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Academy of Medical Sciences

Technology for sustainable health and social care

Summary report of the 2020 FORUM Annual Lecture

The Academy of Medical Sciences

The Academy of Medical Sciences

The Academy of Medical Sciences is the independent body in the UK representing the diversity of medical science. Our mission is to promote medical science and its translation into benefits for society. The Academy's elected Fellows are the United Kingdom's leading medical scientists from hospitals, academia, industry and the public service. We work with them to promote excellence, influence policy to improve health and wealth, nurture the next generation of medical researchers, link academia, industry and the NHS, seize international opportunities and encourage dialogue about the medical sciences.

Opinions expressed in this report do not necessarily represent the views of all participants at the event, the Academy of Medical Sciences, or its Fellows.

All web references were accessed in November 2020.

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Executive summary

Health and social care systems face the twin challenges of increasing demand and intensive competition for resources in a highly constrained financial environment. In the UK, a growing and ageing population is increasing pressures on the NHS and social care. While people are living longer, healthy life span is not increasing as fast and people are living longer in poor health. In addition, advances in medical science are adding to the portfolio of interventions available to clinicians – benefiting patients but also adding to the national healthcare bill. Despite these challenges, we are in a time of unprecedented opportunity to harness innovations in personalised prevention, early detection and diagnosis, data-driven healthcare and cutting-edge treatments to enhance the sustainability of the health and social care systems and improve the health of society.

The proportion of national income dedicated to healthcare grew steadily through most of the 20th and early 21st century, but ever-increasing healthcare expenditure is not sustainable over the long term. New technologies are seen as one key route through which the sustainability challenge can be addressed. Emerging medical and digital technologies are delivering new tools with exciting potential to delay or prevent disease, to empower people to have more control over their health and care, to improve the care that patients receive, and to transform how healthcare is delivered. These innovations will lead not only to improved health outcomes but also the dual benefits of potentially more cost-effective ways of delivering services, and of reducing the demand for some services.

The Academy of Medical Sciences' 18th FORUM Annual Lecture, held on 12 October 2020, examined a range of ways in which new technologies could transform health and social care in coming decades. Professor John A Rogers, Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering and Medicine, Northwestern University, USA, discussed the exciting potential of wireless biosensors to monitor vital signs, particularly their application in neonatal and paediatric intensive care. Then, Dr Pearse Keane, Dr Keith Grimes and Professor Karyn Morrissey summarised technological innovations in automated analysis of retinal scans to diagnose eye disease, community-based health management and remote consultations, and environmental monitoring of smart homes, respectively.

Presentations and subsequent discussions suggested that:

- **Interdisciplinary collaborations are generating a wealth of new innovations with the potential to transform healthcare.** However, the journey from proof of concept to implementation within complex health and social care systems is a major bottleneck.
- **Innovations aimed at preventing ill-health and disease are essential to enhance population health and wellbeing and to reduce demands on health systems.** A focus within health and social care systems on preventing disease and ill-health, rather than just treating disease, and focusing on patient outcomes rather than quantifying activities, could help to incentivise a change in mindset.
- **Technological solutions are typically a complement to, rather than replacement for, clinical interactions with patients.** By reducing or eliminating routine tasks, new technologies can ensure that healthcare professionals' contact time with patients is more productively used and focused on delivering care.
- **Acceptability of technology to the public, patients, and health and social care staff is as important as technical performance to the successful introduction of innovations.** This requires close engagement with patients and health and social care workers throughout the product development cycle.
- **Many innovations fall within the field of 'big data' and will require a strong emphasis on effective data management, analysis and governance, underpinned by strong public support.** Issues such as privacy and the need for non-discriminatory data analytics will be critical. To sustain public support, all stakeholders need to work to build systems that are trusted by the public, patients, and health and social care workers.

2020 FORUM Annual Lecture

The keynote lecture was given by **Professor John A Rogers**, Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering and Medicine, Northwestern University. This was followed by a panel discussion chaired by Professor Sir Robert Lechler PMedSci, President of the Academy of Medical Sciences.

