HSDR Rapid Evaluation Centre Topic Report

A Rapid Mixed Methods Evaluation of Remote Home Monitoring Models During the COVID-19 Pandemic in England

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Abstract

Background

Remote home monitoring services were developed and implemented for COVID-19 patients during the pandemic. Patients monitored blood oxygen saturation and other readings (e.g. temperature) at home and were escalated as necessary.

Objective

To evaluate effectiveness, costs, implementation, and staff and patient experiences (including disparities and mode) of COVID-19 remote home monitoring services in England during the COVID-19 pandemic (waves 1 and 2).

Methods

A rapid mixed-methods evaluation, conducted in two phases. Phase 1 (July-August 2020) comprised: a rapid systematic review, implementation and economic analysis study (in 8 sites). Phase 2 (January-June 2021) comprised: a large scale, multi-site, mixed-methods study of effectiveness, costs, implementation and patient/staff experience, using national datasets, surveys (28 sites) and interviews (17 sites).

Results

Phase 1

Findings from the review and empirical study indicated that these services have been implemented worldwide and vary substantially. Empirical findings highlighted that communication, appropriate information and multiple modes of monitoring facilitated implementation; barriers included unclear referral processes, workforce availability and lack of administrative support.

Phase 2

We received surveys from 292 staff (39% response rate) and 1069 patients/carers (18% response rate). We conducted interviews with 58 staff, 62 patients/carers and 5 national leads.

Despite national roll-out, enrolment to services was lower than expected (average enrolment across 37 CCGs judged to have completed data was 8.7%). There was large variability in implementation of services, influenced by patient (e.g. local population needs), workforce (e.g. workload), organisational (e.g. collaboration) and resource (e.g. software) factors.

We found that for every 10% increase in enrolment to the programme, mortality was reduced by 2% (95% Confidence Interval: 4% reduction to 1% increase), admissions increased by 3% (-1% to 7%), in-hospital mortality fell by 3% (-8% to 3%) and lengths of stay increased by 1.8% (-1.2% to 4.9%). None of these results are statistically significant.

We found slightly longer hospital lengths of stay associated with virtual ward services (adjusted incidence rate ratio 1.05, 95% Confidence Interval 1.01 to 1.09), and no statistically significant impact

on subsequent COVID-19 readmissions (adjusted Odds Ratio 0.95, 95% Confidence Interval 0.89 to 1.02).

Low patient enrolment rates and incomplete data may have affected chances of detecting possible impact.

The mean running cost per patient varied for different types of service and mode; and was driven by the number and grade of staff.

Staff, patients and carers generally reported positive experiences of services. Services were easy to deliver but staff needed additional training. Staff knowledge/confidence, NHS resources/workload, dynamics between multidisciplinary team members and patients' engagement with the service (e.g. using the oximeter to record and submit readings) influenced delivery. Patients and carers felt services and human contact received reassured them and were easy to engage with. Engagement was conditional on patient, support, resource and service factors.

Many sites designed services to suit the needs of their local population. Despite adaptations, disparities were reported across some patient groups. For example, older adults and patients from ethnic minorities reported more difficulties engaging with the service.

Tech-enabled models helped manage large patient groups, but did not completely replace phone calls.

Limitations

Limitations included data completeness, inability to link data on service use to outcomes at a patient level, low survey response rates and under-representation of some patient groups.

Future work

Further research should consider the long-term impact and cost-effectiveness of these services and the appropriateness of different models for different groups of patients.

Conclusions

We were not able to find quantitative evidence that COVID-19 remote home monitoring services have been effective. However, low enrolment rates, incomplete data and varied implementation reduced our chances of detecting any impact that may have existed. Whilst services were viewed positively by staff and patients, barriers to implementation, delivery and engagement should be considered.

Funding

Word count: 631/500

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Supplementary material can be found on the NIHR Funding and Awards report topic page (https://www.fundingawards.nihr.ac.uk/award/NIHR132703).

Supplementary material has been provided by the authors to support the report and any files provided at submission will have been seen by peer reviewers, but not extensively reviewed. Any supplementary material provided at a later stage in the process may not have been peer reviewed.

List of abbreviations

AHSN	Academic Health Science Network
ANPs	Advanced nurse practitioners
BRACE	The Birmingham, RAND and Cambridge Evaluation Centre
CCGs	Clinical Commissioning Groups
CE	European Conformity
CEV	Clinically Extremely Vulnerable
CI	Confidence Interval
CLAHRC	Collaboration for Leadership in Applied Health Research and Care
CO@h	COVID Oximetry @home
COPD	Chronic Obstructive Pulmonary Disease
COVID-19	Coronavirus disease-19
CVW	COVID Virtual Wards
FTE	Full-time equivalent
GEE	Generalised Estimating Equation
GPs	General Practices
HES	Hospital Episode Statistics
HES APC	Hospital Episode Statistics Admitted Patient Care
HRA	Health Research Authority
HS&DR	Health Services and Delivery Research
HTA	Health Technology Assessment
IAU	Improvement Analytics Unit
ICD-10	International Statistical Classification of Diseases and Related Health Problems 10th Revision
ICU	Intensive Care Unit
IMD	Index of Multiple Deprivation
IQR	Interquartile range
IRR	Incidence Rate Ratios
IT	Information Technology
KSS AHSN	Kent, Surrey and Sussex Academic Health Science Network
LOS	Length of stay
LSOA	Lower super output area
MHRA	Medicines and Healthcare Products Regulatory Agency
MS Teams	Microsoft Teams
NASSS	Non-adoption, Abandonment, and challenges to the Scale-up, Spread, and Sustainability
NHS	National Health Service
NHSEI	National Health Service England and Improvement
NHSX	NHS user experience
NIHR	National Institute for Health Research

NIRB	National Incident Response Board
OR	Odds ratio
PERCS	Planning and Evaluating Remote Consultation Services
PGfAR	Programme Grants for Applied Research
PHE	Public Health England
PHR	Public Health Research
PPI	Patient and Public Involvement
RAP sheets	Rapid Assessment Procedure sheets
REC	Research Ethics Committee
REDCap	Research Electronic Data Capture
RSET	Rapid Service Evaluation Team
SARS	Severe Acute Respiratory Syndrome
SARS-CoV-2	Severe acute respiratory syndrome coronavirus
SITREPS	Situation Reports
SOP	Standard Operating Procedure
SPSS	Statistical Package for the Social Sciences
UCL	University College London
UCLH	University College London Hospitals
UK	United Kingdom
US	United States
WHO	World Health Organisation

Glossary

Term	Definition
Analogue	Analogue models are services whereby patients receive a paper diary and provide oximeter readings via phone.
Tech-enabled	Tech-enabled models are services whereby patients enter readings via a tech-enabled solution, e.g. an app, text, automated phone call or email.
Onboarding	Onboarding means that patients were admitted onto the service
Remote home monitoring	Patients (or their carers) submit their readings (via phone or a tech-enabled solution), and these readings are monitored remotely.
COVID Oximetry@home	Model of COVID-19 remote home monitoring whereby patients were referred via community routes prior to a potential admission to hospital (e.g. GP practices, hot hubs, emergency departments).
COVID Virtual wards	Model of COVID-19 remote home monitoring whereby patients were referred to services to enable earlier discharge from hospital.

