PHILIPS

Imperial College London
Consultants

Reducing healthcare inequalities and enhancing the NHS

Dr Leigh Warren, Dr Jonathan Clarke
Imperial College London

This report is the independent opinion of the authors

Contents

Introduction

Reducing health inequality means giving all individuals an equal chance to live a long and healthy life, regardless of who they are or where they live. In the United Kingdom (UK), health outcomes are not equal across individuals and regions. The Marmot Review 10 Years On highlights that between 2016 and 2018, men living in the least deprived 10% of England had a life expectancy 9.5 years longer than men in the most deprived 10% of areas. For women the gap was 7.7 years[1]. People living in more deprived areas of the UK also spend more of their already shorter lives living with the burdens of ill-health than those in less deprived areas[1]. Inequalities exist across a range of social determinants including where people are born, live, work, and the resources they have available to live a healthy life.

The COVID-19 pandemic has imposed unique challenges on health services and individuals across the globe. The impact of this pandemic has disproportionately affected people that live in the most deprived areas, further exacerbating health and social inequalities in the UK[2]. The effects of COVID-19 on health service capacity, and the ability for the National Health Service (NHS) to diagnose and treat disease, are predicted to persist for several years[3]. There has never been a more important time to ensure that access to high-quality healthcare is fairly distributed and nobody is left behind.

Good health allows people to live their best lives, physically, mentally and socially[4]. Healthy individuals are happier and more productive members of society[5]. Increasingly, healthcare does not start and end at the doors of the hospital or GP clinic. Opportunities to prevent illness begin before birth and continue throughout life. Through the challenges of the COVID-19 pandemic, new ways of managing health and wellbeing have emerged that have disrupted existing systems of care delivery. More than ever before, advances in technologies, diagnostics and therapies offer the opportunity for the 66 million people living in the UK to live longer, healthier lives. As these innovations mature, we need to ensure that the benefits of advances in healthcare technologies reach those who most need them. Collaboration between patients, providers, government and industry partners is required to help the NHS to thrive and remain a world leading health system during this transition.

Through the analysis of a range of health outcomes in the UK, this report examines existing and new research findings relating to healthcare inequalities. Some of the questions that this report attempts to answer include: **How can health inequalities in the UK be reduced? and What is the role for data and digital technologies in evening-out health outcomes, enhancing the NHS and allowing people to live their best lives?** In each section of this report, evidence-based policy recommendations provide targeted guidance on the fair and sustainable application of interventions and transformative innovations in the NHS.

Report Research Methods: **Key Points**

In this report, several statistical analyses address questions related to health inequalities in the UK. The data used in these analyses are drawn from a number of different sources, including the 2019 Indices of Multiple Deprivation and most the recently available NHS statistical publications. A full description of the data sources and methods used in these analyses are available in the supplementary methods report here.

Since 1999, responsibility for health services in the UK has been devolved to administrations in Scotland, Wales and Northern Ireland. Administrations in each country have powers to determine health expenditure, resource allocation and what their policy priorities should be, as the UK Government does for England[106]. Figure 2 shows a composite map of the UK demonstrating the distribution of relative deprivation in each country.

Much of the data collected by national statistical authorities is not directly comparable, which is reflected in the data presented in this report. Where analyses are specific to a single country, this country generally has the most comprehensive available data to answer the specific research question under consideration. For the majority of analyses, English data is used and the limitations of generalisability to the rest of the UK should be considered.

Research Methods: **Hospital-Level Analyses**

Several hospital care-level analyses in this section used hospital trust-level data from hospitals in England. Using the approach described in the methods supplement, each included acute hospital trust was allocated a catchment area, which was correlated with a deprivation score based on the deprivation levels of constituent LSOAs. The distribution of deprivation in England, according to the catchment areas of hospital trusts, is shown in Figure 1.

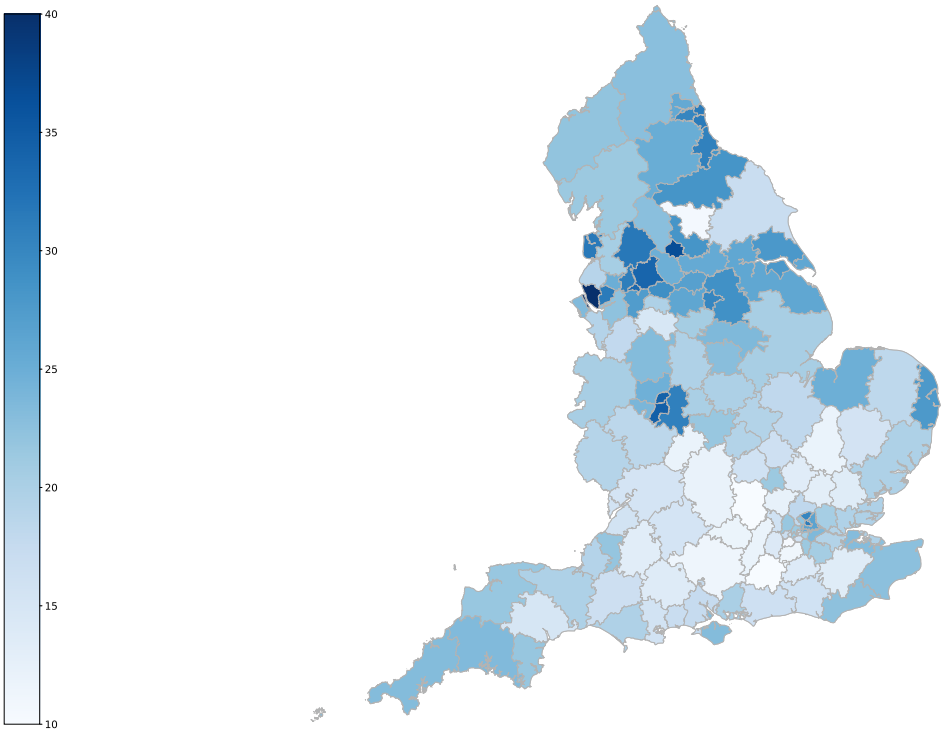


Figure 1 – Map of England showing the distribution of hospital trust catchment areas and corresponding deprivation scores in England. Deprivation scores ranged from 9.2 (least deprived) to 41.8 (most deprived). Data source: 2019 Indices of Multiple Deprivation[6].

Areas of deprivation

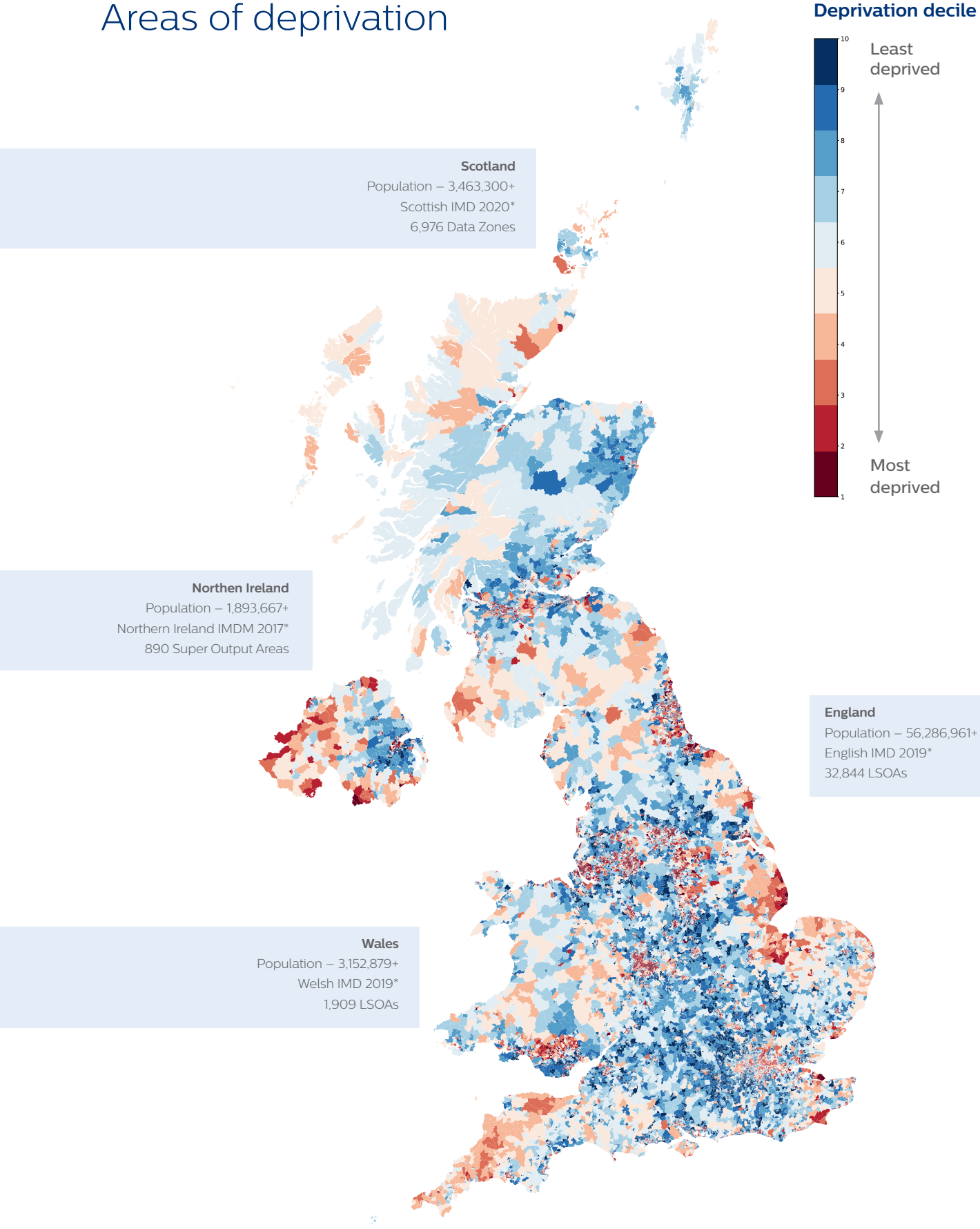


*Figure 2 - Distribution of areas of deprivation in the United Kingdom, ranging from 1 (most deprived – red) to 10 (least deprived – blue). For each country in the UK, population estimates, the name of that country's indices of multiple deprivation and the name and number of constituent areas is included. Further details on indices per country are included in the methods supplement. *Note that each country independently defines indices of deprivation and the number of individuals living in each constituent area – indices are therefore not directly comparable between countries. +Population estimates according to ONS Population Estimates 2018.*

1. Tackling Health Inequalities: **The State of The Nation**

Key Points

- In the UK, people living in more deprived areas have lower life expectancy, live less years of healthy life and suffer from more long-term health conditions
- Patients living in deprived areas have more complex health issues, more consultations with their GPs and more difficulty accessing GP appointments than patients living in less deprived areas
- Diagnostic test waiting times, cancer waiting times and consultant-led referral-to-treatment waiting times are, on average, the same or slightly better in English NHS hospital trusts that care for more deprived communities
- People living in the most deprived areas of England have twice as many contacts with emergency health services as the same number of people living in the least deprived areas
- Hospital trusts that care for the most deprived communities are, on average, more digitally mature
- Although almost all GP clinics in the UK are using electronic health records, many hospital trusts are still using paper records, which is a barrier to the efficient sharing of health data
- In the UK, patient's health data is often held in data silos and fragmented between different providers and settings
- Environmental issues, including housing, overcrowding, climate change and air quality disproportionately affect people living in deprived areas of the UK and contribute to health inequalities
- Over the next decade, the number of people over the age of 65 living in the UK is predicted to increase by 33 per cent - this aging population will place additional strain on health services

In 1970, in The Lancet, Welsh General Practitioner Julian Tudor Hart wrote that "the availability of good medical care tends to vary inversely with the need for it in the population served"[7]. At that time, it was noted that "In areas with most sickness and death, general practitioners have more work, larger lists, less hospital support, and inherit more clinically ineffective traditions of consultation, than in the healthiest areas; and hospital doctors shoulder heavier case-loads with less staff and equipment, more obsolete buildings, and suffer recurrent crises in the availability of beds and replacement staff"[7].

Although the NHS has undergone several changes and improvements in recent decades, inequalities at a patient, provider and system-level persist. Overall life expectancy remains considerably lower for individuals living in deprived areas, as does healthy life expectancy; the time spend in 'good' or 'very good' health, and disability-free life expectancy; the time spent without conditions or illnesses that limit people's ability to carry out day-to-day activities[8].

There are particular types of diseases that affect the gap in life expectancy between areas of deprivation in the UK. Higher mortality rates in the most deprived groups of individuals for heart disease, lung cancer and chronic respiratory diseases, contribute the most to the life expectancy gap in both sexes[9]. Smoking and obesity are the main risk factors for these diseases[9].

Health services in the UK face huge challenges over the coming decade. The number of people over the age of 65 living in the UK is predicted to increase by 33 per cent[10]. Over this same period, the number of working age adults is predicted to rise by only 2 per cent[10]. Health inequality is associated with an estimated cost of £12.52 billion to the NHS, productivity losses of over £30 billion and lost taxes and higher welfare payments in the range of £20-32 billion[1]. The discrepancy between healthcare demand and resource supply will place huge strain on existing health services in the UK.

Increasing pressures on the NHS are already being reflected in health service performance metrics. In 2019, waiting times for diagnostics, consultant-led treatment and cancer treatment were all at record high levels[11]. Over 15% of patients spent over 4 hours in English A&E departments in 2019 – the worst annual performance on record[11]. There were almost five times as many long waits for admission to hospitals in 2019 compared with 2013[11].

Growing demands on the NHS mean a shift towards preventative health care will be required to help prevent ill health rather than waiting for people to get ill and access health services[10]. A transformation in approaches to health and wellbeing at community and primary care levels needs to be accessible, effective and sustainable for all individuals. Digital technologies have a huge role to play in this rethinking of the way that care is delivered[10].

Deprivation in Coastal Communities

Coastal areas and former seaside resorts represent some of the most deprived neighbourhoods (LSOAs) in the UK[12,13]. Many of these areas that previously thrived on tourism have faced challenges in recent decades as people increasingly travel abroad for holidays. Analyses of the English Indices of Multiple Deprivation shows that, on average, these areas have higher levels of overall deprivation, as shown in Figure 3.

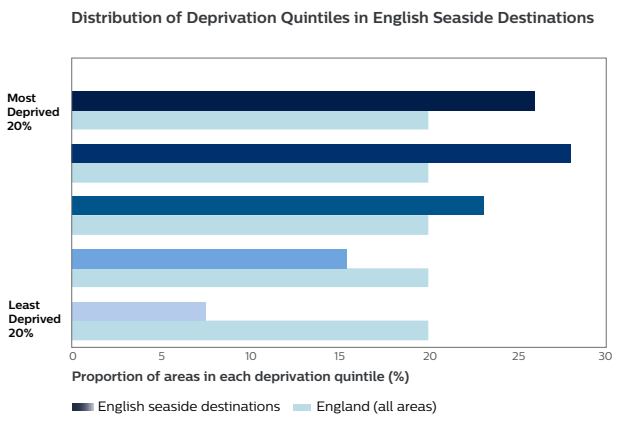


Figure 3 – Distribution of overall deprivation quintiles in LSOA areas defined as 'English Seaside Destinations' by the Office for National Statistics. Data source: Office for National Statistics[12].

Coastal areas in the UK also have higher levels of disability and specific health deprivation[12]. As shown in Figure 4, 30.8% of neighbourhoods in English seaside destinations are amongst the most deprived areas in the country for health deprivation and disability. Only 3% of these neighbourhoods are amongst the least deprived areas in England for health deprivation and disability.