Professor Rogers was joined by three guests who further explored the academic, health system and industry perspectives on new medical and digital technologies:

- **Dr Pearse Keane,** UKRI Future Leaders Fellow, Institute of Ophthalmology, University College London and Consultant Ophthalmologist, Moorfields Eye Hospital
- **Dr Keith Grimes,** Medical Director, Babylon Health
- **Professor Karyn Morrissey,** Associate Professor in the European Centre for Environment and Human Health, University of Exeter

The key points of discussion from both the lecture and subsequent debate are summarised in this meeting report. A video recording of this event is also available on the Academy's website.[1]

This meeting was convened as part of the Academy's FORUM programme, which was established in 2003 to recognise the role of industry in medical research and to catalyse connections across industry, academia and the NHS. We are grateful for the support provided by the members of this programme and are keen to encourage more organisations to take part. If you would like information on the benefits of becoming a FORUM member, please contact FORUM@acmedsci.ac.uk.

[1] Academy of Medical Sciences (2020). *2020 FORUM annual lecture 'technology to support sustainability of health and social care systems'.* https://acmedsci.ac.uk/more/events/2020-forum-annual-lecture

Introduction

The UK health and care systems face a perfect storm of challenges. On the one hand, the demand for services is increasing, particularly as the population gets older. On the other hand, the costs of healthcare continue to outpace inflation, and typically account for an ever-growing proportion of national expenditure. This in part reflects the immense success of medical science, which is constantly delivering new medicines and expanding the range of conditions that can be treated. However, innovative new medical devices and medicines, such as biological or cell-based therapies, are generally expensive and add to the national healthcare bill. New innovations coming through the biomedical research pipeline could help redress this balance, keeping people healthier and independent for longer and enabling remote care, thereby improving the sustainability of the system while also improving the nation's health.

At present, financial challenges are exerting strong pressures on public sector expenditure, including health and social care, which bring into question the long-term sustainability of health and care systems. The COVID-19 pandemic has added further complexity, not only by increasing immediate demands on healthcare and disrupting services in ways that will likely have long-term health consequences, but also by delivering a blow to national finances.

Amid this challenging picture, there are high hopes that new technologies will not only improve the quality of health and social care, but also reduce costs for the health and social care systems. Moreover, technological innovations are creating opportunities to identify risk factors and early signs of disease, and for people to better manage their own health – all of which can help to prevent disease occurring in the first place. Factors such as high take up of new consumer technologies, an extensive digital infrastructure and the nationwide NHS all provide a strong foundation for the introduction of new technologies in the UK.

For example, recent years have seen explosive growth in the ability to collect data from people and the environments in which they live, while tools such as machine learning are automating data analysis and identifying patterns in the large data sets collected. Artificial intelligence (AI) is beginning to transform how users interact with computer systems. Many of these tools are just emerging but could have a transformative impact on the nation's health.

Sensors, machine learning, AI and other digital technologies have the potential to expand the capabilities of health and social care systems, to improve the quality of services, and to enhance the cost-effectiveness of service delivery. Yet development and implementation of new technologies is complex and challenging, particularly for disruptive technologies. This FORUM meeting focused on four examples of the use of new technologies to explore some of the key issues associated with the assimilation of new technologies into health and social care systems.

Biosensors for all

"Bio-integrated sensors have the potential to transform nearly every aspect of medicine."

Professor John A Rogers

Monitoring of the body is central to medical care, and an area in which new sensor technologies are opening up opportunities to gather information on multiple aspects of bodily function and physiology. Professor John A Rogers, Northwestern University, Evanston, USA, described how advances in materials science and data analysis are creating exciting opportunities to enhance monitoring across the life course.

The past decade has seen explosive growth in the development of 'wearables' – devices worn outside the body that collect data on a wide range of physiological parameters. These all have the drawback that sensors are rigid and brittle, limiting the ability to maintain intimate contact with the skin and to collect clinical-quality data.

However, innovations in fabrication, such as the creation of silicon or other semiconductor 'ribbons',[2] as well as their embedding within elastic substrates, have enabled the development of flexible and stretchable sensors that can be applied directly to the skin.[3] Their flexibility means that they can accommodate the uneven surface structures of skin, as well as the distortions that occur as subjects move.

These flexible integrated circuits can incorporate a wide variety of sensor technologies for detecting heart rate, blood pressure and many other physiological parameters. Importantly, they can also wirelessly transmit data, so can be applied directly to the skin without the need for any connections, like a sticking plaster or temporary tattoo.