Scientific summary

Background and rationale

Delays in the presentation of patients with COVID-19 has led to patients arriving at hospital with very low oxygen saturations often without breathlessness ('silent hypoxia'). This has resulted in patients being admitted to hospital with advanced COVID-19, thus requiring invasive treatment, potential admission to intensive care and poorer outcomes.

Remote home monitoring models that systematically record and communicate patients' physiological parameters to clinicians are currently being used globally for a variety of conditions. These models offer a potential solution for reducing the delays in providing appropriate treatment for COVID patients by identifying at-risk patients earlier.

As a result, services providing remote home monitoring using pulse oximetry for COVID-19 patients were developed ad hoc in some areas in England during the first wave of the pandemic (March to July 2020). Learning from these earlier services, NHS England and Improvement (in November 2020) launched a national roll-out of a model of care called 'COVID Oximetry @home (CO@h)', followed by early discharge models, referred to as 'virtual wards' (in January 2021). We refer to these services as COVID-19 remote home monitoring services. All of these services provide patients with an oximeter and ask them to regularly record and relay their oxygen levels (alongside other generic COVID-19 symptoms) to a supporting team of administrators and clinicians via an online app, email or portal, or over the telephone. Patients being monitored are escalated to receive additional care if necessary.

Previous research has explored remote home monitoring for other conditions, but there is a lack of research on the effectiveness, cost, implementation and staff/patient experiences of remote home monitoring models for COVID-19. This study explored the impact and implications of these COVID-19 remote home monitoring services during the first and second waves of the pandemic.

Phase 1

Phase 1 of this evaluation (during wave 1 of the pandemic) aimed to answer the following research questions:

1) How have remote home monitoring services been implemented for COVID-19 and what are their main components, processes of implementation, target patient populations, impact on outcomes, costs and lessons learned?
2) What were the characteristics of remote home monitoring models for COVID-19, experiences of staff implementing these models, data processes and lessons learned during wave 1 of the pandemic?

Phase 2

Phase 2 of this evaluation (during wave 2 of the pandemic) aimed to answer the following research questions:

1) Are COVID-19 remote home monitoring services associated with changes in mortality and use of hospital services? Does the use of tech-enabled oximetry have a measurable effect on mortality and hospitalisations?
2) What were the costs of setting up and running COVID-19 remote home monitoring services and how do these costs vary between tech-enabled and analogue, and analogue-only data submission modes?
3) What are the factors influencing delivery and implementation of COVID-19 remote home monitoring services? Do these vary by type of model, geography, mode of remote monitoring approach (tech-enabled vs. analogue)?
4) What are the experiences and behaviours (i.e. engagement with services, use of other services) of patients receiving COVID-19 remote home monitoring services? Do these vary by type of model, patient characteristics, mode of remote monitoring (tech-enabled vs. analogue)?
5) Are there potential impacts on inequalities?
6) What are the experiences of staff delivering COVID-19 remote home monitoring services? Do these vary by mode of remote monitoring (tech-enabled vs. analogue)?

Methods

This study used mixed methods consisting of two phases.

Phase 1

Phase 1 (data collected between July-August 2020) comprised a rapid systematic review (n=27 articles) and an empirical mixed-methods implementation study of staff experiences, the use of data for monitoring progress against outcomes, variability in staffing and resource allocation, patient numbers and impact and lessons learnt (in 8 sites).

Phase 2

Phase 2 (data collected between January and June 2021) was a large scale, multi-site, mixed methods study, including: effectiveness, cost analysis, implementation and patient/staff experience (in 28 sites). To explore impact and effectiveness of remote home monitoring services relating to hospitalisations and mortality, we used routinely available data, hospital administrative data and aggregated and other information produced by the programme. To explore costs of setting up and running COVID-19 remote home monitoring services, we collected aggregated data on patient numbers, staffing models, and allocation of resources from 26/28 sites. To explore implementation, staff experiences of delivering these services, patient experiences of receiving and engaging with these services (including a focus on inequalities and technology-enabled and analogue vs. analogue-only models), we conducted surveys and interviews with staff, patients and carers, and interviewed national leads.

We involved patients, carers and the public throughout the project. Members of the study team met with members of The Birmingham, RAND and Cambridge Evaluation Centre (BRACE) and Rapid Service Evaluation Team (RSET) Patient and Public Involvement Groups throughout the project (n=4 meetings),

to discuss various aspects of the project, including but not limited to the research questions, data collection tools and findings.

Results

A summary of findings is provided in Figure 1.

PHASE 1

COVID-19 remote home models used internationally

- Services implemented internationally.
- Models varied (online / telephone (more inclusive).
- Limited evidence for patient safety/cost.
- Gaps of effectiveness, cost-effectiveness, patient experience.

Implementation of services in England

- Services varied in relation to settings and mechanisms used for patient triage, monitoring and escalation.
- Implementation facilitators:
  - Good team communication,
  - Culturally appropriate information,
  - Multiple modes of monitoring.
- Mean cost per monitoring: £400-£553.

PHASE 2

Development and implementation of services in England

Development

Rapid development of services in 3 phases:

1. Local development

2. National development and roll-out

3. Local implementation

Implementation and enrolment

- Despite national roll-out, enrolment to services was lower than expected.
- Large variability in the models services implemented.
- Variation influenced by patient, workforce, organisational and resource factors.

Development and implementation facilitated by wave 1 learning (including phase 1 findings), a range of stakeholders and initiatives (community of practice, national learning network and AHSN Patient Safety Collaborations).

Service outcomes

- No association between CO@h services and COVID-associated deaths or admission to hospital.
- No association between CVW service and readmissions, potentially longer lengths of stay.

Cost of services

- Cost for CVW higher than CO@h services.
- Cost per patient lower for tech-enabled than analogue-only sites.
- Most staff running services were clinical staff.

Workforce experience and delivery

- Staff liked delivering the service.
- Valued support, but further training needed.
- Delivery influenced by support, NHS resources, capacity/workload, team dynamics and patient (dis)engagement.

Patient experience and engagement

- Support from staff, and family and friends was key.
- Patients liked the service.
- Human contact reassured patients.
- Mostly easy to engage with but conditional on patient factors, support and resources and service characteristics.

Disparities

- Sites designed service to be inclusive of local populations and broad reach.
- Disparities reported across patient groups regarding experience and engagement with service.
- Certain groups need more support.

Mode of service

- Most services provided tech-enabled and analogue submission options.
- Telephone may offer support for certain groups.
- Tech models may be better equipped for managing large numbers.
- Technology not a substitute for human contact.