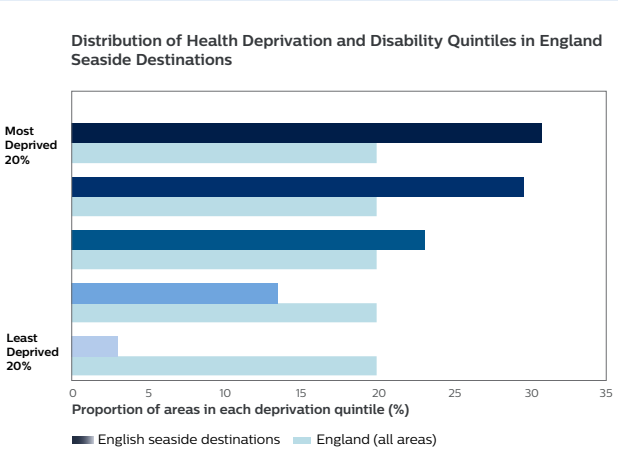


Figure 4 - Distribution of health deprivation and disability quintiles in LSOA areas defined as 'English Seaside Destinations' by the Office for National Statistics. Data source: Office for National Statistics[12]

The combination of a coastal location and limited transport infrastructure leaves people from many seaside towns with reduced access to larger conurbations, where many of their nearest specialist health services are delivered. Recruitment and retention of specialist clinical staff can also be more challenging in in rural and coastal areas, which affects care delivery and availability[14]. In many coastal areas, national funding formulae do not adequately match local healthcare needs[13].

Enhancing the NHS and reducing health inequalities in coastal areas requires more than just funding for health services[15]. Community-level initiatives to promote economic growth in coastal areas can contribute to sustainable improvements health and social wellbeing. Initiatives such as the Coastal Communities Alliance[16] and the UK Government Coastal Communities Fund[17] have aimed to help coastal communities to flourish and strengthen their appeal as places to live, work and visit.

Primary Care

People's health is shaped by the complex interaction between many factors, including behaviours, environment, education, income and health and care services. Primary and social care services sit at the front line of these intertwined factors that contribute to inequalities in health and wellbeing. In the NHS, access to investigations and interventions to address health issues and reduce the burden of deprivation is often coordinated at a primary care level.

The rate of GP consultations per patient living in the most deprived areas is 18% higher than those living in the least deprived quintiles[18], as shown in Figure 5. An individual aged 50 in the most deprived quintile consults their GP, on average, at the same rate as someone aged 70 in the least deprived quintile[19]. These results indicate that patients living in deprived areas are more likely to have GP appointments and, when they do, appointments are likely to be more complicated, due to the increased burden of long-term health conditions in these patients[20].

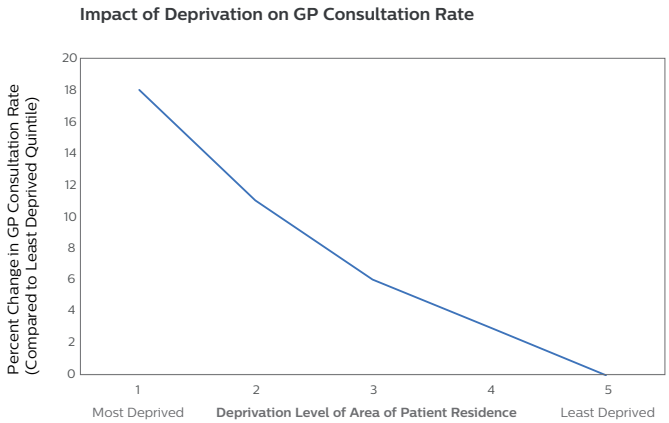


Figure 5 - Percent difference in rate of patient GP consultations per deprivation quintile of patient residence. Data source: British Journal of General Practice[18].

A chronic shortage of GPs and increasingly complex workloads have left patients finding it more and more difficult to book an appointment with their GP[21]. A 2019 survey of almost 3000 people by the National Centre for Social Research assessed views and attitudes on health care services in the UK[22]. Figure 6 displays some of these views, demonstrating considerable differences on primary healthcare services depending on level of deprivation.

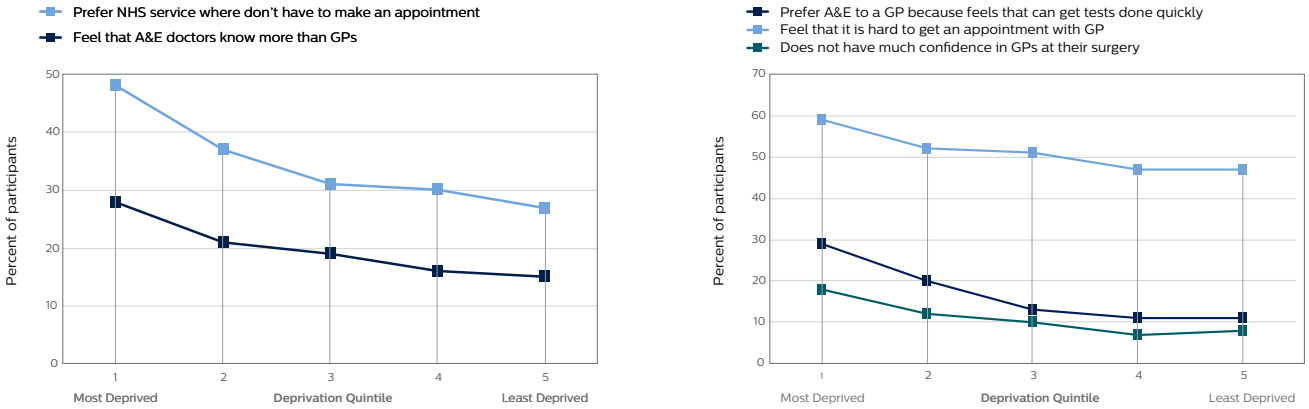


Figure 6 - Perspectives on primary care services and access across deprivation quintiles in the UK. Data source: National Centre for Social Research – 2019 British Social Attitudes Survey[22].

Just over half of people living in the UK find it hard to get a GP appointment[22]. This perceived difficulty in accessing GP appointments was worse for patients with complex health needs – 61% of patients who had visited A&E three or more times in the previous 12 months reported difficulty getting a GP appointment[22]. Those living in more deprived areas also found it harder to get a GP appointment, with 59% in the most deprived quintile reporting difficulty, compared with 47% in the least deprived quintile, as shown in Figure 3[22]. People living in more deprived areas were also much more likely to prefer services where they don't have to make an appointment[22].

People living in deprived areas in the UK reported the lowest confidence in GPs – People living in more deprived areas were more likely to prefer going to A&E than to their GP as they felt that they could get tests done more quickly, as shown in Figure 6[22]. As shown in Figure 7, more deprived groups were also less confident deciding when they need to see a doctor and less likely to have family and friends that could provide care, adding to the impact of poor health[22].

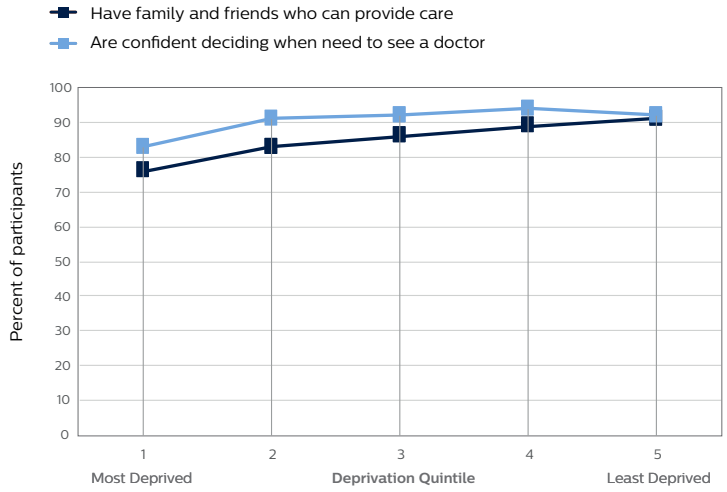


Figure 7 - Proportion of patients with family and friends that can provide care and patient confidence in deciding when need to see a doctor across deprivation quintiles. Data source: National Centre for Social Research – 2019 British Social Attitudes Survey[22].

Communication issues with secondary care have exacerbated GP workloads[23]. Chasing patient records and test results from one or more hospitals that an individual patient has attended is a considerable burden for GPs. Patients suffer when their health information is not available for clinicians to review in the right place at the right time[24].

An increase in GP workload has not been matched by a proportionate increase in funding or staffing[23]. Concerningly, the number of permanent qualified GPs has fallen 6% since 2015[11]. Working in communities with high levels of deprivation puts additional pressure on general practice, and this is not necessarily reflected in funding allocations[23]. Some patients, such as those living in deprived coastal communities, may have difficulty travelling to specialist centres due to limited transport infrastructure[13]. This further adds to the burden on General Practice in these areas. General funding through financial incentive schemes attempt to address issues of deprivation in primary care, however these may not account for the large disparity of workload associated with managing the intersection of health, wellbeing and social needs in deprived areas[25].

GPs need to be supported to improve access and maintain continuity of care. Patients with chronic conditions and multimorbidity are less likely to receive continuity of care, although they may be more likely to gain from it[26]. There is a clear opportunity for digital technologies to help to bridge the gaps in data sharing between settings, care teams and individual providers[27].

Hospital-Level Care

NHS hospitals provide the majority of acute care in the UK and a large proportion of diagnostic testing[11]. Although NHS policies for many years have sought to reduce reliance on secondary care services, hospitals continue to form the backbone of acute care in the UK. In the NHS, allocation processes use a statistical formula to make distribution of resources fair and objective, so that funding reflects local healthcare need and helps to reduce health inequalities[28]. Despite these interventions to distribute resources where they are most needed, there are still aspects of hospital care that could be addressed to improve health outcomes in the most deprived areas.

Despite a significant increase in the number of patients treated in the UK in recent decades, the total number of hospital beds has decreased dramatically. In England, for example, the total number of general and acute, mental illness, learning disability, maternity and day-only beds has reduced from around 299,000 in 1987/88 to 141,000 in 2018/19[29]. The UK also has fewer hospital beds per capita than many other comparable health systems. In the UK, there are approximately 2.5 beds per 1000 inhabitants, compared with 6 per 1000 in France and 8 beds per 1000 inhabitants in Germany[29]. These changes reflect policies to reduce the NHS's reliance on hospitals and bed-based care. To compensate for a reduced number of beds, the NHS needs to ensure that robust systems are in place to ensure patients continue to receive safe, high quality care without being admitted to hospital.

Increased pressures on NHS hospitals are affecting care for patients and working conditions for hospital staff[30]. In 2019, A&E attendances in England rose by almost 5% and waiting lists for treatment and cancer care have risen to record levels[11]. Staff shortages persist across health services in the UK[14]. The NHS in Scotland had 16% more consultant vacancies in 2019 compared with 2018[31]. Nursing and midwifery vacancies increased by 17% over the year, representing a shortage of 3600 nurses and midwives in Scotland. Mental health staff vacancies increased by a huge 42%[31]. In England, numbers of hospital doctors are increasing, with 13% more doctors than 5 years ago[11], although many doctors remain dissatisfied with their work and report NHS staffing levels or workload as the most challenging aspects of their job[32].

People living in the most deprived communities account for twice as many presentations to emergency health services than those living in the least deprived areas[33,34]. In England, people living in the most deprived 10% of areas accounted for 3 million A&E department attendances (55,600 per 100,000 people), compared to 1.5 million (28,700 per 100,000 people) attendances by people living in the least deprived 10% of areas[34]. Figure 8 shows the number of A&E attendances in England by deprivation quintiles for 2018-2019. Similar patterns of increased rates of A&E attendances in the most deprived groups was seen across all countries in the UK[34–37].

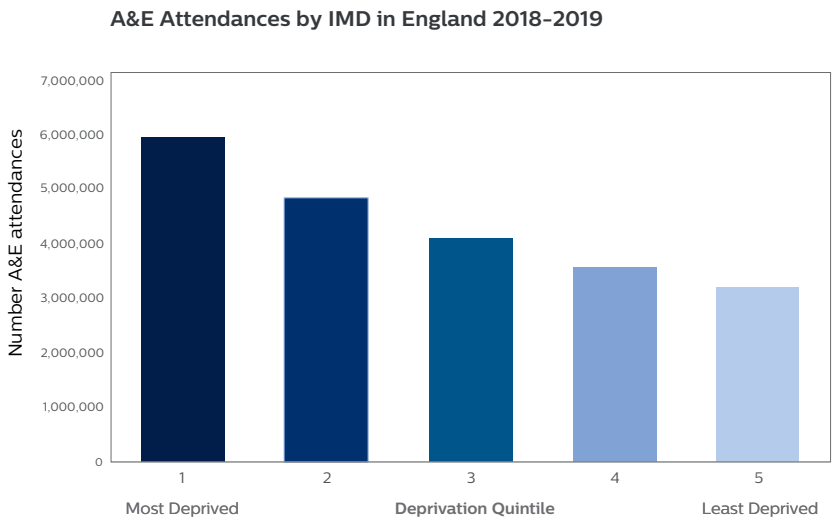


Figure 8 - Accident and Emergency (A&E) attendances by Indices of Multiple Deprivation (IMD) quintiles in the 12-month period in England between 2018-2019. Data source: NHS Digital - Hospital Accident & Emergency Activity 2018-19[34].

Diagnostics

The ability of the NHS to meet growing demand for diagnostic services is crucial to ensuring a proactive, sustainable system that can care for all individuals. Many conditions such as cancer, cardiovascular and respiratory diseases that often require more advanced diagnostics are closely linked with social determinants of health such as employment, environments and socioeconomic status[1]. As with most NHS services, there are increasing demands on access to diagnostics across the UK[38].

Access to early testing for diseases provides the best opportunity for early detection and secondary disease prevention. It is the responsibility of providers, government and industry to ensure that diagnostics are available for vulnerable individuals. There is a potential that poorer health outcomes in deprived areas are exacerbated by increased waiting times for diagnostic tests, delayed referral to treatment and delays accessing surgery or therapies.

In 2019, there were 23.6 million diagnostic tests performed in England's hospitals, an increase of 4.4% in 12 months, and 26% in five years[11]. The number of MRI tests has increased by 29% over the past five years in England and the number of CT scans has increased by 38%[11]. There were an average of 64,664 diagnostic tests performed each day in England in 2019, compared with 51,446 tests per day in 2014[11]. **Waiting times for diagnostic tests in England in 2019 were, overall, at their highest levels since 2008, with some trusts breaching targets[11].** Waiting times do, however, vary considerably between hospitals[38]. Using the methods described in the methods supplement, we compared hospital-level diagnostics waiting times with hospital trust catchment area deprivation levels.

As seen in Figure 9 and Figure 10, hospitals caring for the most deprived communities had some of the lowest proportions of patients waiting for diagnostic tests for more than six weeks and more than thirteen weeks. This interesting finding likely reflects the quality of care provided through several of these hospitals that care for deprived communities, in addition to NHS hospital funding allocations that aim to increase funding in accordance with area deprivation[28]. These findings highlight the importance of community and primary-level care for people living in more deprived areas in the UK to ensure that people are adequately screened and referred for diagnostics to address the increased burden of disease.

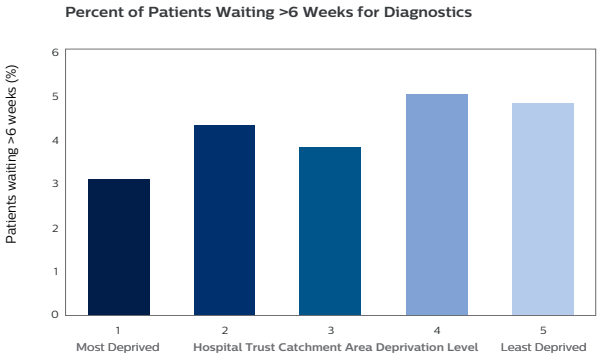


Figure 9 - Percent of patients waiting for diagnostics for more than 6 weeks across hospital-trust deprivation level quintiles. Data source: NHS England Diagnostic Waiting Times and Activity[38].

