel Leung, created a model to nowcast and forecast the potential domestic and international spread of COVID-19 from Wuhan, China. As early as January 2020, they predicted the inevitability of outbreaks in major cities globally due to the exportation of presymptomatic cases and the lack of public health interventions, recommending quickly deployable preparedness plans.[99]

Italian scientists developed a new model named after the eight stages of infection: susceptible (S), infected (I), diagnosed (D), ailing (A), recognised (R), threatened (T), healed (H) and extinct (E), collectively termed SIDARTHE. This model concluded that restrictive social-distancing measures would need to be combined with widespread testing and contact tracing to end the ongoing COVID-19 pandemic in Italy.[100] Researchers in Wuhan ran a computer simulation to estimate the effects of physical distancing measures on the progression of COVID-19 and to inform lockdown de-escalation decisions. It found that lifting interventions suddenly could trigger further peak,s thus recommending that physical distancing measures should be relaxed gradually.[101]

Computer models and databases are useful to guide local and central government in distributing medical resources. The Institute for Health Metrics and Evaluation (IHME), part of the University of Washington, provides visual data on daily death trends, newly infected cases, and

hospital capacity (hospital beds, intensive care unit beds needed and invasive ventilators).[102] The models are continuously updated to provide predictions, but the lack of local data adds uncertainty to these.

## Track and Trace

Countries that implemented 'test, track and trace' earlier – including South Korea, Germany, New Zealand, and Canada – have fared best, while those that did not do so found themselves at an impasse. South Korea is an example of a success story; they prioritised and scaled testing at an early stage, testing on average 12,000 people a day free of charge at numerous drive-through and walk-in centres throughout the country, with results sent to people's phones within 24 hours.[103]

Since the onset of COVID-19, temperature detection technologies have been used to screen people en-masse for fever, one of the cardinal symptoms of COVID-19, and to alert central surveillance officers. In a matter of months, over 500 creative temperature detection systems have been developed, many of them in China.[104] Most use highly sensitive infrared camera thermometers. The Chinese tech company Baidu, for example, uses an infrared sensor and computer vision to detect the forehead temperature of up to 200 people a minute within a range of 0.5 degree Celsius, alerting authorities if a temperature above 37.3 degrees is detected.[105] Similarly, the MEGVII have combined AI face detection with infrared thermal imaging to locate and measure the temperature of people's foreheads.[106] Such advanced temperature screening systems were rolled out in major Beijing railway stations and over 190 supermarkets throughout China.

Confirmed and suspected cases trigger the iterative process of contract tracing, whereby anyone who has been in contact with said individuals is alerted to self-isolate and get tested. The scale and speed of viral transmission, often via asymptomatic spread, makes automated tracking and contact tracing an attractive tool. Digital contact tracing with a mobile app enables short circuiting of contact tracing rather than relying on human memory, diary-keeping and intrusive interrogation by human tracers. Many apps, including Qatar's Ehteraz apps and Singapore's TraceTogether app, are being developed to identify people who have been in proximity to a smartphone user who subsequently develops coronavirus symptoms. Using Bluetooth Low Energy signals, the app will log each time it comes into close range of other devices also running the app.

China tracks the daily movements of its citizens in many ways, such as employing face recognition technology, accessing people's GPS and spending records, and asking people to screen a QR code linked to identity cards to enter public facilities.[107] Similarly, Taiwan built "electronic fences" that track people's location to monitor adherence to quarantine rules.[108]

## Surveillance: the UK response

Among the numerous computer models, researchers from Imperial College London, led by Professor Neil Ferguson, have, most notably, developed models (SEIR) to estimate the impact of COVID-19 and the effect of non-pharmaceutical interventions in several countries.[109] The Imperial models, among others, projected high mortality figures if governments took no action, thus jolting many governments (including the UK and the USA) into changing their policies and implementing stringent suppression strategies. Models have been useful in estimating the number of undiagnosed cases. Ruiyun et al (Imperial College) applied mobility data, a networked dynamic metapopulation model, and Bayesian inference to predict the fraction of undocumented infections and their contagiousness. They estimated that 86 per cent of all infections were undocumented before the 23 January 2020 travel restrictions and that undocumented infections were the source of 79 per cent of the documented cases, explaining the rapid geographic spread of SARS-CoV-2.[110]

## Society's response

Among the uncertainty, what is clear is that COVID-19 will continue to have pervasive and lasting impacts on our lives for the foreseeable future. This unprecedented bio-psycho-social crisis has forced institutions and individuals from all walks of society to adapt and find innovative ways of going about their activities of daily living: shopping and eating, learning and working, socialising and travelling, as well as practicing their faith. The interconnectedness of our health, finances and the social fabric of our societies means that changes to the way we go about day-to-day life will have direct and indirect consequences on wellbeing, now and into the future.

## Shopping and eating

Strict government lockdown policies combined with consumer fear of contracting COVID-19 reduced spending, drastically changed the way we shop and what we buy. To make the shopping experience safer, shops and other retailers have also adapted their practices. There has been a rise in contactless payment, with many shops no longer accepting cash payments. Supermarkets have been increasing their capacity for home delivery and prioritised customers in certain age or comorbidity categories. There has been an accelerated transition towards online retail and for retail and entertainment businesses, physical distancing is becoming the new norm, requiring the redesign of space and new business models.