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Figure 1. Summary of key findings

Phase 1

Findings from the systematic review indicated that remote home monitoring services have been implemented internationally for COVID-19. Findings from the review and empirical study highlighted that models of remote home monitoring for COVID-19 varied internationally and within England.

Many factors facilitated implementation, including good communication within clinical teams, culturally appropriate information for patients and carers, and the combination of multiple approaches for patient monitoring (app and paper-based).

Findings from Phase 1 were disseminated widely and used to inform decisions in relation to the future roll-out of services and the design of Phase 2 .

Phase 2

We received surveys from 292 staff (39% response rate) and 1069 patients/carers (18% response rate), and conducted interviews with 58 staff, 62 patients/carers and 5 national leads.

The rapid development of national remote home monitoring services took place in three phases: local development (during wave 1 of the pandemic), national development and roll-out (between wave 1 and 2 of the pandemic) and local implementation (during wave 2 of the pandemic). Despite national roll-out, enrolment of people to COVID-19 remote home monitoring services was lower than expected and there was large variability in the models of remote home monitoring services that were implemented. This variation was influenced by patient, workforce, organisational and resource factors.

The overall enrolment rate to the service across 37 CCGs judged to have complete data was 8.7%. We found that for every 10% increase in enrolment to the programme, mortality was reduced by 2% (95% confidence interval: 4% reduction to 1% increase), admissions increased by 3% (-1% to 7%), in-hospital mortality fell by 3% (-8% to 3%) and lengths of stay increased by 1.8% (-1.2% to 4.9%). None of these results are statistically significant. For COVID Virtual Wards (CVW), we found that the roll-out of virtual ward services for COVID-19 did not reduce rates of readmission (adjusted odds ratio (OR) 0.95, 95% confidence interval 0.89 to 1.02) or lengths of stay in hospital. In fact, our analysis indicated longer lengths of stay (adjusted incidence rate ratio 1.05, 95% confidence interval 1.01 to 1.09).

The mean running cost per patient monitored under the CO@h services was slightly lower compared with CVW services (£527.5 vs. £599.1). For CO@h and CVW services the mean cost per patient monitored at home was lower in sites using both tech-enabled and analogue modes of data submission compared with the sites using analogue-only modes. The majority of staff involved in running COVID-19 remote home monitoring services were clinical staff. Over 50% of staff (clinical and non-clinical staff combined) were employed at Band 5 or below in the CO@h service, whereas in CVW services there were slightly more staff on Band 6 or above.

Staff generally reported positive experiences of delivery (75% of staff reported a positive impact of their role on job satisfaction), felt that services were easy to deliver and valued support provided.

However, findings indicated that staff would have benefitted from further training; 41% of service leads and 12% of delivery staff identified further training or support needs. Factors influencing delivery of remote home monitoring services for COVID-19 included: staff knowledge and confidence, NHS resources and capacity on staff workload, multidisciplinary team dynamics, and patient (dis)engagement.

Patients and carers reported positive experiences (93% rated the service as good or excellent) and felt that services and human contact received as part of these services reassured them and were easy to engage with. Findings indicated that patients with COVID-19 can engage with remote monitoring services but may require support from staff and family/friends to do so. Engagement was conditional on a range of factors including patient factors, support and resources, and service characteristics. Findings indicate that burden of treatment may be experienced by patients and families with acute conditions.

Many sites designed their service to be inclusive of the needs of local populations to ensure broad reach, and many sites adapted their service locally to suit specific patient needs to encourage engagement. Despite these local adaptations to services, disparities were reported across patient groups. Age ($p<0.001$) and level of education ($p<0.001$) were related to whether patients reported a problem with the service, and health status, ethnicity, gender and level of education were associated with engagement with services, and age ($p=0.005$) and ethnicity ($p=0.001$) were associated with patient reports of understanding information.

Most of the services included in this evaluation offered tech-enabled and analogue data submission options to patients. Older patients ($p=0.005$), patients with a lower level of educational attainment ($p=0.011$) and ethnic minorities ($p=0.043$) were more likely to relay symptoms through phone calls with the service. Staff considered the tech-enabled models better equipped to manage large patient numbers; however, many improvements were suggested to improve functionality of technology systems to better fit clinical and operational needs. For patients and staff, tech-enabled and analogue models were not a substitute for human contact, which was a feature of all models. Staff used phone calls to gain comprehensive knowledge of their patients' condition and ensure they had care in the most appropriate setting.

Limitations
One limitation of our evaluation was that data were commonly incomplete or absent and services were not used as extensively as expected; therefore, we were unable to conclusively determine the effectiveness of services. Additional limitations included the inability to link data on service use to outcomes at a patient level, low survey response rates and the under-representation of some patient groups.

Conclusions
Our evaluation was unable to provide conclusive evidence regarding the effectiveness of COVID-19 remote home monitoring services on hospitalisations, lengths of hospital stay and mortality, due to low rates of enrolment and lack of data. Findings also outline large variability in the models

implemented in relation to design and intensity of monitoring, workforce, enrolment levels and criteria. A number of factors influenced implementation including patient, staff, organisational and resource factors. Services were viewed positively by staff and patients alike, but some challenges to delivery and engagement have been identified and therefore services may not be appropriate for all groups without adaptations. Future remote home monitoring services for COVID-19 and other conditions should ensure that staff are well supported and have capacity to deliver these services, that patients have appropriate support, ability, and understanding to engage with these services. Findings from these studies highlighted the need for quality data to be collected as part of future service implementation in order to enable evaluations of effectiveness in future.

Future research is needed in several areas. For example, longitudinal evidence on the effectiveness and cost-effectiveness of COVID-19 remote home monitoring services (requiring high quality complete linked data sets) is needed. Additionally, research on the appropriateness of different models of remote home monitoring services for different groups of patients, and experiences of staff, patients and carers whose views may not have been captured within this evaluation are needed.

Word count: 1976/2000

Plain English summary

The problem:

COVID-19 patients can experience very low oxygen levels, without feeling breathless. Patients may not realise there is a problem until they become extremely unwell, risking being admitted to hospital too late.

To address this, COVID-19 remote home monitoring services were developed and later rolled out across England. Patients monitored oxygen levels at home using an 'oximeter' (a small device which clips on to your finger) and sent these readings to providers via phone or technology (e.g. an app). Patients could access further care if needed.

We did not know whether these services worked, or what people felt about them.

We looked at:

- How services were set up and used in England
- Whether services work (e.g. by reducing deaths and length of hospital stay)
- How much they cost
- What patients, carers and staff think about these services (including differences between groups and telephone vs. technology).

What we did:

We looked at available existing evidence and collected data from eight services operating in the first wave of the pandemic. During the second wave of the pandemic, we used data available at a national level and conducted surveys (28 sites) and interviews (17 sites) with staff, patients and individuals involved in developing/leading services nationally.