One application explored by Professor Rogers and colleagues has been in neonatal intensive care units.[4] Wireless sensors have been used to collect electrocardiography (ECG) data and to monitor skin hydration status, with data quality matching that provided by clinical-grade 'gold standard' techniques. However, the potential applications are extremely wide, encompassing detection of thermal, electrical, fluidic, mechanical, optical and mechano-acoustic measures. For example, incorporation of optoelectronic systems enables the detection of multiple

[2] Ahn JH *et al.* (2006). *Heterogeneous three-dimensional electronics by use of printed semiconductor nanomaterials.* Science **314(5806)**, 1754-7.
[3] Kim DH *et al.* (2011). *Epidermal electronics.* Science **333(6044)**, 838-43.
[4] Chung HU *et al.* (2019). *Binodal, wireless epidermal electronic systems with in-sensor analytics for neonatal intensive care.* Science **363(6430)**, eaau0780.

cardiovascular measures, including heart rate, blood pressure and blood oxygen levels.[5]

Professor Rogers and colleagues are also exploring the use of the new tools in resource-poor settings. Pilot studies are being carried out in maternal, newborn and paediatric care units in India, Pakistan, Kenya and Ghana. Because the new devices are wireless, mothers can maintain much closer contact with their babies – including 'kangaroo mother care', which has well-established benefits for neonatal health and development. The sensors also enable periods of kangaroo mother care to be detected automatically and correlated with data on vital signs in babies and mothers, revealing new insights into newborn physiology and the importance of skin contact with the mother.[6]

While demonstrating these proofs of concept, Professor Rogers and colleagues have also been addressing practical issues that would need to be resolved in order for the new devices to be deployed at scale and in low-resource settings. His group has been working with commercial partners to ensure that devices can be efficiently manufactured at an affordable cost. He suggested that current costs are around a few cents per patient-day, and that costs were likely to fall as production volumes increase and production technologies became more efficient. By the end of 2020, devices are due to be in use in 23 countries across five continents, including several low- and middle-income countries, with an estimated 15,000 pregnant women and 500 neonates being monitored by mid-2021.[7,8]

Other devices in development by his group include paediatric near-infrared spectroscopy (NIRS) for non-invasive monitoring of brain activity, foetal ECG, and neonatal electroencephalography (EEG). A further exciting application is mechano-acoustic sensing of vital signs via a device attached to a structure known as the 'suprasternal notch', at the base of the throat and top of the breastbone.[9] Sensors at this key location can detect multiple signals, providing data on speech, swallowing, heart function, respiration and coughing, alongside generic information on movement and body orientation. Potential applications include monitoring of stroke patients who are experiencing difficulties with swallowing or speech.

A further potential application could be incorporation of technology to deliver therapeutically useful stimuli to individuals being monitored. For example, for stroke patients, monitoring devices could deliver short electrical or physical stimuli to help regulate swallowing behaviour, which is often impaired in those who have suffered a stroke.

Wireless sensors attached to the body for prolonged periods could also have a role to play in the COVID-19 pandemic. The symptoms of COVID-19, such as fever, cough and shortness of breath, can be detected by autonomous sensors, which allow for 24-hour monitoring in remote locations. Professor Rogers and colleagues have been undertaking pilot monitoring studies of patients, nurses and physicians to examine how the devices might contribute to detection or monitoring of COVID-19 infections.[10]

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[5] Kim J *et al.* (2016). *Battery-free, stretchable optoelectronic systems for wireless optical characterization of the skin.* Sci Adv **2(8)**, e1600418.
[6] Chung HU *et al.* (2020). *Skin-interfaced biosensors for advanced wireless physiological monitoring in neonatal and pediatric intensive-care units.* Nat Med **26(3)**, 418-429.
[7] ClinicalTrials.gov (2019). *Limiting adverse birth outcomes in resource-limited settings (LABOR).* https://clinicaltrials.gov/ct2/show/NCT04102644
[8] ClinicalTrials.gov (2019). *Evaluation of technologies for neonates in Africa (ETNA).* https://clinicaltrials.gov/ct2/show/NCT03920761
[9] Lee K *et al.* (2020). *Mechano-acoustic sensing of physiological processes and body motions via a soft wireless device placed at the suprasternal notch.* Nat Biomed Eng **4(2)**, 148-158.
[10] Jeong H, Rogers JA, Xu S. (2020). *Continuous on-body sensing for the COVID-19 pandemic: Gaps and opportunities.* Sci Adv **6(36)**, eabd4794.