Restaurants and cafes have been forced to temporarily close or transition to home delivery or pick-up. Businesses have had to re-invent their offerings to this new model. Delivery companies such as Deliveroo and UberEats have seen an increased demand for their services, and fast-food chains like Domino's hired 10,000 people to keep up with demand.[111] Also, many food chains have seen this pandemic as an opportunity to engage in corporate social responsibility, and show solidarity for key-workers in particular, by providing discounts and even free meals to healthcare staff.

## Learning and research

Remote learning has become a necessity and there is a huge opportunity to study what does and does not work in an effort to provide quality education to more learners, more affordably.

There has also been an extraordinary degree of partnership and coordination. Universities that have more-mature distance-learning programmes have shared best practices and resources with those having to build e-learning solutions from scratch. In Madison, Wisconsin, a partnership between technologies giant Epic, UnityPoint Health–Meriter's Children's Centre, and UW Health has formed to provide a residential 24/7 childcare centre for parents who work on the front lines of treating COVID-19.[112]

Some scientific journals have adapted their framework for research to create rapid access formats to facilitate information sharing among professionals. For example, the British Journal of General Practice has developed COVID-19 clinical solutions to enable clinicians to share best practice, and new processes or innovations in clinical practice. Journals have been inundated with submissions of research manuscripts relevant to COVID-19 and have been trying to expedite the traditionally slow peer-review process. Many authors are instead opting to publish their articles promptly as open-access pre-prints, which have not been peer-reviewed and may therefore present erroneous conclusions. In order to elevate the good research and debunk the bad, MIT Press and the Berkeley School of Public Health are launching a new COVID-19 overlay journal called Rapid Reviews: COVID-19, which seeks to rapidly review already-published preprint articles.[113]

## Working

The lockdown has served as an accelerant for remote working and changes to rota patterns in an attempt to decrease social density and minimise disease propagation, with increased reliance on email and videoconferencing. Remote working has its upsides in that employees

may have more flexibility and could provide more balance for caring responsibilities. On the flipside, the physical and social isolation can induce negative psychosocial consequences for some. In order to cut costs, companies suffering financial hardships have had to furlough or fire staff; this has significantly affected the job security of non-key workers, many of whom are at the beginning of their careers or come from disadvantaged backgrounds.

COVID-19 could mean acceleration towards a digital wireless world with increased automation in which companies replace some human staff with computer algorithms for improved productivity, efficiency, and infection control. Moreover, governments have been encouraging people to walk or cycle to work where possible so as to not overcrowd public transport. This may have the unintended benefit of also accelerating the transition to greener modes of transport and less sedentary lifestyles, and in turn improve the health of nations.

## Travel and leisure

Inter- and intra-country travel has been restricted, as it is deemed the greatest contributor to disease transmission.

In an effort to ease the boredom and isolation ensuing from lockdown, people have been looking for new forms of entertainment and exercise, while avoiding gyms and other places where they might be more at risk of contracting COVID-19. There has been a wider availability of free cultural, music, dance, theatre, film, and opera productions streamed via online platforms. Gyms and independent fitness instructors have been producing online exercise classes, which are live streamed on YouTube or gym applications (such as Better Centres and PureGym in the UK).

## Practising faith

Countless religious institutions have been taking faith services online. Given church closures, the Vatican Easter sermon was streamed online for the first time in history. Many mosques closed their services during the holy month of Ramadan, running online lectures and recitations instead, and mass gatherings such as the annual Hajj pilgrimage have been cancelled.[114] Online services have been well attended so that religious institutions may well continue investing in online offerings. Spiritual health is often overlooked, yet an important dimension to peoples' wellbeing during a crisis.

# Conclusion

It has become a truism to say that we live in exceptionally unusual and unstable times. In just a few months, the COVID-19 pandemic crossed borders, seas and oceans, taking the lives of thousands, infecting millions and forcing billions to reckon with the economic and personal chaos of lockdown. As the global infection count rises, even the world's most advanced economies have struggled to repurpose state and private sector capacity to meet the growing demands on health services.

As outlined in this report, the crisis has given rise to many acts of ingenuity and collaboration that even the strictest of lockdowns cannot constrain. Lockdowns cannot last forever and COVID-19 is unlikely to disappear on its own. The world is leveraging its collective resources to harness the power of science, innovation and markets to devise a vaccine. Until then, we are learning to live alongside the virus. Many have stopped seeing return to previous norms as a destination and instead have started reimagining what the new normal should and will be. Sustained creativity and innovation in the UK and internationally will be essential tools in helping us shape our next normal, mitigating against misery, mayhem and mortality.

While innovation may have become a byword of the healthcare response to the pandemic, evaluation will be crucial to take stock of the impact on patients and healthcare staff. As raised by the NHS Reset campaign: "We need a consistent and forensic focus on identifying, analysing and showcasing the innovation that has happened in different settings as we seek to understand which changes are improvements and for whom – coupled with the honesty to accept not everything will stand up to this scrutiny."[115]

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