What we found:

These services have been used worldwide, but vary considerably. We found many things that help these services to be used (e.g. good communication), but also that get in the way (e.g. unclear referrals).

Our findings did not show that services reduce deaths or time in hospital. But these findings are limited by a lack of data.

Staff and patients liked these services, but we found some barriers to delivering and using the service. Some groups found services harder to use (e.g. older patients, those with disabilities and ethnic minorities).

Using technology helped with large patient groups, but it did not completely replace phone calls.

Conclusion: Better data is needed to know whether these services work. Staff and patients liked these services. However, improvements may make them easier to deliver and use (e.g. further staff training and giving additional support to patients who need it).

Word count: 350/300

Chapter 1. Context

Background

In December 2019, cases of a new form of coronavirus, 'severe acute respiratory syndrome (SARS) coronavirus' (SARS-CoV-2), were identified in Wuhan in China.[1] The SARS-CoV-2 virus causes an infectious disease, which is referred to as 'COVID-19'.[2] In January 2020, the World Health Organisation (WHO) declared the outbreak to be a "public health emergency of international concern".[3] COVID-19 has been responsible for millions of deaths and hospitalisations worldwide.[4] The WHO reported that globally there have been 256,966,237 confirmed cases and 5,151,643 deaths (as of 22nd November, 2021).[5] COVID-19 cases have continued to fluctuate since January 2020. For example, since January 2020, England alone has experienced three waves of the COVID-19 pandemic (wave 1: March-May 2020, wave 2: October 2020-February 2021, wave 3: began in July 2021 but has been complex to track, and is therefore currently difficult to estimate the end date was).[6]

COVID-19 is characterised by some common symptoms including a fever, a continuous cough, tiredness and loss of taste and/or smell.[2] In wave 1, there was a lack of knowledge of COVID-19 and treatment options compared to later waves. During the COVID-19 pandemic, restrictions on travel, social interaction and access to public spaces, known as a 'lockdown', were introduced worldwide. For example, within the United Kingdom (UK), individuals were asked to stay at home (with the exception of critical workers, e.g. healthcare professionals, food retail workers) and to socially distance from others.[7] To minimise spread of the disease and increase capacity of healthcare services, many routine healthcare appointments were cancelled across the National Health Service (NHS) or delivered remotely, [8-11] and parts of the workforce were redeployed.

COVID-19 is an acute disease with differential effects on the population. Diagnosis of COVID-19 can have many health, mental health, economic and social impacts on individuals. Whilst many individuals develop mild to moderate illness, for some the disease can be life-threatening.[2] COVID-19 has been responsible for thousands of deaths and hospitalisations in the UK.[6] As of November 2021, the UK reported 143,927 COVID-19 deaths.[5] In particular, some groups have been shown to have worse mortality and outcomes from COVID-19, e.g. older adults, those with significant medical comorbidities, males, those living in more deprived areas, Black and Asian ethnic groups, and those working in certain occupations (such as taxi/bus/coach drivers, retail assistants, construction workers, social care workers, and nurses).[12]

Patients with COVID-19 may present with 'silent hypoxia' (very low oxygen saturations, often without breathlessness).[13, 14] Patients may not be aware that they have low blood oxygen saturations, which may lead to delays in patients being escalated and admitted to hospital, presenting with more serious advanced symptoms of the disease. This has resulted in some patients needing invasive treatments and/or being admitted to intensive care units, with a higher likelihood of mortality.[15, 16]

To deliver better and more personalised care to people in their own homes, services which enable patients to self-manage their health and care at home (e.g. remote home monitoring) have been identified as a priority within the NHS @home programme [17] and the NHS long term plan.[18] Prior to the pandemic, remote home monitoring models have been used to monitor and provide care for patients with chronic health conditions (e.g. heart failure, Chronic obstructive pulmonary disease (COPD), diabetes, kidney disease, cancer).[19-21] However, the COVID-19 pandemic enhanced and accelerated the need for healthcare services to use technology in care delivery.[22]

To reduce pressure on hospitals and infection transmission, and to ensure that COVID-19 patients receive appropriate care in the right place and are appropriately escalated as early as possible, COVID-19 remote home monitoring models using pulse oximetry have been developed and implemented in many different countries during the pandemic,[23-32] and are now recommended by the WHO.[33] The

type of remote monitoring varies, in relation to the frequency of monitoring, mode of monitoring and recording (analogue or technology-enabled), referral criteria and the inclusion of pulse oximetry.[23-32]

Within remote monitoring models, patients take readings at home and submit these to a healthcare professional in another location for review.[34] Pulse oximeters are small devices which can be placed on a person's finger and used to measure blood oxygen levels. Pulse oximeters were used as previous research indicates that oxygen saturation may predict outcomes such as mortality and admissions to intensive care units.[35] Patients, or their carer, measure blood oxygen saturations with a pulse oximeter (along with other measurements e.g. temperature) at home. They record these readings in one of two ways: i) recording readings on a paper diary and providing readings via telephone (analogue), or ii) recording and submitting readings using digital technology such as mobile apps, automated telephone or text (technology-enabled). Once patients have submitted readings, a healthcare provider reviews these readings elsewhere, escalating care when necessary.[32, 36]