One constraint on the use of these types of device is that they are based on the detection of physical measures. Biochemical analyses could offer a wider range of applications, but would require invasive sampling, which would add considerable complications to study design and regulatory approvals. A possible alternative could be analysis of chemical secretions or sweat.[11,12] Although development work is underway, for many metabolites it is not yet clear how well levels in sweat correlate with levels in the blood.

[11] Bandodkar AJ, Jeang WJ, Ghaffari R, Rogers JA (2019). *Wearable Sensors for Biochemical Sweat Analysis.* Annu Rev Anal Chem **12(1)**, 1-22.
[12] Choi J *et al*. (2020). *Skin-Interfaced Microfluidic Systems that Combine Hard and Soft Materials for Demanding Applications in Sweat Capture and Analysis.* Adv Healthc Mater, e2000722.

Health at home, in the hand and in the hospital

Following Professor Rogers' talk, a panel of experts presented three emerging technology driven approaches that could change the way care is delivered. These technologies - using AI, remote care and technology in the home - aim to detect disease more effectively, triage care more efficiently, or prevent incidences of ill-health entirely.

A window into the soul (and body)

Dr Pearse Keane, a consultant ophthalmologist at Moorfields Eye Hospital and researcher at the University College London Institute of Ophthalmology, described how automated image analysis could have a transformative impact on the diagnosis of diseases affecting the eye.[13]

In 2017, ophthalmology overtook orthopaedics as the most intensively used UK healthcare service, with 10 million consultations per year. Now, nearly one in ten of all clinical appointments in the NHS are for eye-related issues. Delays in receiving care and treatment can have a catastrophic impact on patients, including sight loss. Automation and AI provide possible ways in which this huge and growing workload could be better managed. For example, Dr Keane was involved in a collaboration with Google DeepMind that developed an AI system trained by deep learning to interpret retinal scans and identify a range of eye conditions. Remarkably, the AI algorithm reached or exceeded the performance levels of human experts after training on fewer than 15,000 retinal scans.[14] Such advances have the potential to overcome an important bottleneck – shortages of specialists able to analyse images – thereby enabling much greater use of imaging technologies in diagnosis. An initial 'triage' by the algorithm could enable likely urgent cases to be prioritised for immediate referral to specialists.

A similar approach was used to detect diabetic eye disease through analysis of two-dimensional images, as an alternative to more involved three-dimensional imaging.[15] An algorithm trained on simple fundus images – photographs of the retina – exceeded expert performance in accuracy of diagnosis.

One important by-product of the study was the development of a secure technical infrastructure to hold patient data. This has formed the basis of a new project under the umbrella of Health Data Research UK (HDR-UK) to provide a national eye health data hub to

[13] Keane P, Topol E (2019). *Reinventing the eye exam.* Lancet **394(10215)**, 2141.
[14] De Fauw J *et al.* (2018). *Clinically applicable deep learning for diagnosis and referral in retinal disease.* Nat Med **24(9)**, 1342-1350.
[15] Varadarajan AV *et al.* (2020). *Predicting optical coherence tomography-derived diabetic macular edema grades from fundus photographs using deep learning.* Nat Commun **11(1)**, 130.

support research into detection, diagnosis and treatment.[16] This is part of a wider effort to generate national 'research-ready' health data sets.

More generally, suggested Dr Keane, the eye may provide an important window into other aspects of health. The retina offers a way to non-invasively examine neurons and blood vessels, providing clues to systemic conditions such as cardiovascular disease and neurodegenerative conditions.[17] Particular insight has come from the use of machine learning on large data sets, such as those collected by the UK Biobank project.[18] Hence, there is growing potential for readily available retinal imaging to provide diagnostic biomarkers for a range of non-eye-related conditions, such as Alzheimer's disease – an idea known as 'oculomics'.[19]

A virtual GP

One of the NHS's areas under greatest pressure is general practice. Dr Keith Grimes, Clinical Digital Health and Innovation Director at Babylon Health,[20] described how electronic tools could help better connect patients and healthcare professionals, and enable individuals to protect and manage their health.

The Babylon Health model is based on an integration of digital tools and human-based services, continuously through health, periods of illness and chronic disease. At the heart of its technology is an AI system that is a first point of contact for users, including a 'chatbot' that enables users to find out about possible causes of symptoms, based on those in the general population, and be triaged appropriately.