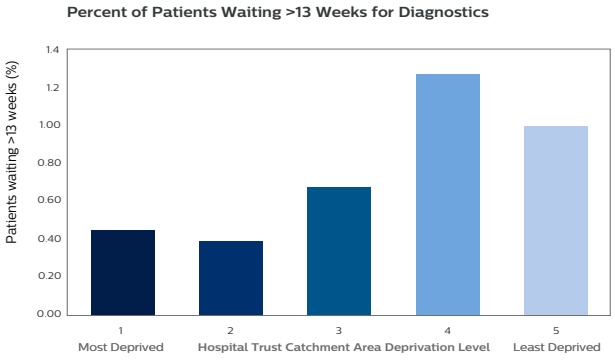


Figure 10 - Percent of patients waiting for diagnostics for more than 13 weeks across hospital-trust deprivation level quintiles. Data source: NHS England Diagnostic Waiting Times and Activity[38].

Case study: **Heart and Circulatory Disease, Deprivation and a Potential Role for Artificial Intelligence (AI)**

In the UK, over 7.4 million people are currently living with heart and circulatory diseases[39]. The already high prevalence of these diseases, which includes coronary disease, heart failure, atrial fibrillation and stroke, is predicted to significantly rise in coming decades[39]. Many heart and circulatory diseases are chronic, affecting people's ability to live healthy lives. Furthermore, these diseases lead to premature deaths for around 44,000 people in the UK every year[39].

Recent advances in diagnostics and mobile technologies provide future opportunities for early detection and prevention of disease, while reducing demands on healthcare systems[40,41]. The application of artificial intelligence to cardiovascular imaging data, for example, when combined with electronic health record data, can better characterise disease and personalise therapy for patients[40].

As shown in Figure 11, heart and circulatory diseases disproportionately affect people living in more deprived parts of the UK. 13.4% of males residing in the most deprived areas of the UK are living with heart and circulatory diseases, compared with 10% residing in the least deprived areas. Females residing in more deprived areas are also more likely to be affected.

Improving access to diagnostic tests and monitoring for people living in deprived communities could contribute to earlier diagnosis and better outcomes for patients with heart and circulatory diseases[42]. Service-level limitations to diagnostics, such as monitoring equipment and interpretation of imaging results, are modifiable factors at a system and organisation level. Digital advances like this represent a significant opportunity to transform outcomes for many patients around the world, with the benefits felt most acutely by individuals living in deprived communities.

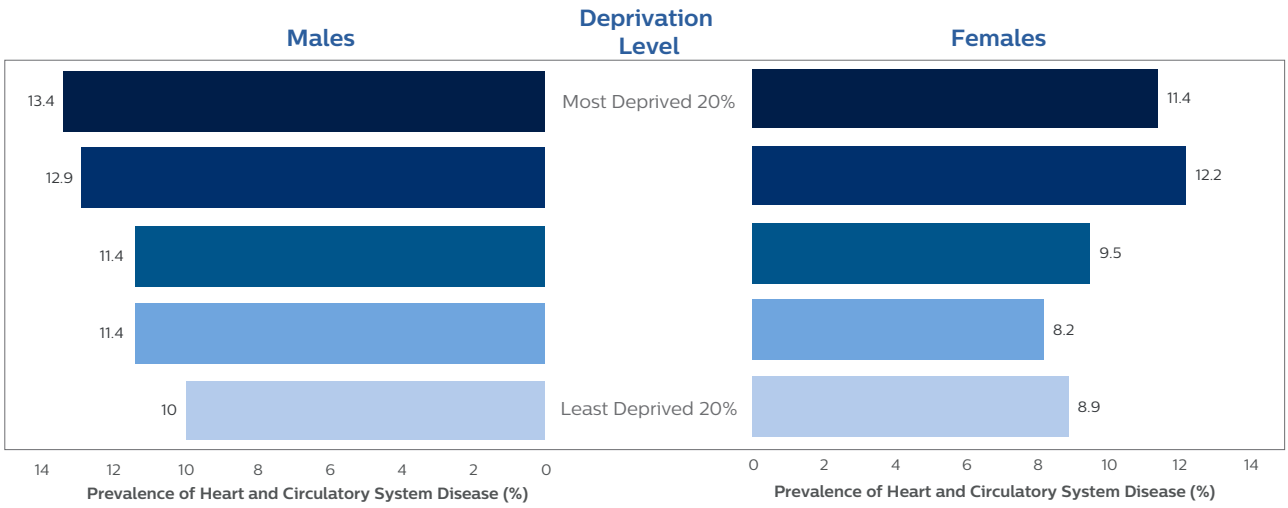


Figure 11 - Prevalence of Heart and Circulatory System disease (%) by Index of Multiple Deprivation (IMD) and gender, England 2017/18. Data source: NHS England - Health Survey for England 2018[43]

Data Infrastructure

Poor data infrastructure and low public trust in data sharing negatively affects health outcomes in the UK. In some UK healthcare settings, such as primary care, the use of electronic health records is widespread[27]. Other parts of the health and social care system have much less developed data infrastructure, with paper records still in use in several organisations[24]. Seamless vertical integration of health data between primary, secondary, tertiary and social care has not been realised[44]. Previous attempts to link up UK healthcare data, such as the Care.Data program and the National Program for Information Technology, were not well accepted by healthcare consumers or providers and failed to deliver a national health record network[24,27].

Almost all GPs currently use electronic systems during consultations and operate near-paperless practices. In contrast, much of the correspondence that GPs receive from NHS hospitals remains paper-based and has to be scanned into practice systems[27].

In 2017-2018, each trust in England self-assessed their digital maturity across three key themes of readiness, capabilities and infrastructure[45]. Each hospital trust in England was thereby allocated an organisational digital maturity score, which combined the results from each individual domain. Using the trusts included in this study, we compared the trust-level digital maturity scores with hospital trust catchment area deprivation quintiles, as shown in Figure 12.

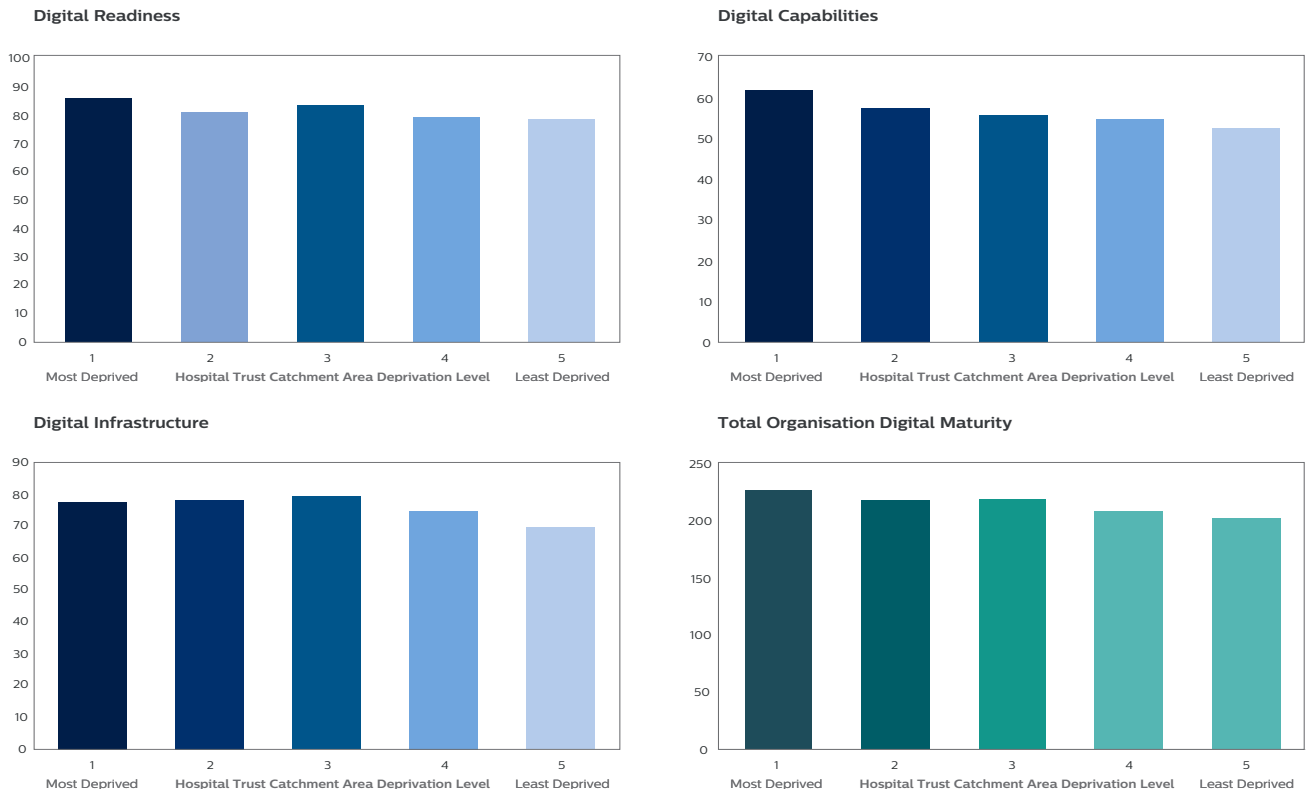


Figure 12 - Organisational Digital Maturity scores according to the deprivation score of the populations in the catchment areas associated with included hospital trusts in England. Data source: NHS England – Digital Maturity Assessment[45].

This analysis indicates that, across all domains of digital maturity, **hospital trusts caring for the most deprived communities in England are on average, slightly more digitally advanced** than trusts that care for the least deprived communities. This encouraging finding highlights that at a hospital level, patients that live in deprived areas have equal, or better, access to the benefits of digital healthcare services.

Further analysis of the types of health record systems in use at hospital trusts identified that **of the 20% of hospital trusts that provide care for the most deprived populations, 23% (6/26) were still using paper records**. In comparison, 15% (4/26) of the hospital trusts that care for the least deprived populations were using paper records. This use of paper records in hospital trusts represents an additional burden for patients that move between these hospitals and their GP.

Integrated Healthcare Systems

Disconnected healthcare systems negatively impact on the provision of safe, high quality care[46]. Patients with complex care needs and long-term conditions are particularly vulnerable to deficits in the sharing of health information between settings and healthcare providers.

Deprivation increases the likelihood of having more than one long-term condition at the same time, increasing the complexity of care for these patients as they move between specialists, therapists and their GP[8]. **On average, people in the most deprived fifth of the population develop multiple long-term conditions 10 years earlier than those in the least deprived fifth[8].** These groups of individuals therefore have a greater need for integrated healthcare systems along the care continuum[8].

In the UK, as in most healthcare systems around the world, **patient's healthcare data is often fragmented and held in data silos across multiple organisations[24,44,47].** Significant technical and social barriers to the sharing of data between GP clinics, hospitals, social care providers, pharmacies and many other health providers remain firmly embedded in health systems[24]. To achieve a vision of seamless healthcare, data needs to be available when and where it is required[44]. This need is felt most desperately by individuals with complex care needs and low health literacy[48]. **Improvements to data sharing and interoperability represent an opportunity to empower patients and reduce health inequalities.**

Developing a functional health data ecosystem requires getting the basic digital architecture right. This requires the use of open standards, prioritising interoperability and maintaining data security. Transformative technologies using common standards and Application Programming Interfaces (API) have the potential to better connect data across all levels of the healthcare system. Better connected care through improved infrastructure can improve health outcomes in areas of deprivation and reduce health inequalities.

Case study: **A radiology reporting hub to connect imaging services in Cheshire and Merseyside**

People accessing healthcare in Cheshire and Merseyside often face a complicated patient journey that involves moving between many different general and specialist hospitals[49]. With over 2.6 million radiology studies being performed per year in the region's hospitals, previous requirements for the manual transfer of imaging studies between hospitals represented a significant workflow burden for patients and providers[49].

Patients would often arrive at clinics without images being available, leaving doctors unable to make informed decisions on treatments[49]. Images would have to be imported between hospitals and often patients would require additional scans, simply because the original was not available – this led to unnecessary further radiation and delays in treatment[49]. 24/7 radiology reporting was also complicated in the region as different radiologists worked in different places and in different ways[49].

A new regional network model commenced in 2015 which involved connecting multiple hospital-based radiology archives with a single virtual data centre using Carestream architecture[49].

Consolidating image sharing and reporting on a single hub has enhanced the delivery of integrated radiology services and introduced significant workload efficiencies[49]. This use of integrated digital technologies had removed the logistical load of moving patients' images between sites in response to patient flows. Patients can now move between hospitals in the region, knowing that their images are likely to be accessible as and when they are required[49].

Health and The Environment

From climate to food to housing and air quality, health and the environment are intrinsically linked[50–52]. Understanding the impact of environmental exposure on health outcomes is critical to ensuring that environmental factors do not contribute to health inequality. Innovations such as sensors, artificial intelligence and the 'Internet of Things' have the potential to connect people, data and technology and mitigate the impact of environmental factors on those most at risk.

Air Quality

The British Heart Foundation has suggested that **deaths in the UK attributable to toxic air over the next decade could exceed 160,000 unless action is taken[53].** Globally, the World Health Organisation estimates that one out of every nine deaths results from air pollution-related diseases[54]. Around 3 million deaths globally are estimated to be solely attributable to ambient (outdoor) air pollution[54]. The majority of deaths related to air pollution are due to heart disease, stroke and chronic obstructive pulmonary disease. Asthma and cancer are also affected by poor air quality[54].

In this research, levels of nitrogen dioxide (NO_2) and PM2.5 in England were mapped using average 2018 air quality data from the Department for Environment, Food and Rural Affairs (DEFRA)[55] and compared with area deprivation. These data are collected from over 1,500 sites in the UK and modelled to produce nationally representative estimates of air quality[56].

NO_2 is a gas that is produced mainly by road transport and is known to be harmful to health[57]. PM2.5 refers to are particulate matter (PM) smaller than 2.5 micrometres, which can settle in airways and lungs and cause health problems[57]. Figure 13 and Figure 14 show the distribution of levels of NO_2 and PM2.5 in small areas (LSOAs) in England. Figure 15 and Figure 16 map NO_2 and PM2.5 levels in the hospital trust-level catchment areas referred to elsewhere in this report. Figure 17 and Figure 18 show the distribution of levels of NO_2 and PM2.5 in the Greater Manchester region.

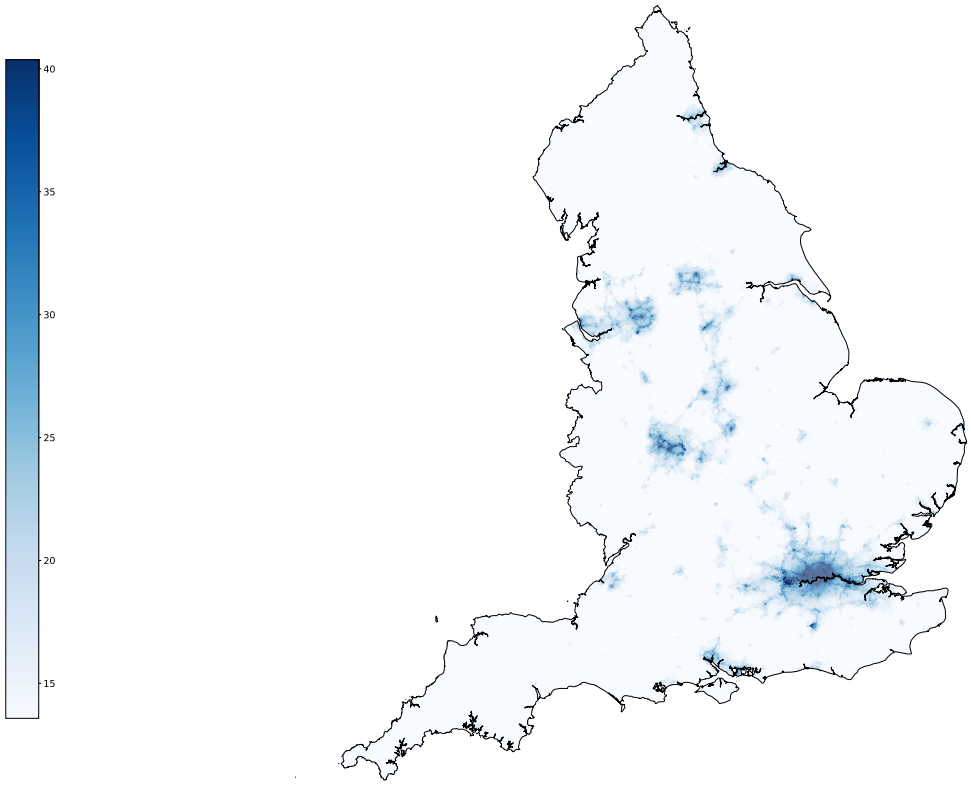


Figure 13 – Average annual mean concentration of NO_2 in England in 2018 (LSOA level).
Data Source: Department for Environment, Food and Rural Affairs - 2018 Air Quality Statistics[55].