In England, during the first wave of the pandemic, COVID-19 remote home monitoring models (pre-hospital and early discharge models) using pulse oximeters were implemented in a number of areas.[36] During 2020, NHS England and Improvement (NHSEI) purchased and distributed them to clinical commissioning groups throughout England. NHSEI purchased 706,000 oximeters across waves one and two [Zolna, 2020 personal communication]. These pulse oximeters were European Conformity (CE) marked (as recommended by Medicines and Healthcare Products Regulatory Agency (MHRA) guidance)[37] and were available to local sites within three days through an ordering system set out in the standard operating procedure (SOP). In November 2020, NHSEI launched a national roll-out of COVID Oximetry @home services (CO@h).[38] Patients were referred within the community to the CO@h service (e.g. via General Practices (GPs), COVID-19 specific community clinics called hot hubs, emergency departments). In addition, in January 2021, NHSEI launched a national roll-out of 'COVID virtual ward' (CVW) models, whereby patients were referred on to services upon being discharged from hospital early.[39] CVW models aimed to reduce pressures on hospitals by enabling early discharge and continuation of recovery at home. The national model of COVID-19 remote home monitoring, advocated by NHSEI was for self-monitoring and self-escalation (with reference to clinical judgement), based on their learning from wave 1.[38, 39] Self-monitoring and self-escalation refer to patients (or carers, where appropriate) monitoring their own readings and escalating their own care as necessary, with an option for prompts or check-in calls to take readings on certain days. This differs from remote home monitoring models whereby patients (or carers) submit readings to providers who monitor these readings remotely. NHSEI supported the national roll-out and local implementation of COVID-19 remote home monitoring services, including providing financial support for primary care to establish and implement COVID-19 remote home monitoring services,[40] resourcing NHS digital to supply data to COVID-19 remote home monitoring providers to identify people who may benefit from these services,[41] and the commissioning and funding of Academic Health Science Network (AHSN) Patient Safety Collaboratives. This study included both CO@h and CVW models. Collectively, throughout this report, we refer to these services as remote home monitoring for COVID-19 patients (Figure 2 for a summary of these models).
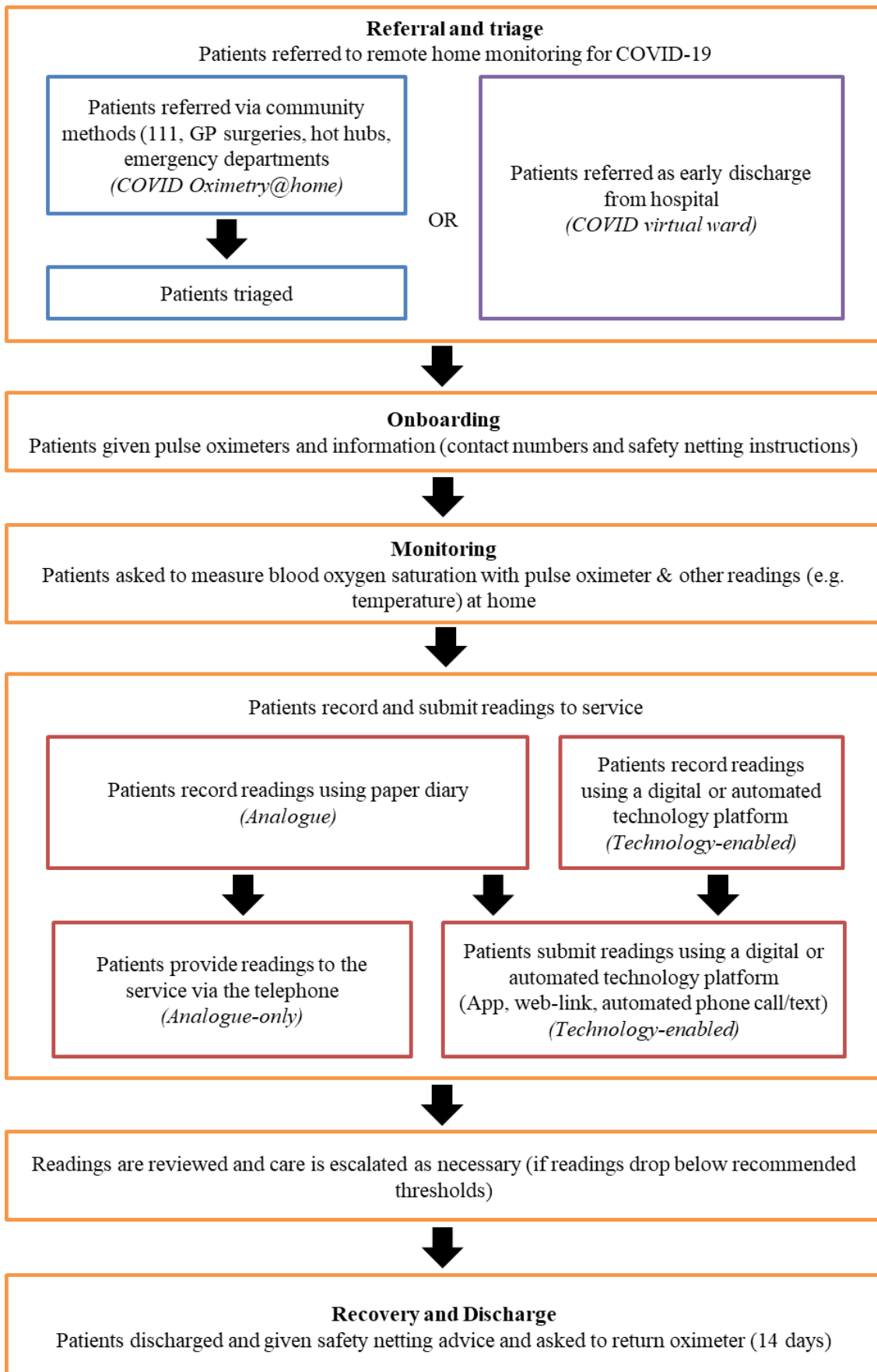
Figure 2. A summary of remote home monitoring for COVID-19 services.

In addition, NHS user experience (NHSX) supported the implementation of COVID-19 remote home monitoring services through facilitation of the use of technology-enabled platforms. In the initial stages of roll-out (during wave 1), NHSX helped pilot sites to use technology-enabled platforms as part of their CO@h and CVW services by signposting services to tech companies (however, it was up to local sites to decide if technology offered by tech companies met their needs). In wave 2, NHSX funded and supported the implementation and evaluation of technology-enabled solutions for COVID-19 remote home monitoring services.

Despite previous research on the use of remote home monitoring models for other chronic health conditions,[19-21] there is a lack of studies exploring models of care developed to implement remote home monitoring across different healthcare contexts during the COVID-19 pandemic. It is important to explore the implementation of remote home monitoring models within the context of a pandemic as it is likely that this context differs in relation to healthcare pressures, patient needs and uncertainties. There is also a lack of studies evaluating the effectiveness and implementation of remote home monitoring models for COVID-19 patients, including in-depth analyses of patients' and staff's experiences of receiving and delivering care. This mixed-methods evaluation of remote home monitoring models in England aimed to address this gap by exploring the impact of the implementation of COVID-19 remote home monitoring models (on length of stay (LOS) in hospital, re-admission and health outcomes), the costs of implementing these models, the experiences of patients with remote home monitoring, staff involvement and experiences of delivering care and the processes used to implement these models at national and local levels. The study had a particular focus on inclusivity of these services and potential impact on inequalities.

Study aims

Phase 1

The Phase 1 study comprised the following:

1. International rapid systematic review of remote home monitoring services for COVID-19 patients.[32]
2. Rapid study of implementation of remote home monitoring services for COVID-19 patients during the first wave of the coronavirus pandemic in England (mixed-methods).[36]

The rapid systematic review aimed to analyse the implementation and impact of remote home monitoring models for COVID-19 patients.

The empirical implementation study aimed to: develop a conceptual map of remote home monitoring models, explore the experiences of staff implementing these models during the COVID-19 pandemic, document impact of services, understand the use of data for monitoring progress against outcomes, and document variability in staffing and resource allocation.

Phase 2

Building on Phase 1, we conducted a multi-site, mixed methods national evaluation involving 28 purposively selected COVID-19 remote home monitoring services (October 2020-November 2021).

This evaluation aimed to explore effectiveness, costs, implementation and experience (staff/patients) of COVID-19 remote home monitoring, and comprised four workstreams:

1. Effectiveness.
2. Cost analysis.
3. National survey of implementation and staff and patient experience.
4. In-depth case studies of implementation and staff and patient experience.