The technology is based on a continually updated store of medical knowledge; a comprehensive electronic health record that captures and ensures secure access to patient data; natural language processing tools to make sense of patient inputs and allow flexibility in patient reporting; and the potential to incorporate remote monitoring of patients, for example through wearables. The information collection enables an analysis to be made of an individual's lifestyle, and hence their risk of multiple conditions. Guidance can also be provided on condition management. Data also enable risk stratification to identify those most in need of further support. Babylon's technology also analyses data on symptoms and risk factors to enable the appropriate triage based on the likely cause.

The technology is intended to complement and support rather than supplant human interactions. The Babylon Health model also includes the opportunity for virtual consultations with participating NHS general practitioners, as well as physical examinations when required. As well as being more convenient for people by preventing a physical journey to their GP, it also allows for interactions with healthcare staff during infectious disease epidemics such as COVID-19. Importantly, the value of these interactions is enhanced by the availability of information on patients, symptoms and clinical measures to clinicians in advance of consultations.

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[16] https://www.insight.hdrhub.org
[17] Poplin R *et al.* (2018). *Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning.* Nat Biomed Eng **2(3)**, 158-164.
[18] Chua SYL *et al.* (2019). *Cohort profile: design and methods in the eye and vision consortium of UK Biobank.* BMJ Open **9(2)**, e025077.
[19] Wagner SK *et al.* (2009). *Insights into Systemic Disease through Retinal Imaging-Based Oculomics.* Transl Vis Sci Technol **9(2)**, 6.
[20] https://www.babylonhealth.com

Houses, homes and happiness

Health and wellbeing are strongly influenced by environmental factors, including the environments in which we live and work, and our social connectedness. Collectively, social determinants of health have a greater impact on health and wellbeing than healthcare.[21] As well as data from individuals, information can now be remotely collected on multiple environmental factors with the potential to affect health, and analysed to identify correlations between such factors and health outcomes. Professor Karyn Morrissey, at the European Centre for the Environment and Human Health, University of Exeter, described how the EU-ERDF funded Smartline project is taking this approach in the South-West of England.[22]

Seeking to understand the role that digital technology can play in addressing health and wellbeing, the Smartline project has installed an extensive digital infrastructure to collect indoor environmental data across 250 households in coastal towns. These households are all social housing tenants and, whilst social housing properties are generally well maintained, tenants of social housing are on average an older, lower-income population, with complex health needs. The environmental information collected is being integrated with more traditional data types such as surveys and interviews to tease apart key influences on health and wellbeing in the home and wider community.[23]

The project involves a wide range of stakeholders, including local housing associations and digital enterprises. It also aims to develop a better understanding of the digital technology readiness of individuals and communities, and to raise awareness of their needs in order to encourage innovation to address them.

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[21] The King's Fund. *Broader determinants of health: Future trends.* https://www.kingsfund.org.uk/projects/time-think-differently/trends-broader-determinants-health

[22] https://www.smartline.org.uk

[23] Moses L, Morrissey K, Sharpe RA, Taylor T (2019). *Exposure to Indoor Mouldy Odour Increases the Risk of Asthma in Older Adults Living in Social Housing.* Int J Environ Res Public Health **16(14)**, 2600.

Cross-cutting themes

Following the presentations, all four speakers took part in a discussion session with the audience. Discussions focused on some of the wider societal, structural and technological considerations that need to be addressed to enable the widespread adoption of the technologies discussed. These themes cut across all types of technologies and make the case for developers, users and commissioners of technologies to work together in supporting their use for the benefit of both the health of society and the sustainability of health and social care systems.

The need for interdisciplinarity

All the technological solutions discussed were based on extensive interdisciplinary collaborations. For example, sensor technology development relies on partnerships between materials scientists, engineers, data scientists and clinicians. Some of the most important insights come from groups such as nurses, who have unique insights into the practical challenges and opportunities in patient care.

In addition, moving from research and proof of concept to implementation calls for additional skills in innovation and new product development, regulatory approvals, manufacture and distribution, emphasising the importance of connections across academia, industry, the health and social care systems and the wider regulatory sector.

Quality and efficiency of care delivery

Many technological innovations have the potential to enhance or extend the quality of care delivered. Resourcing implications may not be clear and may be complex to determine. In particular, new technologies may have great potential to reduce the time spent by clinicians on tasks such as collating patient data. This may allow more of clinicians' time to be spent on productive interactions with patients.

This may be particularly important in low-resource settings, where there may be fewer clinicians per capita. Tools that can save clinicians' time, support more effective triaging of patients, or enable task-shifting could ensure that the best possible use is made of a scarce human resource.