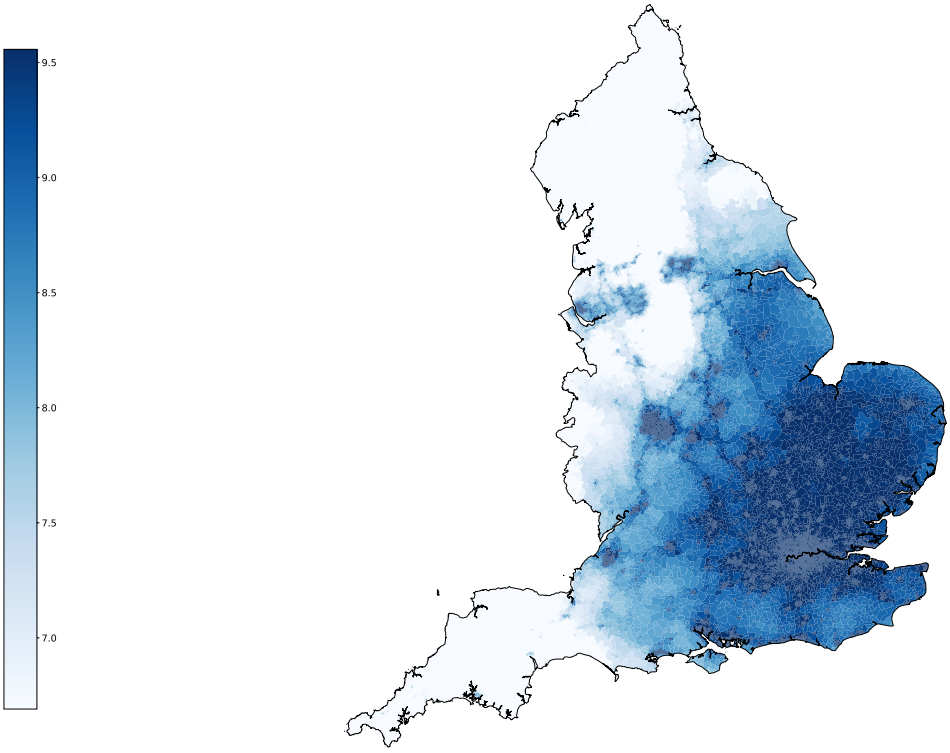


Figure 14 – Average annual mean concentration of PM2.5 in England in 2018 (LSOA level).
Data Source: Department for Environment, Food and Rural Affairs - 2018 Air Quality Statistics[55].

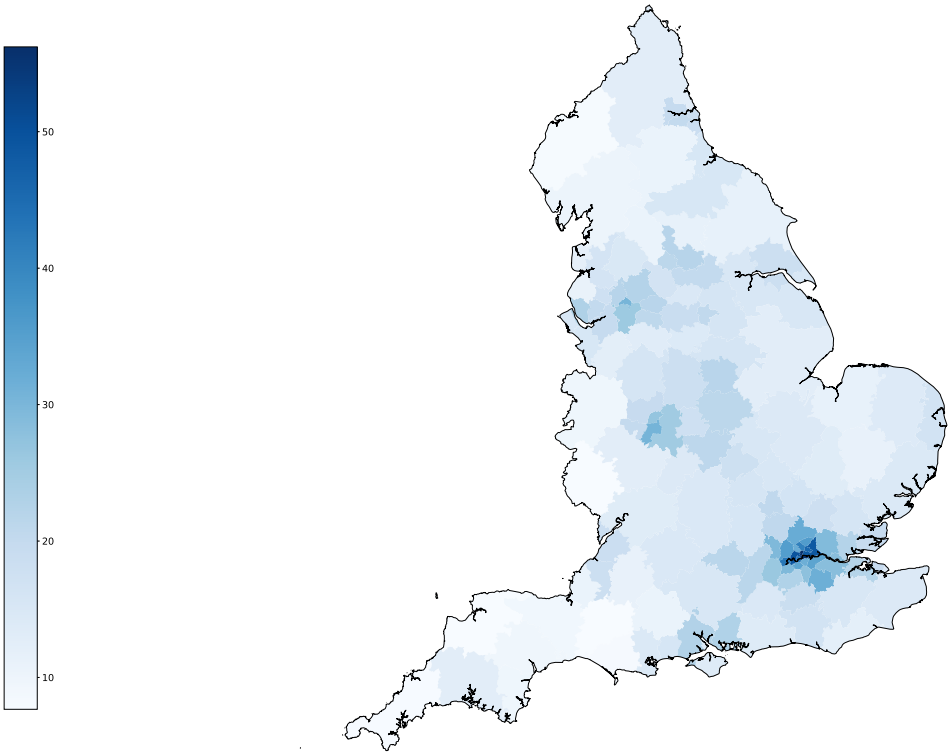


Figure 15 – Average annual mean concentration of NO_2 in hospital trust catchment areas in England in 2018.
Data Source: Department for Environment, Food and Rural Affairs - 2018 Air Quality Statistics[55].

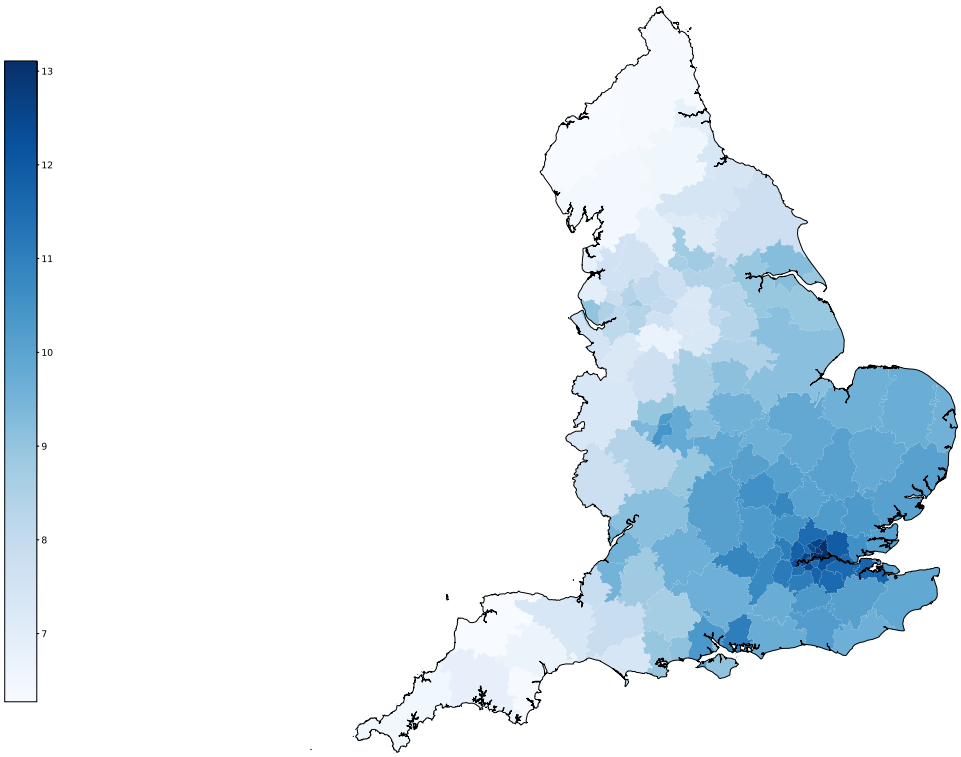


Figure 16 – Average annual mean concentrations of PM2.5 in hospital trust catchment areas in England in 2018.
Data Source: Department for Environment, Food and Rural Affairs - 2018 Air Quality Statistics[55].

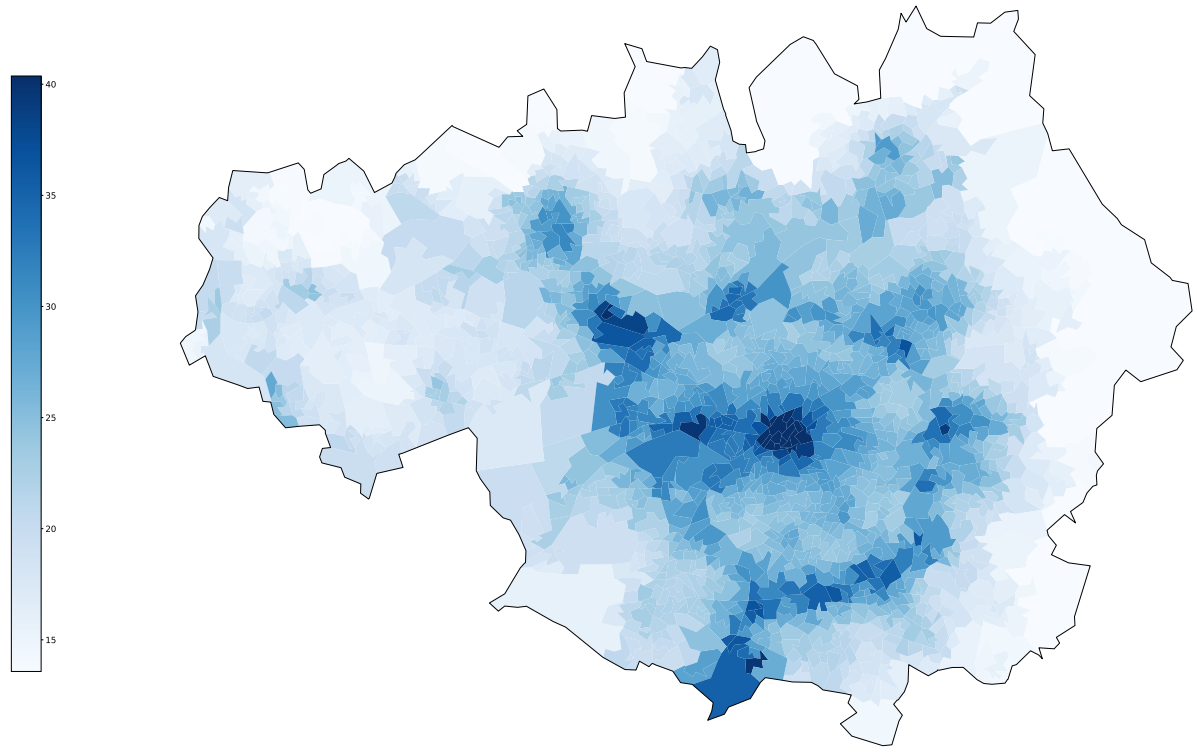


Figure 17 – Average annual mean concentration of NO_2 in Greater Manchester in 2018.
Data Source: Department for Environment, Food and Rural Affairs - 2018 Air Quality Statistics[55].

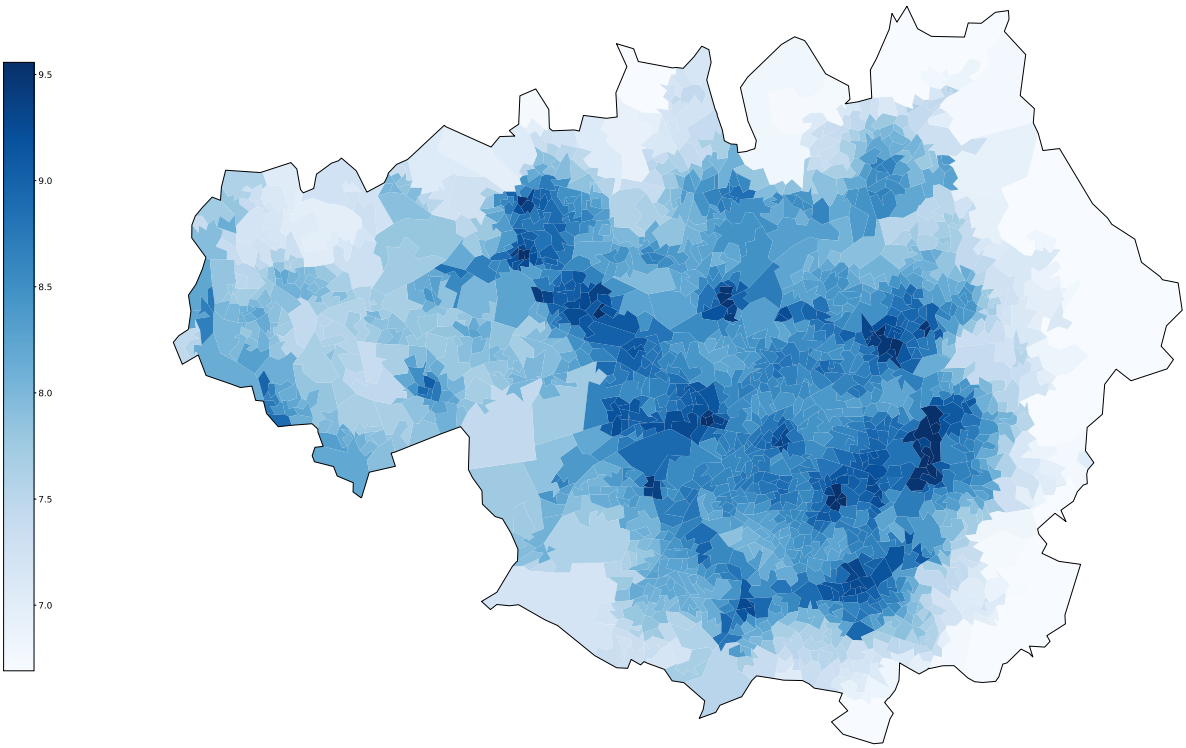


Figure 18 – Average annual mean concentration of PM2.5 in Greater Manchester in 2018.
Data Source: Department for Environment, Food and Rural Affairs - 2018 Air Quality Statistics[55].

On average, air pollution is worse in areas of higher deprivation in the UK[58,59]. In parts of London, which have the worst air quality in the UK, 46 percent of LSOAs in the most deprived decile have concentrations above the EU limit value for nitrogen dioxide (NO_2). In comparison, only two percent in the least deprived decile were above the limit[60]. The research conducted in this report also shows that many of the most deprived hospital trust catchment areas are associated with worse air quality. This potentially increases the burden of treating respiratory, heart and circulatory and other diseases implicated with air pollution in these hospitals.

The health implications of air pollution on people living in the UK are well documented in a recent publication by Kings College London[61]. For example, this research estimates that living near a busy road in London increases a person's risk of hospitalisation for stroke by 6.6%[61]. The effect of cutting air pollution in Birmingham by one fifth would result in 50 fewer lung cancer cases per year[61]. Mapping of NO_2 levels in Greater Manchester, as shown in Figure 17, demonstrates the higher ambient levels of this pollutant in the city centre and along the Manchester inner ring road, increasing exposure to harmful emissions for people living, working or attending schools in these areas.

Significant fluctuations in emission trends associated with the 2020 COVID-19 pandemic have complicated more recent analyses of overall trends in air quality. With a potential increase in the use of personal vehicles and avoidance of public transport following the pandemic, this is an important time to avoid significant worsening of air quality in the worst affected areas of the UK. Active travel initiatives such as cycling and walking, which have direct and indirect health benefits through emission reduction, should be encouraged.