Research questions

Phase 1

Systematic review:

1. What are the aims of remote home monitoring models?
2. What are the main components of these models?
3. What are the patient populations considered appropriate for remote monitoring?
4. How is patient deterioration determined and flagged?
5. What are the expected outcomes of implementing remote home monitoring?
6. How have these models been evaluated?
7. What are the benefits and limitations of implementing these models?

Implementation study:

1. What were the conceptual models guiding the implementation of remote home monitoring models during the COVID-19 pandemic?
2. What were the processes that acted as barriers and facilitators in the design and implementation of pilots of these models during wave 1 of the pandemic?
3. What were the expected outcomes of the virtual wards implemented during wave 1 of the pandemic?
4. What data were collected by pilot sites and how has it helped them monitor progress against their expected outcomes?
5. What quantitative evidence did the sites use from national and international experiences of these models to help inform clinical management decisions?
6. How were resources allocated (including staffing models) to implement the remote home monitoring pilots during wave 1 of the pandemic?
7. What are the lessons learned from implementing remote home monitoring models during wave 1 of the pandemic? Can some of these lessons be used for planning care delivery for winter 2020-2021?

Phase 2

1. What was the impact of remote home monitoring for COVID-19 patients on mortality and use of hospital services? (workstream 1)
2. What were the costs of setting up and running CO@h and CVW models? (workstream 2)
3. What were the factors influencing delivery and implementation of remote home monitoring for COVID-19 patients? (workstream 3)
4. What were the experiences and behaviours (i.e. engagement, use of other services) of patients receiving remote home monitoring for COVID-19 patients? (workstream 3)
5. Were there potential impacts of remote home monitoring for COVID-19 patients on existing health inequalities? (workstream 3)
6. What were the experiences of staff delivering remote home monitoring for COVID-19 patients? (workstream 3)

See *Chapter 2* for protocol deviations.

Structure of this report

- **Chapter 1** (context) outlines the rationale for this evaluation.
- **Chapter 2** (methods) presents the design and methods used (Phase 1 and 2). Detailed methods are presented within each findings chapter.
- **Chapter 3-11** (findings) outline the findings.
    - **Chapter 3** - Phase 1.
    - **Chapter 4** - Implementation study (workstream 3 and 4).

- o **Chapters 5 and 6** - Effectiveness study (workstream 1).
- o **Chapter 7** - Cost analysis (workstream 2).
- o **Chapters 8 to 11** - Patient and staff experience findings (workstreams 3 and 4).
- **Chapter 12** (discussion and conclusion) - key findings, strengths and limitations, implications/lessons learned and future research.

Other related evaluations

Two other evaluations of remote home monitoring models for COVID-19 were commissioned alongside this evaluation, conducted by: i) Institute of Global Health Innovation, NIHR Patient Safety Translational Research centre, Imperial College London and, ii) the Improvement Analytics Unit (Partnership between the Health Foundation and NHSEI). Both evaluations investigated the impact of the CO@h service on mortality and hospital service use.[42-45] Imperial College London also examined inequalities in the enrolment of eligible patients on to the CO@h service and conducted quantitative evaluations of differences between technology-enabled and analogue pathways.[46]

BRACE and RSET also investigated the use of pulse oximetry in care homes across England and completed a mixed methods rapid evaluation using an online national survey sent to all care homes in England and qualitative interviews with staff from six care homes acting as case study sites (see [47]).

Working with stakeholders

Throughout the evaluation, the team worked with a range of stakeholders at national and local levels (Phase 1: community of practice, Phase 2: NHSEI, NHS Digital, NHSX, community of practice, national learning network and Clinical advisory group).

Chapter 2. An overview of the methods used in the COVID-19 remote home monitoring evaluation

This chapter outlines the methods used in Phase 1 and Phase 2 of the evaluation. Individual chapters provide further details.

Phase 1

This phase was developed as a result of a four-week scoping exercise including initial scoping of the literature, discussions with a small number of sites, documentary analysis and discussions with colleagues at Public Health England (PHE) and NHSEI.

Methods

Setting

In England, within healthcare organisations (trusts/Clinical Commissioning Groups (CCGs)) who delivered remote home monitoring services for COVID-19 patients (including CO@h and CVW models). The evaluation took place between July and September 2020.

Procedure

SYSTEMATIC REVIEW

A rapid systematic review of virtual ward models (led by primary and secondary care) was conducted. The systematic review followed the method proposed by Tricco *et al.*[48] See *Chapter 3*.

IMPLEMENTATION STUDY

A rapid multi-site implementation study which combined qualitative and quantitative approaches. Interviews were conducted with staff across eight sites in England. Additionally, we collected data on impact, costs, and staffing models. See *Chapter 3*.

Ethical approval

This phase received ethical approval from the University of Birmingham Humanities and Social Sciences ethics committee (ERNE_13-1085AP37) and was categorised as a service evaluation by the Health Research Authority (HRA) decision tool and University College London/University College London Hospitals (UCL/UCLH) Joint Research Office.

Phase 2

The protocol was informed by Phase 1 and developed with input from our Clinical Advisory Group (colleagues at PHE, NHSEI, NHS Digital and NHSX), and with other research teams working in this area.

Methods

Setting

In England, within healthcare organisations (trusts/CCGs) which delivered remote home monitoring services for COVID-19 patients (including CO@h and CVW models). The evaluation took place between October 2020 and November 2021 (data collection took place between February and June 2021, but the patient survey retrospectively included January 2021).

Design

A rapid multi-site study combining qualitative and quantitative approaches to analyse the implementation and impact of remote home monitoring services for COVID-19 patients. The design of Phase 2 built on Phase 1 methods and findings and consultation with our Clinical Advisory Group, Patient and Public Involvement (PPI) group and the 70@70 nurses. Specifically, findings from Phase 1 informed focus on outcomes and patient experience, and the sampling approach.

Ethical approval

The study protocol was divided into two separate protocols:

(1) Covered workstreams 1 and 2 and the staff elements of workstreams 3 and 4, received ethical approval from the University of Birmingham Humanities and Social Sciences ethics committee (ERN_13-1085AP39) and was categorised as a service evaluation by the HRA decision tool and UCL/UCLH Joint Research Office (Jan 2021).

(2) The patient experience study (survey and case study interviews – workstreams 3 and 4) was reviewed and given favourable opinion by the London-Bloomsbury Research Ethics Committee (REC reference: 21/HRA/0155: Feb 2021).

The study team were aware of the sensitive nature of this research for organisations and individuals, and has experience in conducting research on similar sensitive topics. We maintained the independence of the research, followed an informed consent process, and maintained the anonymity of participants and organisations.

The patient experience study was categorised as an urgent public health study. The primary and local clinical research networks supported the team to get local approvals and participant identification centre agreement sign off at each site.