Acceptability to the public, patients, and health and social care professionals

All presenters highlighted the importance of engaging with individuals and patients to build trust and ensure the acceptability of new technologies. Ideally, such groups should also be involved in the design of new technological innovations, which is likely to enhance their acceptability and improve usability.

Acceptability to healthcare workers was also seen as critical. Failure to consider practical issues, including existing systems and ways of working, can be a major obstacle to the adoption of new technological innovations in health and social care settings.

Patient-centred tools and empowerment

Related to this point, discussants noted the importance of considering existing patient experience with technology. In particular, the high penetration of mobile phones, even in low-resource settings, makes them highly attractive vehicles for delivering new technological innovations.

However, even in high-income settings, smartphones may not necessarily be in common usage, particularly in certain groups, such as older age groups and socio-economically disadvantaged populations. In low-resource settings, less technologically advanced phones ('feature phones') may be more common, and factors such as shared usage may add further complications. Technological solutions need to be tailored to the consumer tools available in particular settings, with sophisticated analytics potentially taking place centrally rather than on user devices. This further emphasises the need to engage users in design.

Preventing the digital divide and exacerbation of health inequalities

Given unequal access to communication technologies, such as broadband internet connections or smartphones, there is a risk that technological innovations might magnify existing health inequalities. Attention needs to be given to differing levels of access to and familiarity with new technologies to avoid worsening of health inequalities. Conversely, new communication technology could help to reduce barriers to healthcare use, such as travel or long waiting times.

Robust data governance is essential in a connected future

Many of the technological innovations discussed lie in the realm of big data. Any applications involving patient data raise issues of data management and governance, and the ability to provide access to data while safeguarding patient confidentiality. Participants stressed the importance of strong engagement with patients and rigorous systems to ensure data security. It will also be critical to ensure that data analytic systems are sensitive to the diversity of the UK population and do not embed ethnic or other biases.

A further key point emphasised was the importance of data standards and interoperability of data management systems to ensure data quality and efficient sharing of data.

Cloud-based approaches were seen as offering multiple advantages, including rigorous data security, storage capacity and processing power.[24] The endorsement by NHS Digital of cloud-based approaches, and publication of guidance on use of cloud-based services,[25] was welcomed. Use of 5G networks was also seen as potentially offering powerful new opportunities, with the caveat that such networks are not yet available to all.

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[24] Keane PA, Topol EJ (2020*). Medicine and meteorology: Cloud, connectivity, and care.* Lancet **395(10233)**, 1334.

[25] NHS (2018). *NHS and social care data: off-shoring and the use of public cloud services.* https://digital.nhs.uk/data-and-information/looking-after-information/data-security-and-information-governance/nhs-and-social-care-data-off-shoring-and-the-use-of-public-cloud-services

Responsive regulation to adapt to new challenges

It was also recognised that the growing use of AI presented challenges to regulatory authorities. For 'autonomous' tools, designed to provide a specific answer, existing guidelines related to medical devices may be appropriate to ensure the safety of these specific tools. In this case, software developers and product manufacturers of these tools would have a responsibility for ensuring that their products safely and reliably do what they are intended to do, and would be held accountable for any failings.

However, the situation becomes less clear when software tools are used to inform clinical decision-making. A clinician will ultimately be held accountable for his or her actions but may be strongly influenced by analytic tools. This raises questions of how well a clinician should be expected to understand what an AI or other tool is doing. A further complication is that some AI systems are typically 'black boxes' (data in, answer out) and it may not necessarily be clear from the outside how their algorithms are operating, or how new versions of the algorithm change over time.

In addition, liability for harm often arises when clinicians are seen to deviate from what is considered standard clinical practice. Yet the value of AI may be in identifying care more tailored to individuals, rather than standardised treatments. These complexities emphasise the importance of early and regular dialogue between product developers, users and regulatory authorities.

Adoption and implementation remain a challenge

This is a time of great innovation in healthcare, with emerging technologies offering many new opportunities to rethink how care is delivered. However, adoption of new technologies within the NHS is generally slow. There are a multitude of factors influencing take up of digital innovations, from health system fragmentation to organisational cultures that are often risk averse when it comes to the adoption of new innovations.[26] It was acknowledged that moving from proof of concept to widespread adoption in the healthcare system was highly challenging. In a system like the NHS that is in practice highly devolved, with individual institutions or organisational units able to make their own decisions, it was suggested that bottom-up adoption might be more effective than top-down policy-driven initiatives. At the same time, it is essential that any new technology, particularly patient facing technology, should be acceptable and easily accessible to the general public.