To reduce health inequities in the UK, environmentally and financially sustainable funding mechanisms are needed. Funds may stem from public or private organisations; however, the delivery of impactful solutions depends on effective investment planning that considers the costs and benefits of implementing innovations, from the perspective of society at-large or that of the health system itself. For either perspective, sustainable solutions to health inequities in the UK must, on average and in the long run, provide greater economic benefit than cost.

Case study: **Reducing Air Pollution in Greater Manchester**

A 2018 analysis estimated that 1.6 million life years will be lost in Greater Manchester in the coming century due to poor air quality – the equivalent to each person having their life expectancy reduced by six months[62]. There are several specific illnesses directly or indirectly attributable to poor air quality in Manchester. For example, on high air pollution days in Manchester, there are on average 14 more hospital admissions for stroke each year than on lower air pollution days[61].

In Greater Manchester, concentrations of NO_2 are, on average, higher in more deprived areas. Figure 19 compares the distribution of LSOA deprivation quintiles (A) with average annual mean concentration of NO_2 (B) in Greater Manchester. NO_2, which is primarily from vehicle emissions, is in the highest concentration in Central Manchester and surrounding areas.

Air pollution in Manchester is affecting both adults and children. On days where there are high levels of air pollution in Manchester, an extra 8 children (4.4%) are likely to be hospitalised for asthma[61]. Cutting air pollution by one fifth would increase children's lung capacity by an estimated 2.6%[61]. This reduction in air pollution would also decrease the risk of babies being born underweight in Manchester by 0.1%[61].

Manchester has developed a Low Emissions Strategy and Air Quality Action Plan to address air pollution, which includes recommendations for reductions in congestion, use of electric vehicles and increasing use of low-emission public transport[63]. Clean air zone schemes, similar to the Ultra-Low Emission Zone (ULEZ) introduced in London in April 2019 have also been proposed for Manchester. These zones aimed to reduce the number of older, polluting vehicles using the zone by charging a daily fee for driving in the designated area. A recent evaluation following the first six months of the ULEZ zone in London showed that the number of polluting and non-compliant vehicles in the zone reduced by 38% and the levels of NO_2 reduced by 29%[64].

In association with the University of Manchester, in 2018 the Philips Foundation launched a 'Clean Air for Schools' programme in Greater Manchester[65].
Air purifiers were installed in inner city classrooms and an educational programme for students, teachers and parents about reducing air pollution was commenced. Results from the Clean Air For Schools programme are expected to be released in late 2020 to early 2021.

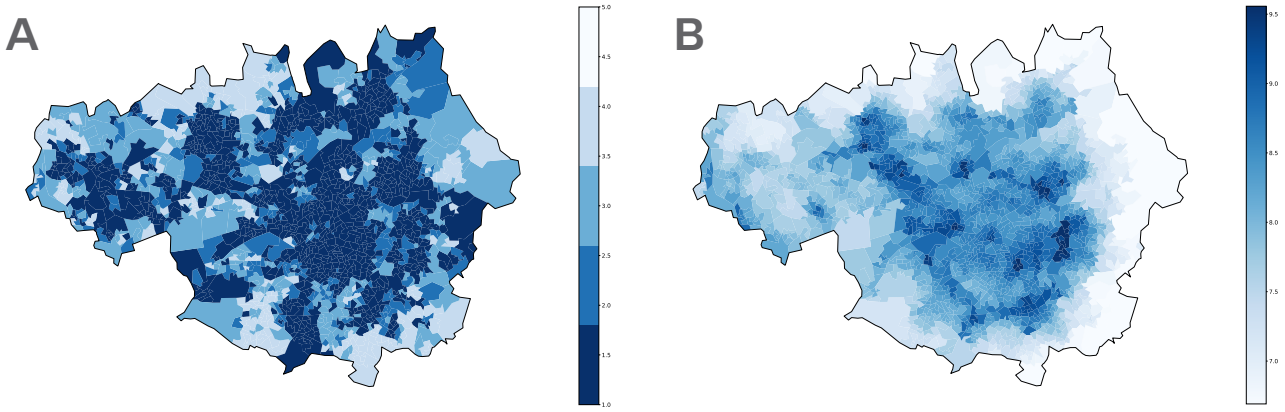


Figure 19 – Greater Manchester comparison of deprivation quintiles in 2019 (A) and average annual mean concentration of NO_2 per LSOA in 2018 (B). Data Sources: 2019 Indices of Multiple Deprivation[6], 2018 Air Quality Statistics – Department for Environment, Food and Rural Affairs[55].

Cost Analysis Case study: **Investing in Air Quality Interventions**

This analysis estimates the costs and benefits of investing in air quality interventions in the UK, from a societal perspective and over a 10-year time horizon. The assumptions about the effectiveness of any intervention are based on estimates of reduced exposure to environmental particulates. The route to achieving reductions in population exposures are not specified by the deterministic model, below. This means that top-down policies that aim to reduce environmental particulates, such as the pedestrianisation of city centres, can be complemented by individualised innovations, such as household air quality monitors that prompt behaviour change for those at risk.

Table 1 summarises the economic burden of prominent diseases that are exacerbated by pollution. Costs are estimated for Greater London and the rest of the United Kingdom (adjusted to 2019 prices); detailed information about the cost sources can be found in the methodology supplement.

Condition	Best case reduction rate in London	Best case reduction rate, excl. Greater London
Cardiac arrest	2.2	2.0
Stroke	2.7	2.9
Asthma (under 14)	4.2	4.6
Lung cancer	7.6	6.0
Respiratory disease	1.4	1.4
Cardiovascular disease	0.5	0.5

Table 1 - Best case rates of reduction of high-priority diseases that are exacerbated by environmental particulates. Data source: King's College London[61].

	Annual cost of disease in England, inflation-adjusted (2019), millions	Base case reduction rate	Annual cost saving from disease avoidance*, millions
Cardiac arrest	£ 778.7	0.2	£ 1.7
Stroke	£ 766.0	0.3	£ 2.1
Asthma (<14 years of age)	£ 10.8	0.4	£ 0.047
Lung cancer	£ 161.5	0.7	£ 1.2
Respiratory disease	£ 303.0	0.1	£ 0.42
Cardiovascular disease	£ 16,500	0.05	£ 8.1
			£ 13.5

*Table 2 - Potential annual cost savings from reducing urban populations' exposure to environmental particulates, for high-priority diseases. These estimates are conservative as the breadth of societal costs are not captured fully. *Assumes a base case effect size, which is 10 per cent of previously reported best case effect sizes from reducing exposures for these conditions. Data source: The King's Fund[66], BMJ Open[67], European Stroke Journal[68], Heart[69], The Lancet Oncology[70].*

The expected benefits from funding solutions that can achieve as little as 10 per cent of the best-case reduction in particulate exposure are large. Assuming all parameters are unchanged, ignoring inflation and discounting of future assets, savings of £13.5 million could be achieved each year. However, the actual benefits are likely to be higher given re-emerging evidence of growing admissions for cardiovascular disease[71] and the role of CVD as a major driver of the societal costs from pollutants[72].

Given the volume of cases caused by exposure to particulates, interventions that can be deployed in England for less than the total of the potential savings in Table 2, are promising solutions. Any one intervention that reduces environmental exposure to urban particulates generates many downstream benefits to several diseases, which represents an attractive societal investment.

Climate Change

Climate change affects health and worsens health inequalities[73]. There are direct and indirect effects of climate change that disproportionately affect deprived groups of people, including economic and food insecurity, extreme temperatures and air pollution.

The 2010 Marmot Review stated that **"climate change presents unprecedented and potentially catastrophic risks to health and wellbeing"[74]**. Low income groups are more affected by extreme weather conditions due to housing quality and older people are at higher risk of illness associated with extreme hot or cold weather[1]. Annual UK heat-related mortality is projected to increase from approximately 2,000 heat related deaths (in the 2000s), to more than 7,000 in the 2050s[75].

Housing

Poor housing is associated with poor health[76]. Previous research has shown that targeting housing improvements at those with poor health and inadequate housing conditions can improve the overall health of communities[76]. Overcrowding affects around 679,000, or three percent, of the 23 million households in England, with a disproportionate prevalence in deprived and ethnic minority groups[1]. Overcrowding is a known contributor to increased rates of respiratory infection, mental health disturbance and several other health conditions[1]. Many of these conditions both increase the risk of infection with COVID-19, and worsen the health and wellbeing effects of COVID-19 control strategies, including social isolation and financial and food insecurity[76]. The ongoing spread of COVID-19 through communities in the UK should be a stimulus for social care providers to address overcrowding and housing conditions in deprived communities.

Several studies have shown that investment in housing to improve thermal comfort can lead to health improvements, especially when these are targeted at individuals with chronic respiratory diseases[76]. Investments in housing efficiency and warmth can also help to mitigate the disproportionate effects of climate change on deprived people living in the UK[77]. Smart home technologies such as smart thermostats can help to improve housing conditions, along with reducing greenhouse gas emissions and their associated effects on air quality[78].

Recommendations

- **Address the social determinants of health through national, regional and local action**
  - Engage a wide range of stakeholders to develop sustainable, transparent and accountable solutions to health inequality
  - Involve communities in developing and implementing strategies that address the social determinants of health
- **Focus on preventative healthcare and early intervention**
  - Invest in general practice in areas of deprivation where consultation rates are higher, and patients have more complex health needs
  - Improve access to general practice in areas of deprivation through addressing workforce shortages and funding telehealth and digital online services
  - Ensure that healthcare innovations and digital technologies to prevent, diagnose and treat disease are available to everyone, and education on the use of digital services is provided where required
  - Ensure that people living in the most deprived areas of the UK have rapid access to diagnostic testing to support early diagnosis and intervention
- **Improve access to health and social care services for people living in coastal areas**
  - Invest in physical (e.g. transport, community health facilities) and digital infrastructure in coastal areas
  - Empower local communities in coastal areas to develop and implement initiatives to improve health and social wellbeing
- **Better integrate healthcare systems to improve care continuity for patients with multiple health conditions and complex care needs**
- **Act now on air pollution and environmental issues that impact on health inequality in the UK**
  - Use a data-driven approach to identify, measure and improve air quality in the worst affected parts of the UK, many of which are areas of relative deprivation
  - Expand the use of low emission zones in urban areas to reduce the health impact of vehicle emissions
  - Achieve the UK government aim for net zero carbon emissions by 2050 or earlier
  - Improve housing conditions and efficiency by subsidising the use of smart home technologies

2. Transformative Healthcare Technologies

Key Points

- Digital technologies provide new opportunities to tackle many of the challenges currently facing the NHS, including an ageing population and health inequalities
- Novel digital innovations are already helping the NHS to be safer, more efficient, personalised, and preventative
- The COVID-19 pandemic has hastened the adoption of digital technologies in the NHS, including the use of telehealth, online services and remote monitoring. Many of these changes to the way that healthcare is delivered in the UK are likely to persist in the post-COVID era
- Digital online services, such as booking appointments, ordering prescriptions and accessing health records online are less likely to be used by people living in more deprived communities
- Technologies such as telemedicine, remote care and the Internet of Things represent opportunities to better manage chronic health and social care needs and reduce health inequalities in the UK
- Automation and artificial intelligence can help to reduce the workload of healthcare providers, allowing them to focus on what they do best – caring for patients

We live in an era of opportunity for transformative healthcare technologies. Despite this, there is widespread agreement around the world that healthcare is at least a decade behind other industries in the use of information technology[79]. Embracing digital technologies is widely regarded as a critical factor in enhancing the NHS and improving people's lives in the coming years as emphasised by the COVID-19 pandemic[27]. Digital innovations do, however, need to be applied fairly across society to ensure that they do not disproportionately benefit people from different regions, ages, ethnic groups or socio-economic backgrounds and thereby widen health inequalities. As the research included in this report has shown, **people living in deprived areas are more likely to access healthcare in the UK and more likely to have multiple chronic conditions. These groups have the most to gain from advances in healthcare technologies.**

Technologies that have the potential to further transform healthcare are broad and exist in all areas of diagnosing, treating and preventing illness. Examples of these technologies include electronic health records, web and cloud-based tools, apps, diagnostics, remote monitoring and care devices, telemedicine, artificial intelligence, digital pathology and predictive analytics. Several of these technologies will be addressed through the NHSX Tech Plan, which will be published in phases from 2020. As commented by the NHSX CEO, Matthew Gould, this plan will aim to "reimagine every clinical pathway, every process, every role and every assumption we make about how the NHS works."[80]

In a short space of time, the COVID-19 pandemic has accelerated the use of digital technologies such as telemedicine by several years. The assumption that primary care requires most interactions to be conducted in-person has been challenged. In many instances, the pandemic has taught both patients and care providers that telemedicine, email or digital messaging services can be quicker, easier and safer. There will always be a place for face-to-face interactions and examinations, but this pandemic has shown that a large part of care can be provided digitally. It has reinforced the findings from previous research that has shown that patients want to, and can, use remote services to manage many of their care needs.

Empowering Patients and Reducing Health Inequalities Through Digital Healthcare

Empowering patients with technology and training NHS care providers to embrace new innovations can open many doors to better, fairer care for all. At a primary care level, we used the 2019 English National GP Patient Survey to analyse the uptake of digital services provided through GP clinics, including booking appointments online, ordering repeat prescriptions online and accessing medical records online. Results from these analyses are shown in Figure 20.

Figure 20 – Percent uptake of digital services by patients at a primary care level across Clinical Commissioning Group (CCG) deprivation quintiles. Data Source: NHS England - 2019 English National GP Patient Survey[81].

Across all communities, irrespective of deprivation, uptake of digital primary care services by patients is low. For each area assessed in this analysis, **the uptake of digital services was lowest in the most deprived communities, and highest in the least deprived communities.** This may reflect levels of health and digital literacy in these communities and represents an opportunity to improve access to healthcare and services for the most deprived.

In a 2019 report by the National Centre for Social Research, **36% of people overall prefer NHS services where no appointment is needed. This rose to 48% of those living in the most deprived areas and 48% of those with no educational qualifications[22].** There is also considerable scope to increase the use of online tools to help tackle demand; 58% of people with internet access say they would look online to help understand a health problem, and 47% would use the internet to decide what to do about it[22].

The findings in this section suggest that people living in deprived areas want to use digital healthcare services, although are currently less likely to have access to digital healthcare. This area should be a priority for policy makers and care providers to enhance the NHS, reduce inequality and improve people's lives.

The Internet of Things

The Internet of Things (IoT) is a term used to describe a hardware and software ecosystem that connects people through physical and digital components. Hardware, including smartphones, wearable devices and sensors in houses, cars, hospitals and several other settings are connected through Wi-Fi, Bluetooth and 4G or 5G networks. By 2021 it is estimated that there will be over 30 billion connected devices connected to the internet worldwide, and this is expected to rise to over 75 billion by 2025[82].

For healthcare, the IoT represents a huge opportunity to integrate care delivery, maximise efficiency and improve outcomes for patients. Opportunities are particularly prominent at the community level, where IoT could help to shift the focus of healthcare from cure to prevention, and empower people to have greater control over decisions that affect their health and wellbeing[83]. Public concerns about privacy, safety, security and governance of connected devices and data need to be considered as these innovations are adopted.

Digital Healthcare Systems

Digital healthcare systems, including electronic health records (EHR) and clinical imaging and laboratory systems, can increase the efficiency, safety and the quality of care delivered in the NHS. Improving digital capabilities, using open standards and increasing access to patient accessible records can improve continuity of care between primary and secondary level care[46]. Digitalising systems also opens up opportunities to capitalise on 'big data' to improve care and reduce health inequalities. The rich data held in these systems can be used to provide customised decision support to develop 'learning healthcare systems' and also understand individual patient journeys between care providers to enable truly 'joined-up' care.