Theoretical lens

We analysed remote home monitoring models using different theoretical lenses. We explored remote home monitoring models within the social and political context in which they are designed and implemented (including the clinic and home), the multiple realities, assumptions and values that play a role in their implementation, the organisational structures that shape experiences of receiving and delivering care and the socio-political issues that frame development, diffusion and use of technology.[49] This lens went beyond an analysis of remote home monitoring solely as a technological innovation to consider dimensions such as: self-management, accountability and clinical responsibility, 'personalised care', inequalities in access to care and 'caring at a distance'.[50-52]

Furthermore, we used a framework with a socio-technical lens that incorporates Non-adoption, Abandonment, and challenges to the Scale-up, Spread, and Sustainability (NASSS) of technologies for health and social care (see *Chapter 11*). This includes expected and necessary changes/adaptation to staff working practices and the context for widespread use of the technology. This framework (informed by theory and evidence) describes the barriers to successful uptake of innovations and provides a guide to the type of issues that should be considered by evaluators. [53]

Procedure

The evaluation consisted of four workstreams (Figure 3).

Effectiveness (workstream 1)	Economic analysis (workstream 2)	National survey (workstream 3)	In-depth case studies (workstream 4)
• Evaluated effectiveness using a combination of data aggregated at the population-level and patient-level hospital administrative data. • For CO@h we undertook multi-variate regression analyses to investigate the impact of patient enrolment to the service within each CCG on overall mortality, in-hospital mortality, hospital admissions and lengths of hospital stay. • The CO@h analysis was undertaken for 37 CCGs where the onboarding data was assumed to be complete. • To evaluate post-hospital discharge CVW we undertook multi-variate regression analyses to investigate their impact on lengths of hospital stay and readmissions. • The CVW analysis was carried out with all live COVID discharges between August 2020 and February 2021, from 123 acute trusts.	• Collected aggregate data from 26 of the 28 sites that used remote home monitoring services for COVID-19 patients for the period October 2020-April 2021 on the number of patients monitored, the staffing models and the allocation of resources. • A cost analysis was conducted of setting-up and running CO@h (N=22 sites) and CVW (N=13 sites) services. • Calculated the mean cost per patient of the CO@h and CVW services. • Conducted a cost analysis to compare the costs of using technology-enabled and analogue vs. analogue-only data submission mode.	• Conducted a national survey of patients and carers across 25/28 sites, and a national survey of staff across 28 sites. • The surveys helped us to understand processes of implementation and staff and patient experience. • Data collection took place between February and June 2021, but the patient survey retrospectively included January 2021.	• Interviewed patients and carers and staff from 17/28 case study sites. • Interviewed national leads. • Some case studies included think aloud interviews (digital extension only). • The In-depth case studies helped us to understand processes of implementation and staff and patient experience in more depth. • Data collection took place between February and June 2021.

Figure 3. Overview of the methods for each workstream.

WORKSTREAM 1. THE CLINICAL EFFECTIVENESS OF COVID-19 REMOTE HOME MONITORING SERVICES

This workstream aimed to use combinations of aggregate population-level data and hospital administrative data to both describe and estimate the impact of the roll-out of remote home monitoring models for CO@h and CVW services.

Study design

The study of the impact of CO@h on mortality and admissions was designed as an area-level analysis combining aggregated data from different sources. The aim was to use these as time series to enable us to investigate 'dose-response' relationships between the evolving rates of enrolment to the services within each area and their outcomes, 'enrolment rates' being defined as the ratio of people enrolled on to services to the number of new cases each fortnight. For the in-hospital outcomes, we used an observational design relating in-hospital mortality and lengths of stay at an individual patient level to the rate of enrolment to CO@h services within the area at the time of admission.

For the analysis of impact of virtual ward services, we designed an admission-level multivariate regression analyses for COVID patients being discharged from hospital. The aim was to examine the association between various factors - including the availability of a virtual ward – with the length of COVID inpatient spells, and likelihood of subsequent COVID readmissions.

Setting and population

We evaluated the CO@h service across the Clinical Commissioning Group (CCG) areas in England (N=37) where we judged there was complete data on numbers of people enrolled on to services (onboarded) between 2nd November 2020 and 21st February 2021. The study population included anyone aged 65 or over with a laboratory-confirmed positive test for COVID-19 and any hospital admission within that age group for COVID or suspected COVID.

For the virtual ward study, we extracted information from inpatient Hospital Episode Statistics (HES) data on all individuals discharged alive from any of 123 English hospital trusts where there had been a confirmed or suspected COVID-19 International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) primary diagnosis code recorded during the stay. We included all patients discharged between 17 August 2020 and 28 February 2021, a period covering the beginning, the peak, and the start of the decline of England's second COVID wave. Where a patient had two or more relevant inpatient stays, all stays were included in our analysis.

Data sets used

For our analysis we used data from a number of sources (see Supplementary file 1).

Procedure and data analysis

For CO@h we analysed four main outcomes: mortality from COVID-19, hospital admissions for people with confirmed or suspected COVID-19, in-hospital mortality for these admissions and their lengths of stay. Because we were using population-level data, we first calculated enrolment rates for CO@h over time and then used multivariate regression models to investigate relationships between levels of enrolment and outcomes.

To analyse outcomes for patients admitted to hospital, we used individual-level HES. Again, we used multivariate regression models relating enrolment rates to outcomes, adjusting for individual patient characteristics (See *Supplementary file 1)*.

For the CVW analysis we developed multivariate regression models to examine the impact of the availability of CVW on two outcomes: the LOS of the COVID-19 inpatient stay, and on subsequent readmissions for COVID-19. Our models adjusted for the following person, inpatient spell, and trust characteristics: age at admission, gender, ethnic group, Charlson Comorbidity Index category,[54] whether the stay was the person's first COVID hospital stay, whether the inpatient stay was an emergency admission, Index of Multiple Deprivation (IMD) decile, the time period of the discharge

date, hospital trust, and a trust-and-week-specific measure giving the proportion of all acute beds occupied by COVID-19 patients.

Further details are provided in *Supplementary file 1*.

WORKSTREAM 2. ECONOMIC ANALYSIS

The aim of workstream 2 was to conduct a cost analysis of remote home monitoring that comprised an analysis of setting up and running remote home monitoring services for COVID-19 patients. As described in the study protocol, we originally planned to undertake a cost-utility analysis of remote home monitoring services for COVID-19 patients.[55] However, in the absence of any impacts on mortality or hospitalisation being demonstrated by the effectiveness analysis (workstream 1), a cost-utility was considered uninformative and our analysis focused only on analysing the costs of setting up CO@h and CVW services and mean running cost per patient monitored.