Demonstrating the cost-effectiveness of new technologies could be challenging

Given the financial constraints on health and social care systems, cost-effectiveness assessments inevitably have a major impact on adoption. However, introduction of new technologies presents major challenges to such assessments. For example, they may be associated with high upfront costs and financial benefits that are hard to quantify, likely to accrue far in the future, or in different domains. Siloed and short-term approaches to budgeting can therefore make it difficult to justify investment decisions. It was suggested that strategic decision-making needed to take a 'whole system' perspective to address this challenge.

[26] Asthana S, Jones R, Sheaff R (2019). *Why does the NHS struggle to adopt eHealth innovations? A review of macro, meso and micro factors.* BMC Health Serv Res **19(1)**, 984

Conclusion

The panel agreed that emerging technologies have the potential to have a transformative impact on health and social care systems. In the UK, and globally, a vibrant research community is working across disciplinary barriers to address some of the major challenges facing healthcare in the 21st century. With ongoing financial pressures on health and social care systems, exacerbated by the COVID-19 pandemic, as well as the challenges of ageing populations, there is an urgent need to identify how health and social care systems can deliver high-quality care in a sustainable way and how more emphasis can be given to health promotion.

With a rich pipeline of innovation, a major challenge remains the receptiveness of the NHS and social care systems to digital and other innovations. This reflects structural, institutional and individual barriers to adoption of new tools and practices that need to be systematically identified and addressed. Clearer pathways for the adoption of innovation need to be identified. In addition, the training of the health and social care workforce needs to include a stronger focus on greater openness to innovative practices.

One important change needs to be the shift in emphasis from disease treatment to health promotion. New technologies are providing ever-greater opportunities for individuals and health systems to focus on maintaining good health and wellbeing, rather than intervening when ill-health has already developed. As well as helping to support healthier lifestyles, technological innovations are increasingly providing opportunities to identify disease or pre-disease states early, and to delay and better manage disease progression and complications – a win–win for patients and health systems. Disease prevention will be fundamental to the sustainability of both the health and social care systems.

To support this shift in mindset, health systems need to focus on improving health outcomes as an overall goal, rather than simply quantifying healthcare activities. This would naturally drive a greater focus on prevention and incentivise change.

The COVID-19 pandemic has accentuated deep-seated challenges within the health system and public health. But it has also stimulated creative thinking and catalysed changes in practice that in some cases were overdue. This has included both increasing use of virtual consultations[27] to rapid analysis of data in 17 million electronic patient records to identify factors associated with poor COVID-19 outcomes.[28] While coping with COVID-19 is absorbing time and money, it may also be opening up opportunities to consider how healthcare can be enhanced – not least by the adoption of new technology.

[27] Gerada C (2020). *Primary care has transformed into a 'dial-in' or 'click first' service.* Health Service Journal, March 27. https://www.hsj.co.uk/technology-and-innovation/primary-care-has-transformed-into-a-dial-in-or-click-first-service/7027249.article

[28] Williamson EJ, *et al.* (2020). *Factors associated with COVID-19-related death using OpenSAFELY.* Nature **584(7821)**, 430-436.

Annex I - Agenda

Monday 12 October 2020, 15.00-17.00

2020 FORUM Annual Lecture - Technology for sustainable health and care	
15.00 – 15.05	Welcome and introduction Professor Sir Robert Lechler PMedSci (Chair), President, Academy of Medical Sciences
15.05 – 15.44	Keynote Professor John A Rogers, Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering and Medicine, Northwestern University
15.40 – 16.45	Panel discussion: 'Technology to support sustainability of health and social care systems' Chaired by Professor Sir Robert Lechler PMedSci, President, Academy of Medical Sciences • Professor John A Rogers, Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering and Medicine, Northwestern University • Dr Pearse Keane, UKRI Future Leaders Fellow, Institute of Ophthalmology, University College London and Consultant Ophthalmologist, Moorfields Eye Hospital • Dr Keith Grimes, Medical Director, Babylon Health • Professor Karyn Morrissey, Associate Professor in the European Centre for Environment and Human Health, University of Exeter
16.45 – 16.50	Closing comments from the President Professor Sir Robert Lechler PMedSci (Chair), President, Academy of Medical Sciences

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