Integration of provider-held data with patient reported outcome measures and wearable devices represents an additional opportunity to empower patients and develop personalised, 'precision medicine' approaches. For hospitals and communities to benefit from these opportunities, structured health data needs to be held digitally. The use of open standards and application programming interfaces can assist digital technologies to resolve these issues and should be a focus for policy makers and service managers.

Remote Care and Telemedicine

The COVID-19 pandemic has been a stimulus to reshape services in the NHS and increase the use of remote care and telemedicine. In many ways, there is now a new status quo for healthcare that has upended many traditional models of care. Capitalising on these advances by making telemedicine and remote monitoring more widespread, personalised and proactive represents a huge opportunity for the NHS at community, primary and secondary care levels.

Earlier in this report, it was noted that the UK has one of the lowest rates of hospital beds per capita against comparable countries. **In the setting of an aging population and increased demand for these limited beds, innovative ways to manage increasingly unwell patients outside the hospital setting will need to be developed.** This includes 'hospitals at home' using advanced wearable sensors and telehealth.

Case study: **Wearable Sensors to Detect Patient Deterioration**

During periods of illness or recovery from surgery, patients may deteriorate and become critically unwell. An estimated 150,000 people are affected by sepsis in the UK every year and as many as 1 in 4 people with sepsis will die[84]. Evidence suggests that for every hour delay in diagnosis of sepsis, the mortality rate goes up by 8%[84]. Early detection of sepsis and other causes of patient deterioration can alert clinicians to start or change treatments earlier and significantly improve outcomes for patients.

Wearable sensors that monitor vital signs like heart rate and respiratory rate provide a much-needed option for continuous patient monitoring outside the environment of an Intensive Care Unit without restricting a patient's ability to ambulate. For example, the Philips Biosensor BX100, which received FDA and CE mark clearance in May 2020, is approved for use in a hospital setting, after surgery or following ICU discharge to a general ward[85,86]. This is a wireless, single-use patch that is worn on the left side of a patient's chest for up to five days and can connect to a hospital's information system using Bluetooth connectivity[85].

Remote monitoring using wearable sensors could also open opportunities to expand more care into the home setting in the future and reduce demand on much-needed NHS hospital beds. These sensors also have a potentially valuable role to play monitoring patients with COVID-19, many of whom will require care outside of hospital Intensive Care Units[86].

Automation and Artificial Intelligence

Automation represents a significant opportunity for the NHS to improve the quality, safety and efficiency of care[87]. There is scope for automation in several areas of healthcare, including diagnostics, robotics, treatment planning, prescribing, medical documentation and scheduling.

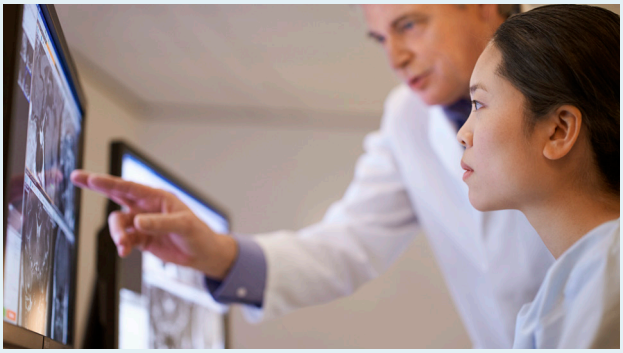
Automation and AI can help to free up time for clinicians to provide more personalised care by reducing the burdens of many routine processes. Automation could help to compensate for medical and nursing shortages in several parts of the NHS. For example, the increasing workloads faced by pathologists and radiologists could be reduced by automated processing of images and specimens and assisted reporting. With improvements in the quality and safety of automation, many nursing tasks, such as recording patient observations and dispensing medications could also be automated to allow nurses to spend more time with patients.

Cost Analysis Case study: **Investing in imaging solutions**

This analysis adopts an NHS perspective for England to estimate costs and benefits of investing in diagnostic imaging solutions. Effectiveness estimates are not used in this case due to the complicated nature of costing diagnostic benefits. Instead, the more pressing issue of deploying solutions that address the NHS's growing demand for and insufficient supply of radiology services are explored.

In the last financial year, the NHS spent £2.2 billion on imaging services, with a record outsourcing expenditure of £164 million[88]. The latter of these figures is an important contemporary characteristic of imaging services, which are under-supplied.

Distribution of the main imaging types performed by the NHS for the last full year is shown in Figure 21. Plain film images (X-rays) account for the largest proportion of all images performed. The cost for one of each of these images is estimated using a human capital approach, shown in Table 3. The direct cost of delivering these images is driven by the cost of using existing technologies (comprising fixed capital and variable costs from equipment and staff).



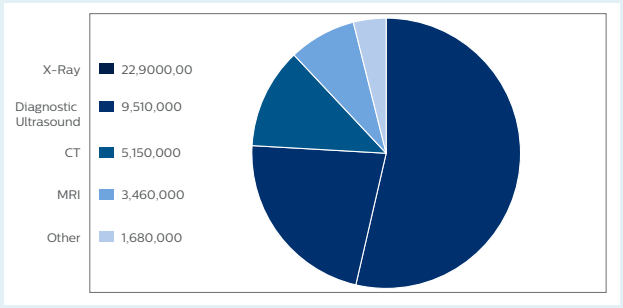


Figure 21 - Proportion of diagnostic images performed by the NHS in England in 2018/19 (most recent full-year data).
Data source: NHS England – Diagnostic Imaging Dataset 2018-19[90]

The undersupply of imaging services indicates the need for investment in long-term solutions, some of which are being made by the UK government[91]; however, for the interim period, workflow solutions are needed to ensure timely patient access to diagnostic solutions, given current resource constraints. To estimate staff time as a cost, Table 3 provides estimates of time spent producing the four main types of diagnostic image, involving the patient. Costs assume an hourly wage of £18.50 and 1.5 full-time equivalent staff required to perform the imaging tasks[92].

	Time, hours (low estimate)	Time, hours (high)	Current annual cost, millions (low)	Current annual cost, millions (high)	Future annual cost, high (2029)
X-ray	0.1	0.5	£ 63.5	£ 317.7	£ 365.1
Diagnostic ultrasound	0.1	0.5	£ 26.4	£ 132.0	£ 151.6
CT	0.1	0.5	£ 14.3	£ 71.5	£ 82.1
MRI	0.25	0.75	£ 24.0	£ 72.0	£ 82.8
			£ 128.2	**£ 593.2**	**£ 681.6**

Table 3 - Current and future annual costs of providing imaging services in the NHS, excluding capital / technology costs. The estimate of between £128.2 million and £593.2 million per annum is separate to accounting costs for imaging services..

The estimates in Table 3 conservatively estimate the time required to operate existing image-capturing equipment (viewed as an input to the diagnostic imaging services in the NHS), which is undersupplied due to workforce shortages. They do not include the cost of processing images, which are tasks performed by consultant radiologists whose hourly wage is considerably higher.

The shortage of consultant radiologists is a concern for the NHS. The current shortfall in consultants is 1,104 and this is projected to be 1,867 by 2023, given expected demand growth[91]. Assuming the median consultant salary in the UK, the current value of these positions to the NHS is approximately £99.2 million per annum, assuming the median consultant salary (£89,856). By 2023, the equivalent value to the NHS is £167.8 million per annum.

As a cost from human capital, we can provide more detailed assumptions about radiology image processing using throughput data from the Royal College of Radiologists[93]. Assuming a consultant radiologist can examine and process an uncomplicated plain film (X-ray) image in 2 minutes, each year 763K hours of their time is used. With a further assumption of a 37-hour working week and a median hourly wage for radiologists of £46, the value of current activity is approximately £35 million, assuming a low throughput scenario. The value of all current activity is summarised in Table 4. The hourly wage is assumed to the same as above, except for trainees' activities, which are priced at £25 per hourly, assuming a base salary of £49K per annum and no overtime costs for a 37-hour working week.

	Low throughput per hour	High throughput per hour	Cost per annum, low throughput, millions	Cost per annum, high throughput, millions	Median cost per annum, millions
Plain Film	30	60	£ 35.1	£ 17.6	£ 26.3
Checking Films (trainee)	6	12	£ 95.4	£ 47.7	£ 71.6
CT	3	6	£ 79.0	£ 39.5	£ 59.2
MRI	3	6	£ 53.1	£ 26.5	£ 39.8
Complex CT/MRI	1	2	£ 12.9	£ 6.4	£ 9.7
Cardiac MRI	1	2	£ 2.9	£ 6.4	£ 9.7
PET CT	1	2	£12.9	£ 6.4	£ 9.7
Mammography	4	6	£ 3.2	£ 2.1	£ 2.7
Barium study	2	4	£ 6.4	£ 3.2	£ 4.8
US	4	6	£ 109.4	£ 73.0	£ 91.1
Complex US	2	3	£ 6.4	£ 4.3	£ 5.4
					£ 330.0

Table 4 - Summary of annual costs for processing radiology images in the NHS in England. Two hourly throughput scenarios are presented, based on Royal College of Radiology estimates, and these are valued on an annual basis using NHS England's reported volume of each type of image. Using these assumptions, the median annual cost estimate for processing diagnostic images is £330 million. Data Source: Royal College of Radiologists[93]

In this case study, the costs and benefits to health have not been estimated directly, given the lack of data. However, given the acute and future need to optimise imaging services to ensure timely patient access to them, the value of staff time at the input and processing stages indicates the value of alternative solutions. Recruitment targets for radiology services that are provided by the NHS indicate the Service's valuation of and allocation to diagnostic imaging[88]. Human capital approaches indicate the potential areas for efficiency from interventions that address workforce shortages by reducing input and processing time, particularly in UK regions where staff shortages are highest.

Recommendations

- **Consider the adoption of new healthcare innovations through the lens of health equity, so that socioeconomic disparities in health outcomes narrow, rather than widen**
  - Ensure that the potential impact on pre-existing health inequalities is central to the design and implementation of digital healthcare technologies
- **Digitise systems across the NHS to improve service delivery, data capture, analytics and health system planning**
  - Improve data sharing between social care, primary and specialist care
  - Encourage the use of common standards for data capture across all digital systems in the NHS
  - Ensure interoperability is built into digital healthcare systems
- **Expand the use of telehealth and patient-facing digital services in the NHS to improve access to health and wellbeing services**
  - Use a data-driven approach to identify, measure and improve air quality in the worst affected parts of the UK, many of which are areas of relative deprivation
  - Expand the use of low emission zones in urban areas to reduce the health impact of vehicle emissions
  - Achieve the UK government aim for net zero carbon emissions by 2050 or earlier
  - Improve housing conditions and efficiency by subsidising the use of smart home technologies
- **Invest in digital infrastructure at all levels of health and social care**
  - Ensure that all NHS GP clinics and hospitals are using electronic health record systems by 2023
  - Support the use of radiology and laboratory networks or 'hubs' to improve regional reporting efficiency and reduce the impact of local workforce shortages
  - Encourage the development and use of artificial intelligence and automation where proven to be safe and effective, including laboratory and radiology processing and reporting
- **Support patients to support themselves by increasing the availability of patient accessible records at all levels of care with appropriate data protections in place**
- **Support clinicians and provider organisations in the adoption of new technologies by developing clear regulatory frameworks, designed with patients and providers in mind**
- **Encourage novel digital innovations by funding research and supporting adoption into the NHS**
  - Support the implementation of new digital technologies into the NHS where safe and proven to improve health outcomes or patient experiences
  - Explore the clinical applications of wearable sensors, remote digital monitoring, and the Internet of Things and how these innovations could improve people's lives and reduce health inequalities
  - Offer patients the opportunity to actively participate in the monitoring, evaluation and personalisation of their care using wearable devices and digital applications

3. COVID-19, Health Inequality and Health Technologies

Key Points

- The COVID-19 pandemic has rapidly changed how healthcare, particularly primary care, is provided
- Many of the steps towards digital healthcare delivery have taken place over a matter of weeks rather than years
- The COVID-19 pandemic has emphasised the existing health inequalities that exist within the UK
- It is crucial that lessons learned during peak waves of the crisis are carried forward
- Long waiting lists for planned surgical and diagnostic activity during and following the COVID-19 pandemic will require innovative models of care, including greater integration of healthcare data and automation of services

The COVID-19 pandemic has placed extraordinary pressures on individuals and healthcare systems around the world. Many of the health and wellbeing challenges posed by COVID-19 have disproportionately affected particular groups of people in the UK. Vulnerable populations are more likely to be affected by COVID-19, and also more likely to suffer the ill-effects of reduced access to their standard care needs[94]. The research presented in this section reflects on the impact of COVID-19 on healthcare, health inequalities and health technologies in the UK.

COVID-19 and Health Inequalities

There are several factors associated with an increased risk of being affected by COVID-19 in the UK[95]. These include age, male gender, deprivation and pre-existing comorbidities[95]. A report published by Public Health England in June 2020 also showed an association between ethnicity and COVID-19, with a higher rate of death among Black, Asian and Minority Ethnic (BAME) groups[95]. People working in some occupations such as nursing, midwifery, social care, bus and taxi driving and lower skilled workers in construction and processing plants also had higher rates of death from COVID-19[95]. Geography also plays a role in rates of death associated with COVID-19, with the highest rates in urban areas and in London, the North West, North East and West Midlands regions of England[95].

The impact of COVID-19 on populations in the UK is, clearly, intertwined with multiple health, social and environmental disparities. Overall, these contribute to inequality in the impact of COVID-19 that disproportionately affects some of the most vulnerable groups of people in the UK. Although difficult to untangle the individual impact of each of these factors, there are some clear associations that can be drawn out of an analysis of available data relating to in-hospital deaths in the UK.

Using NHS hospital trust-level COVID-19 data and previously defined hospital trust catchment area deprivation scores, Figure 22 shows the association between COVID-19 deaths and deprivation in England.

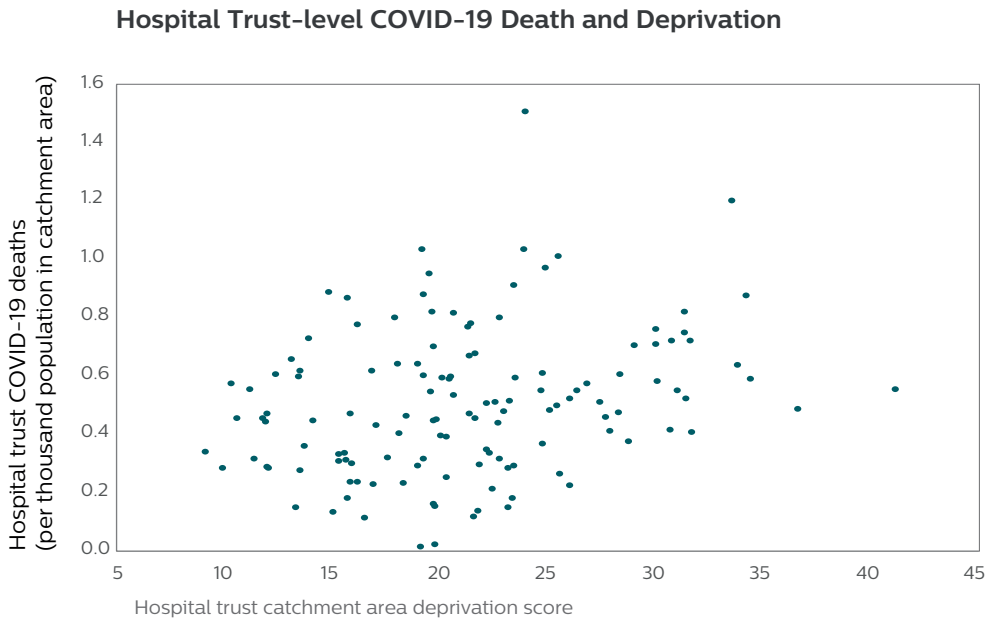


Figure 22 - Association between hospital-trust level COVID-19 death rates (per thousand area population) and hospital-trust catchment area deprivation scores in England. Data sources: NHS England[96], English Indices of Multiple Deprivation 2019[6].

Figure 23 shows the association between hospital-trust level COVID-19 death rates and the proportion of people from BAME groups living in the catchment areas associated with hospital trusts in England

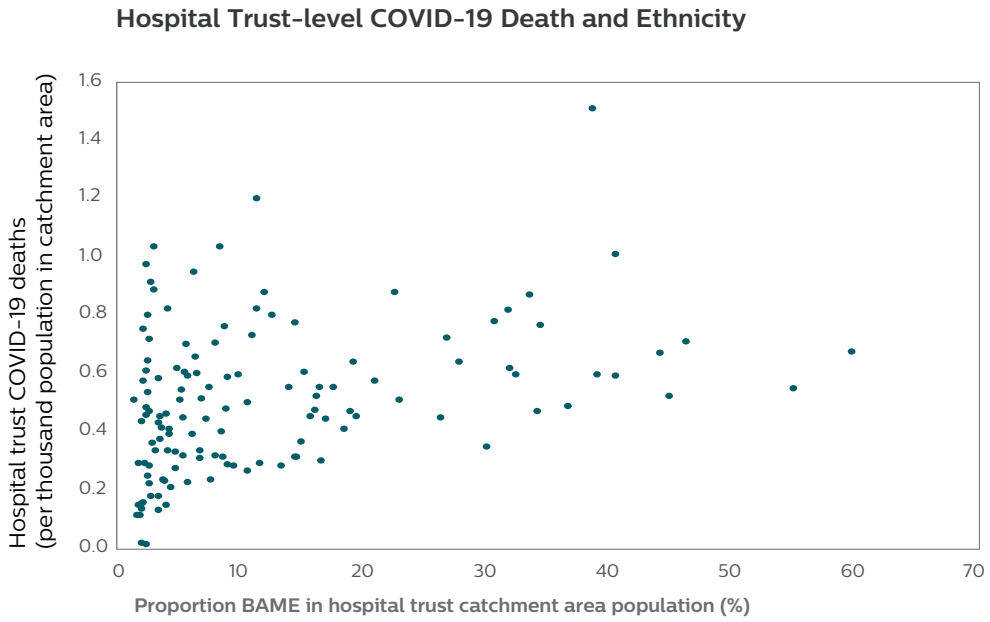


Figure 23 - Association between hospital-trust level COVID-19 death rates (per thousand area population) and hospital-trust catchment area proportion of people from BAME groups. Data sources: NHS England[96], English Indices of Multiple Deprivation 2019[6].

Geography and environmental conditions also play a potential role in the effects of COVID-19 on particular populations in the UK[95]. Figure 24 shows the association between deaths from COVID-19 in hospital trusts in England and the average annual levels of nitrogen dioxide (NO_2) in the catchment areas of each hospital trust. **The relationship between air quality and risk of COVID-19 is a complex one which is highly prone to confounding and misattribution of causation.** In Figure 24, the strong relationship between NO_2 and COVID-19 mortality is confounded by their shared relationship to urbanicity[97]. In the UK, areas with the highest NO_2 levels are in cities, which in turn have some of the more deprived populations, with a higher proportion of BAME residents and with a higher population density, all of which are related to COVID-19 transmission and risk of mortality.

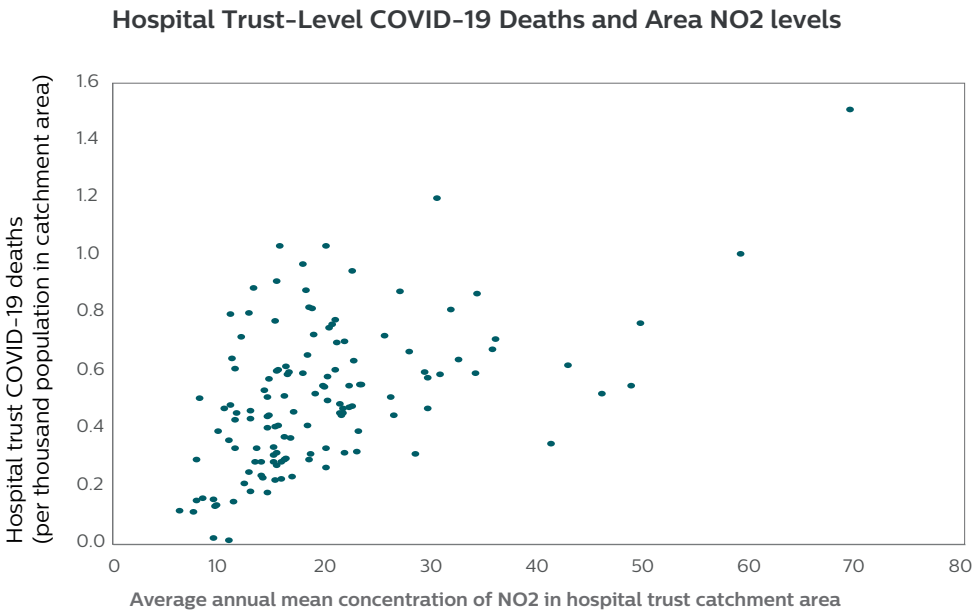


Figure 24 - Association between hospital trust-level COVID-19 deaths and the average annual mean concentration of NO_2 in the catchment areas of each hospital trust. Data sources: NHS England[96], English Indices of Multiple Deprivation 2019[6], 2018 Air Quality Statistics – Department for Environment, Food and Rural Affairs[55].

Individuals with pre-existing health conditions, including diabetes, hypertensive diseases, chronic kidney disease, chronic obstructive pulmonary disease and dementia are more likely to die from COVID-19 than people without pre-existing health conditions[95]. Recent studies also highlight an association between obesity and higher rates of death from COVID-19[98]. As these chronic conditions are more likely to affect people living in deprived areas of the UK, COVID-19 has added an additional burden for these already vulnerable groups. **There has never been a more important time to ensure that the health impacts of these conditions are reduced. Enhancing the ability of the NHS to address these challenges needs to be a key priority as health systems continue to manage the effects of COVID-19 beyond 2020.**

While clear associations between COVID-19 mortality and a range of social, economic, demographic, and environmental factors have been identified, disentangling the complex web of relationships between these features is an ongoing research priority. With more data, more time, and the benefit of drawing together independent studies from different contexts, this relationship will become clearer.

However, **the absence of consistently quantified causal effects of each factor does not preclude action. What is clear already is that those with long term health conditions, from BAME backgrounds, living in poorer areas or in less well-paid jobs are particularly at risk.** COVID-19 has brought the scale and impact of health inequality and its determinants firmly into public focus, and is a call to action. As recently commented by Professor Sir Michael Marmot - "What the COVID crisis exposes is that we can do things differently. We must not go back to the status quo, we cannot do that....I'd like to see a wellbeing economy emerge from this crisis."[99]

Health Technologies and COVID-19

During the COVID-19 pandemic, healthcare systems, including the NHS, have needed to make rapid changes to service delivery processes and care pathways. Many of these changes have required the enhanced use of digital technologies. In many ways, the forced disruptions to healthcare systems have hastened the digital transformation of healthcare[94]. Remote working, telehealth and video consultations have rapidly expanded across all health and social care settings. Electronic prescribing, web-based therapies and self-monitoring health apps have blossomed in an era of social distancing and isolation. **The COVID-19 pandemic has also exposed some existing deficiencies in data infrastructure in the UK and highlighted the need for better data sharing between healthcare providers and settings.**

Telehealth and Virtual Care

There has been a global surge in adoption of telehealth and video consultations during the COVID-19 pandemic[100]. Telehealth, video consultations and virtual care have the potential to improve access to care beyond the COVID-19 pandemic. Increasing access to care, particularly at a community level, has clear benefits for groups of people living in deprived circumstances in the UK. This expansion in remote clinical practice may potentially increase the accessibility to healthcare for those who previously found this difficult due to impaired mobility or lack of transport links. Similarly, regions that face difficulties recruiting specialist clinical staff may instead remotely draft in expertise from elsewhere.

As the digitisation of essential healthcare services progresses, it is essential that vulnerable populations are not left behind[100]. Patients who do not own a personal electronic device, struggle to use it, or can't afford the cost of internet or mobile phone data may find themselves excluded as healthcare moves to a 'digital first' delivery model[101]. Experience from the COVID-19 pandemic has shown that uptake of telemedicine can be most difficult for those with greatest need, and therefore may widen inequalities in access to healthcare.

Digital Infrastructure

Deficits in digital infrastructure, such as poor data-sharing between primary and secondary care and limited interoperability between electronic health record systems, have contributed to the burden of COVID-19 on both patients and healthcare providers. The demand for home or virtual access to digital records, imaging and laboratory results has soared as health systems move to home-working arrangements for providers and virtual care approaches. The need for remote access to health information has highlighted the limitations of paper-based records, which are still in use in many hospitals in the UK[24].

Waiting lists for planned surgical diagnostic activity are at unprecedented lengths. Addressing this backlog will require innovative models of care, including greater integration of healthcare data and automation of services that capitalise on digital infrastructure and digital services.

Case study: **Telemedicine During the COVID-19 Pandemic and Beyond**

For many patients and care providers in the UK, telemedicine was a rarely used, novelty technology prior to the COVID-19 pandemic. Video appointments were estimated to have made up only around 1% of the approximately 340 million annual visits to primary care doctors and nurses in the NHS[102]. Telehealth services were limited in both scope and scale due to technical restrictions, reimbursement complexities and unfamiliarity to both patients and clinicians. Within weeks of COVID-19 reaching the UK, it became clear that telehealth would become a critical tool in the maintenance of clinical services while social distancing measures were in place[103].

As a result of policies and technologies that had previously kick-started the use of telehealth in the UK in recent years, the NHS was relatively well-positioned to rapidly expand telehealth services in both primary and secondary care[103]. By June 2020, all secondary care providers and 95% of NHS practices in England had video consultation capability, with similar rapid rollouts in Scotland, Wales and Northern Ireland[104]. In June, Matt Hancock, the Secretary of State for Health and Social Care, reported that at least half of NHS consultations were being conducted via telehealth[105].

Telehealth can improve workflow and increase productivity for providers and patients, for example by avoiding the need for patients to sit in waiting rooms, or for clinicians to wait for patients to arrive for appointments. This can minimise the indirect effects of physical and mental health issues on employment, education and social wellbeing. There are challenges associated with telehealth, however, and not all care interactions will be suitable to be conducted digitally[104]. Achieving the right balance of virtual and in-person appointments will need to be personalised to each patient and each problem. The 'new normal' in healthcare needs to meet the needs of all users, not just the digitally engaged. Monitoring of patient outcomes and opinions on this significant disruption to previous healthcare pathways is critical to ensure that it reduces, rather than worsens, health inequalities in the UK.

Recommendations

- **Use the COVID-19 pandemic as a catalyst for addressing health inequalities in the UK**
  - Investigate and tackle the underlying factors that have led to worse outcomes from COVID-19 in people living in deprivation, from BAME groups and in people with existing medical conditions
- **Capitalise on the momentum towards a digital NHS that the COVID-19 pandemic has stimulated**
  - Continue to expand the use of telehealth, mobile applications and online healthcare services, such as ordering prescriptions and accessing health records and results
- **Consider adoption of digital healthcare technologies within the NHS from the perspective of all users, not just the most digitally engaged**
  - Ensure that safety nets are in place to provide safe, effective healthcare for individuals less able to make the transition to a 'digital first' model of care

Conclusion

There is no escaping the fact that health inequalities exist in the UK. This report has quantified these health inequalities and explored some of the reasons underlying them. Factors contributing to health inequality in the UK are, clearly, complex, and include social determinants of health, the environment, and local primary and secondary care delivery.

The research highlighted in this report suggests that the closer that patient outcomes and health service measures are positioned to the social determinants of health, the more disparate they tend to be. At a hospital-level, it seems that trusts caring for the most deprived communities are performing remarkably well and, in fact, outperform hospitals that care for less deprived groups across many of the outcomes assessed in this report. Many of these hospitals are large, inner city hospitals, closely affiliated to universities with the scale to provide high-quality clinical services to a diverse range of populations. At a social and primary care level, the complex factors that contribute to health inequality are more challenging. Primary care services are often busier, more difficult to access and less well perceived by people living in more deprived areas. The NHS is improving people's lives; although it is apparent that support is often being implemented too late for many of the most vulnerable people in society. Reducing inequality in the UK requires intervention at the social and primary care level, with a focus on preventing health problems and intervening early once identified.

Patients with chronic conditions and complex health needs require high-quality, connected health infrastructure and systems. Improvements in the management of clinical data offer the opportunity to bridge the information divide between primary and secondary care, and patients themselves to ensure a comprehensive, secure, learning health system where all clinical information is available to patients and their clinicians whenever it is needed. Deprived populations are also less likely to have access to and utilise novel health technologies that help to empower them to manage their own care. There is a danger that the most vulnerable members of society may miss out on the present and future benefits of digital innovations – a risk which needs to be addressed by healthcare providers, government and industry.. Measures to mitigate the risk of digital healthcare innovations widening health inequalities must form part of any implementation strategy and become central to the culture of healthcare innovation.

As highlighted in this report, the COVID-19 pandemic has added additional strains on the health and social care system and exacerbated the challenges faced by deprived communities. The impact of COVID-19 on vulnerable groups should prompt more research into how and why deprived and minority ethnic populations have suffered so disproportionately for such a long time. Environmental issues, such as poor housing, air pollution and climate change, place additional burdens on vulnerable groups during and beyond the COVID-19 pandemic.

Health inequality continues to take an unjust toll on the most deprived people in society. Solutions require investment in health, not just healthcare. With patients, providers, government, industry and other stakeholders committed to change, we can work towards enhancing the NHS and improving people's lives.

References

1. Marmot M, Allen J, Boyce T, et al. Health equity in England: the Marmot review 10 years on, https://www.health.org.uk/sites/default/files/upload/publications/2020/Health Equity in England_The Marmot Review 10 Years On_full report.pdf (2020).

2. Iacobucci G. Covid-19: Deprived areas have the highest death rates in England and Wales. BMJ; 369.

3. Soreide K, Hallet J, Matthews JB, et al. Immediate and long-term impact of the COVID-19 pandemic on delivery of surgical services. Br J Surg. Epub ahead of print 2020. DOI: 10.1002/bjs.11670.

4. World Health Organisation. Constitution of WHO: principles. WHO.

5. Grossman M. On the Concept of Health Capital and the Demand for Health. J Polit Econ. Epub ahead of print 1972. DOI: 10.1086/259880.

6. Ministry of Housing C and LG. Thge Indices of Deprivation 2019 (IoD2019), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/835115/IoD2019_Statistical_Release.pdf (2019).

7. Tudor Hart J. THE INVERSE CARE LAW. Lancet. Epub ahead of print 1971. DOI: 10.1016/S0140-6736(71)92410-X.

8. Williams E, Buck D, Babalola G. What are health inequalities? 2020.

9. Public Health England. Chapter 5: inequalities in health. 2018.

10. Darzi A. Better Health and Care For All. London, https://www.ippr.org/files/2018-06/better-health-and-care-for-all-june2018.pdf (2018, accessed 1 March 2018).

11. Baker C. NHS Key Statistics: England, February 2020, file:///Users/Leigh/Downloads/CBP-7281.pdf (2020).

12. Office for National Statistics. A Profile of Deprivation in Larger English Seaside Destinations, 2007 and 2010. 2013.

13. House of Lords Select Committee on Regenerating Seaside Towns and Communities. The Future of Seaside Towns, https://publications.parliament.uk/pa/ld201719/ldselect/ldseaside/320/32004.htm#_idTextAnchor006 (2019).

14. Buchan J, Charlesworth A, Gershlick B, et al. A Critical Moment: NHS staffing trends, retention and attrition. 2019.

15. Office for National Statistics. More than half of heroin/morphine misuse death hotspots in England and Wales are seaside locations. Office for National Statistics.

16. Coastal Communities Alliance. About Us.

17. UK Government. Coastal Communities, https://www.gov.uk/government/collections/coastal-communities#:~:text=Coastal communities,to live%2C work and visit.&text=The UK coastline plays a,to live%2C work and visit. (2020, accessed 17 June 2020).

18. Mukhtar TK, Bankhead C, Stevens S, et al. Factors associated with consultation rates in general practice in England, 2013-2014: A cross-sectional study. Br J Gen Pract. Epub ahead of print 2018. DOI: 10.3399/bjgp18X695981.

19. Boomla K, Hull S, Robson J. GP funding formula masks major inequalities for practices in deprived areas. BMJ (Online). Epub ahead of print 2014. DOI: 10.1136/bmj.g7648.

20. Smith SM, Soubhi H, Fortin M, et al. Managing patients with multimorbidity: Systematic review of interventions in primary care and community settings. BMJ (Online). Epub ahead of print 2012. DOI: 10.1136/bmj.e5205.

21. Majeed A. Shortage of general practitioners in the NHS. BMJ. Epub ahead of print 2017. DOI: 10.1136/bmj.j3191.

22. National Centre for Social Research. British Social Attitudes 36. London, https://www.bsa.natcen.ac.uk/media/39363/bsa_36.pdf (2019).

23. The King's Fund. Understanding pressures in general practice, https://www.kingsfund.org.uk/publications/pressures-in-general-practice (2016).

24. Warren LR, Clarke J, Arora S, et al. Improving data sharing between acute hospitals in England: An overview of health record system distribution and retrospective observational analysis of inter-hospital transitions of care. BMJ Open. Epub ahead of print 2019. DOI: 10.1136/bmjopen-2019-031637.

25. Doran T, Fullwood C, Kontopantelis E, et al. Effect of financial incentives on inequalities in the delivery of primary clinical care in England: analysis of clinical activity indicators for the quality and outcomes framework. Lancet. Epub ahead of print 2008. DOI: 10.1016/S0140-6736(08)61123-X.

26. Salisbury C, Johnson L, Purdy S, et al. Epidemiology and impact of multimorbidity in primary care: A retrospective cohort study. Br J Gen Pract. Epub ahead of print 2011. DOI: 10.3399/bjgp11X548929.

27. Wachter RM. Making IT Work: Harnessing the Power of Information Technology to Improve Care in England, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/550866/Wachter_Review_Accessible.pdf (2016, accessed 1 December 2018).

28. NHS England. Allocations, https://www.england.nhs.uk/allocations/ (2020, accessed 8 May 2020).

29. Ewbank L, Thompson J, McKenna H, et al. NHS hospital bed numbers: past, present, future. Kings Fund, https://www.kingsfund.org.uk/publications/nhs-hospital-bed-numbers (2020, accessed 20 May 2020).

30. Sizmur S, Raleigh V. The risks to care quality and staff wellbeing of an NHS system under pressure. King's Fund.

31. Carmichael H. Scotland's NHS facing a 'chronic shortage' of doctors, warns BMA. The National, March 2020.

32. Locke T. UK Doctors' Professional Satisfaction Survey. 2018.

33. NHS Scotland. Understanding Emergency Care in NHS Scotland. 2015.

34. NHS England, NHS Digital, NHS Improvement. Hospital Accident and Emergency Activity.

35. StatsWales. Accident and emergency, https://statswales.gov.wales/Catalogue/Health-and-Social-Care/NHS-Hospital-Waiting-Times/Accident-and-Emergency (2019, accessed 25 May 2020).

36. Ireland D of HN. Hospital activity statistics, https://www.health-ni.gov.uk/topics/dhssps-statistics-and-research/hospital-activity-statistics (2020, accessed 25 May 2020).

37. Scotland PH. Accident and Emergency Data Mart, https://www.isdscotland.org/Health-Topics/Emergency-Care/Accident-and-Emergency-Data-Mart/ (2020, accessed 15 May 2020).

38. NHS England. Data Quality and Methodology Statement – Monthly Diagnostic Waiting Times and Activity.

39. British Heart Foundation. CVD STATISTICS – BHF UK FACTSHEET. London, file:///Users/leighwarren/Downloads/bhf-cvd-statistics---uk-factsheet.pdf (2017).

40. Dey D, Slomka PJ, Leeson P, et al. Artificial Intelligence in Cardiovascular Imaging: JACC State-of-the-Art Review. Journal of the American College of Cardiology. Epub ahead of print 2019. DOI: 10.1016/j.jacc.2018.12.054.

41. Piette JD, List J, Rana GK, et al. Mobile health devices as tools for worldwide cardiovascular risk reduction and disease management. Circulation. Epub ahead of print 2015. DOI: 10.1161/CIRCULATIONAHA.114.008723.

42. Siontis GCM, Mavridis D, Greenwood JP, et al. Outcomes of non-invasive diagnostic modalities for the detection of coronary artery disease: Network meta-analysis of diagnostic randomised controlled trials. BMJ. Epub ahead of print 2018. DOI: 10.1136/bmj.k504.

43. NHS Digital. Health Survey for England 2018. Health Survey for England.

44. Warren L, Clarke J, Darzi A. Data sharing: A targeted strategy to improve sharing between hospitals. National Health Executive, 2020, pp. 30–31.

45. NHS England. Digital Maturity Assessment.

46. Warren L, Clarke J, Arora S, et al. Improving health record interoperability between acute hospitals in England: An overview of health record distribution and retrospective observational review of inter-hospital transitions of care. Submiss to Lancet Digit Heal.

47. Clarke JM, Warren LR, Arora S, et al. Guiding interoperable electronic health records through patient-sharing networks. npj Digit Med; 1, https://www.nature.com/articles/s41746-018-0072-y (2018).

48. Warren LR, Clarke JM, Arora S, et al. Transitions of care across hospital settings in patients with inflammatory bowel disease. World J Gastroenterol. Epub ahead of print 2019. DOI: 10.3748/wjg.v25.i17.2122.

49. Carestream. An Efficient Implementation of a Regional Radiology Reporting Hub. 2019.

50. McMichael AJ. The urban environment and health in a world of increasing globalization: Issues for developing countries. Bull World Health Organ. Epub ahead of print 2000. DOI: 10.1590/S0042-96862000000900007.

51. Watts N, Adger WN, Agnolucci P. Health and climate change: Policy responses to protect public health. Environnement, Risques et Sante. Epub ahead of print 2015. DOI: 10.1016/S0140-6736(15)60854-6.

52 Sinharay R, Gong J, Barratt B, et al. Respiratory and cardiovascular responses to walking down a traffic-polluted road compared with walking in a traffic-free area in participants aged 60 years and older with chronic lung or heart disease and age-matched healthy controls: a randomised, crosso. Lancet. Epub ahead of print 2018. DOI: 10.1016/S0140-6736(17)32643-0.

53. British Heart Foundation. Progress towards cleaner air and why we need to do more. London, file:///Users/Leigh/Downloads/bhf_08_ap_ireport_final.pdf (2019).

54. World Health Organization. Ambient Air Pollution: A global assessment of exposure and burden of disease. 2016.

55. Department for Environment Food and Rural Affairs. Air Quality Statistics, https://www.gov.uk/government/statistics/air-quality-statistics (2020, accessed 31 May 2020).

56. Department for Environment F and RA. UK Air: Air Information Resource.

57. King's College London. London Air, https://www.londonair.org.uk/LondonAir/Default.aspx (2020, accessed 31 May 2020).

58. Mitchell R, Popham F. Greenspace, urbanity and health: Relationships in England. J Epidemiol Community Health. Epub ahead of print 2007. DOI: 10.1136/jech.2006.053553.

59. Fecht D, Fischer P, Fortunato L, et al. Associations between air pollution and socioeconomic characteristics, ethnicity and age profile of neighbourhoods in England and the Netherlands. Environ Pollut. Epub ahead of print 2015. DOI: 10.1016/j.envpol.2014.12.014.

60. Brook R, King K. Updated Analysis of Air Pollution Exposure in London Report to Greater London Authority. Aether.

61. Williams M, Evangelopoulos D, Katsouyanni K, et al. Personalising the Health Impacts of Air Pollution – Summary for Decision Makers. London, 2019.

62. Dajnak D, Walton H, Smith J, et al. Greater Manchester Health and Economic Impact Assessment study. 2018.

63. Transport For Greater Manchester and Greater Mancher Combined Authority. Greater Manchester Air Quality Action Plan 2016-2020. 2016.

64. Enekel K, Quinio V, Swiney P. Cities Outlook 2020. 2020.

65. Littlewood E. The Philips Foundation, Global Action Plan and the University of Manchester launch first of its kind 'Clean Air for Schools' programme in Greater Manchester, https://www.philips.co.uk/a-w/about/news/archive/standard/news/press/2019/20191018-philips-launches-clean-air-for-schools-programme.html (2019).

66. Tian Y, Dixon A, Gao H. Data briefing - Emergency hospital admissions for ambulatory care-sensitive conditions: identifying the potential for reductions. King's Fund.

67. Petrie J, Easton S, Naik V, et al. Hospital costs of out-of-hospital cardiac arrest patients treated in intensive care; a single centre evaluation using the national tariff-based system. BMJ Open. Epub ahead of print 2015. DOI: 10.1136/bmjopen-2014-005797.

68. Patel A, Berdunov V, Quayyum Z, et al. Current, future and avoidable costs of stroke in the UK. Eur Stroke J. Epub ahead of print 2018. DOI: http://dx.doi.org/10.1177/2396987318770127.

69. Luengo-Fernández R, Leal J, Gray A, et al. Cost of cardiovascular diseases in the United Kingdom. Heart. Epub ahead of print 2006. DOI: 10.1136/hrt.2005.072173.

70. Luengo-Fernandez R, Leal J, Gray A, et al. Economic burden of cancer across the European Union: A population-based cost analysis. Lancet Oncol. Epub ahead of print 2013. DOI: 10.1016/S1470-2045(13)70442-X.

71. British Heart Foundation. British Heart Foundation Cardiovascular Disease Statistics Compendium 2017. London, file:///Users/leighwarren/Downloads/bhf-cvd-statistics-compendium-2017.pdf (2017).

72. Shah ASV, Langrish JP, Nair H, et al. Global association of air pollution and heart failure: A systematic review and meta-analysis. Lancet. Epub ahead of print 2013. DOI: 10.1016/S0140-6736(13)60898-3.

73. Costello A, Abbas M, Allen A, et al. Managing the health effects of climate change. Lancet. Epub ahead of print 2009. DOI: 10.1016/s0140-6736(09)60935-1.

74. Marmot M, Allen J, Goldblatt P, et al. Fair society, healthy lives (The Marmot Review): Strategic Review of Health Inequalities in English post-2010. 2010. Epub ahead of print 2010. DOI: 10.1016/j.puhe.2012.05.014.

75. CCC. The Committee on Climate Change. Heat and Preventable Deaths in the Health and Social care system, https://www.theccc.org.uk/wp-content/%0Auploads/2019/07/Outcomes-Heat-preventable-deaths-case-study.pdf. (2019).

76. Thomson H, Thomas S, Sellstrom E, et al. Housing improvements for health and associated socio-economic outcomes. Cochrane Database of Systematic Reviews. Epub ahead of print 2013. DOI: 10.1002/14651858.CD008657.pub2.

77. Committee on Climate Change. Reducing UK emissions - 2019 Progress Report to Parliament. 2019.

78. Sahu KS, Oteomo A, Morita PP. Improving Public Health Surveillance methods via Smart Home technologies. Online J Public Health Inform. Epub ahead of print 2019. DOI: 10.5210/ojphi.v11i1.9795.

79. Imison C, Castle-clarke S, Watson R, et al. Delivering the benefits of digital health care | The Nuffield Trust. Nuff Trust.

80. Kinnear A. Tech Plan: Bringing together people, technology and infrastructure to transform care for patients, http://www.scwcsu.nhs.uk/blog/Help-NHSX-design-the-Tech-Plan-for-health-and-social-care/ (2020, accessed 25 May 2020).

81. NHS England. GP Patient Survey.

82. Statista. Internet of Things (IoT) connected devices installed base worldwide from 2015 to 2025.

83. The Government Office for Science. The IoT: making the most of the Second Digital Revolution. WordLink. Epub ahead of print 2014. DOI: GS/14/1230.

84. Alford J. How wearables could help tackle sepsis. Institute of Global Health Innovation: Imperial College London, 2019.

85. Reuter E. Philips receives FDA clearance for patch that monitors breathing. MedCity News, 2020, https://medcitynews.com/2020/05/philips-receives-fda-clearance-for-wearable-monitoring-device/?rf=1&mc_cid=79a90b1fb5&mc_eid=55b8768135 (2020).

86. O'Reilly K. Philips launches next generation wearable biosensor for early patient deterioration detection, including clinical surveillance for COVID-19, https://www.philips.com/a-w/about/news/archive/standard/news/press/2020/20200526-philips-launches-next-generation-wearable-biosensor-for-early-patient-deterioration-detection-including-clinical-surveillance-for-covid-19.html (2020).

87. Darzi A. Better Health and Care For All: A 10-Point Plan For The 2020s. London, https://www.ippr.org/files/2018-06/better-health-and-care-for-all-june2018.pdf (2018).

88. NHS England and NHS Improvement. Transforming imaging services in England: a national strategy for imaging networks. 2019.

89. Frontier Economics. Exploring the costs of unsafe care in the NHS. Front Econ London.

90. NHS England. Diagnostic Imaging Dataset 2018-19 Data. 2019.

91. Board of the Faculty of Clinical Radiology. Clinical Radiology UK workforce census 2018 report, https://www.rcr.ac.uk/system/files/publication/field_publication_files/clinical-radiology-uk-workforce-census-report-2018.pdf (2019).

92. The British Medical Association. Pay scales for junior doctors in England. Bma.

93. Royal College of Radiologists. Clinical radiology workload: guidance on radiologists' reporting figures. 2012.

94. Keesara S, Jonas A, Schulman K. Covid-19 and Health Care's Digital Revolution. N Engl J Med. Epub ahead of print 2020. DOI: 10.1056/nejmp2005835.

95. Public Health England. Disparities in the risk and outcomes of COVID-19. 2020.

96. NHS England. COVID-19 Daily Deaths, https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-daily-deaths/ (2020, accessed 15 June 2020).

97. Wu X, Nethery RC, Sabath BM, et al. Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. medRxiv. Epub ahead of print 2020. DOI: 10.1101/2020.04.05.20054502.

98. Dietz W, Santos-Burgoa C. Obesity and its Implications for COVID-19 Mortality. Obesity. Epub ahead of print 2020. DOI: 10.1002/oby.22818.

99. Plan B. A "WELLBEING ECONOMY" MUST EMERGE FROM COVID-19 - Panel Discussion, https://planb.earth/wp-content/uploads/2020/03/Press-release-26-March-2020-final.pdf (2020).

100. Eberly LA, Khatana SAM, Nathan AS, et al. Telemedicine Outpatient Cardiovascular Care during the COVID-19 Pandemic: Bridging or Opening the Digital Divide? Circulation. Epub ahead of print 2020. DOI: 10.1161/circulationaha.120.048185.

101. DeGuzman PB, Bernacchi V, Cupp CA, et al. Beyond broadband: digital inclusion as a driver of inequities in access to rural cancer care. J Cancer Surviv. Epub ahead of print 2020. DOI: 10.1007/s11764-020-00874-y.

102. Mueller B. Telemedicine Arrives in the U.K: '10 Years of Change in One Week'. The New York Times, April 2020.

103. Greenhalgh T. Using virtual consultations in the fight against COVID-19. The Health oundation - news and comment, 2020.

104. Horton T, Jones B. Three key quality considerations for remote consultations. 2020.

105. de Quetteville H. Matt Hancock downplays role of contact tracing app. The Telegraph, June 2020.

106. National Audit Office. Healthcare Across the UK: A Comparison of the NHS in England, Scotland, Wales and Northern Ireland. 2012.

http://www.philips.co.uk