Procedure and data analysis

Remote home monitoring models were costed using data on staff (clinical and non-clinical) and non-staff resource use during the second wave. Contacts at each of the 28 sites (see workstream 3/4 for further details) were asked to complete a form in Microsoft Word (see *Project website documentation – Study instruments*) and 26 sites returned it electronically to the researchers. The data collection process was conducted between April and June 2021. Information was collected on staff (including the number of staff, their function/seniority and the number of hours worked) and non-staff resources used for setting up and running the sites (including information on the type and costs of digital monitoring platform used, oximeters, other medical equipment, etc.). We also collected information regarding the number of patients involved (triaged, monitored, deteriorated, escalated and deaths). The cost analysis was conducted separately for CO@h and CVW services.

Costs of setting up remote home monitoring services for COVID-19 patients

We calculated the costs incurred for setting up and running the CO@h and CVW models, also examining the variation by whether data submission was undertaken using technology-enabled with analogue modes versus analogue-only modes. The set-up costs were reported separately as mean costs per site. Note that the lifetime of the sites extends beyond the period observed in the study (e.g. some of the equipment like digital platforms, thermometers can be used for longer than the study time) and therefore we did not calculate the mean set-up costs per patient or per unit of time. The running costs were calculated as mean costs per patient monitored and included the costs of staff (clinical and non-clinical) who were involved in running the services, and non-staff costs including costs of pulse oximeters (based on the number of patients monitored and assuming that 70% of pulse oximeters would be returned and reused) and other monthly expenditures related to maintaining the digital platforms. We adjusted the resources used and costs incurred per patient by applying weights based on the number of patients monitored by each service (CO@h and CVW) and the total numbers of patients monitored at each site. To investigate the effect of the type of service, data submission mode, seniority of Full-time equivalent (FTE) staff and the total number of patients monitored factors on the mean running cost, we have used an ordinary least square regression model.

Technology-enabled versus analogue-only modes

In order to explore the differences in staff, resources, types of patients and patient outcomes further between tech-enabled and analogue versus analogue-only data submission modes, additional data were collected from four of the 28 sites. All of these four sites used both tech-enabled and analogue data submission modes. We conducted an in-depth analysis of the time spent per patient for specific activities of the programme and calculated the cost per patient for all the activities. The mean cost for each activity per patient was calculated based on the time spent for each activity and staff working on each activity.

WORKSTREAMS 3/4. IMPLEMENTATION AND PATIENT AND STAFF EXPERIENCES

The aim of these workstreams was to a) understand the development of national COVID-19 remote home monitoring services and, b) analyse the implementation of COVID-19 remote home monitoring services, and patient and staff experiences of care.

These workstreams included data from: staff surveys and interviews, patient/carer surveys and interviews, interviews with national leaders and documentary analysis of relevant national operating procedures. See *Supplementary file 1* for detailed methods.

Sample and recruitment

Selection of sites

Twenty-eight services were included in our national evaluation. To obtain maximum variation, we sampled services based on a range of criteria, including the setting (primary care or secondary care), type of model (pre-hospital, early discharge, both), mechanism for patient monitoring (paper-based, app, both), geographic location (across different areas of the country), timing of implementation (implemented since wave 1 of the pandemic or recently implemented) and involvement in the evaluation with the other evaluation partners (Imperial and Improvement Analytics Unit (IAU)).

To conduct an in-depth analysis of implementation, staff and patient experiences, 17 of these sites were selected as in-depth case study sites using the aforementioned criteria. In four of these sites, we also conducted in-depth comparisons of technology-enabled versus analogue models (see *Economic Analysis* above). These sites were identified by NHSX to ensure inclusion of different digital platforms.

Sites were recruited through an expression of interest process whereby we presented our study at local and national meetings and asked sites to express interest in participating. Clinical Research Networks facilitated the set-up of sites and local governance approvals. Some sites were identified through our Phase 1 evaluation.

Staff (survey and interviews)

We conducted a survey of staff involved in delivering COVID-19 remote home monitoring services in 28 services (including clinical leads, delivery staff and data staff). The study coordinator at participating sites distributed links to the online surveys to staff involved in delivering/leading services via email.

For staff interviews, we purposively sampled staff involved in delivering services, leading services and data processes at each of the 17 sites. Potential participants were approached by staff at participating sites and were introduced to the researcher/asked to contact the researcher if they would like to take part. The researcher sent potential participants an information sheet. If they agreed to participate they were asked to sign a consent form.

Patients and carers (survey and interviews)

To take part in our evaluation, participants needed to be:

   a) 18 or over
   b) Proficient in English (or one of the following languages: Polish, Bengali, Urdu, Punjabi, French and Portuguese)
   c) Eligible to receive remote home monitoring services for COVID-19 patients, and must also have been offered and received COVID-19 remote home monitoring services.

We were flexible within our sampling to consider both national and local eligibility criteria.

Twenty five of the 28 sites agreed to run the patient survey. NHS staff from participating services sent the patient survey to patients and carers either via post, text or email. Patients/carers completed the surveys and returned these to the researchers either electronically or via post.

For patient interviews, we aimed to purposively sample four to six patients or carers who received services or declined/disengaged from services at each of the 17 case study sites. We sampled using a range of criteria including age, gender, ethnicity, employment status, mechanism for onboarding, type of monitoring and outcomes. Potential participants were approached by staff at participating sites and were asked if they would be interested in taking part. Participants were then sent an information sheet by the researcher. If the patient/carer agreed to take part in the study, they were asked to sign consent forms and send them to the researcher ahead of the interview.

National lead interviews and documentary analysis

To understand development of the national service and capture changes in design and implementation over time, we conducted interviews with national leaders who were purposively selected from different roles across organisations. We also analysed key documents (e.g. SOPs).

For the national lead interviews, national leads were contacted via email and asked if they would like to take part. If happy to take part, they were asked to give their consent in advance of the interview. Researchers then arranged a convenient time for the interview.

Measures

Staff (survey and interviews)

The staff survey was developed for this study. We developed different questions for different groups (service leads and staff delivering the service). The staff survey included questions about experiences delivering remote home monitoring services for COVID-19 patients. The questions were reviewed and piloted prior to use (see *Project website documentation – Study instruments* for survey questions).

We developed a topic guide for staff interviews. Different questions were developed for different groups (a) service leads, b) staff delivering the service, c) data). The topic guide included questions about the service, experiences of delivering services and views on patient engagement (see *Project website documentation – Study instruments* for topic guide). Interviews at four of the 17 sites included think-aloud questions about using the technology.

Patients/carers (survey and interviews)

The patient/carer survey was developed for this study. The survey included questions about experiences receiving remote home monitoring services for COVID-19 patients. The questions were reviewed and piloted prior to use (see *Project website documentation – Study instruments* for survey questions).

We developed a topic guide for patient/carer interviews. Different questions were developed for those who received the service, and those who declined or disengaged. The topic guide included questions on their experiences of receiving services and engagement (see *Project website documentation – Study instruments* for topic guide).

Survey and interview questions were informed by relevant service documentation,[38, 39] theoretical frameworks relating to social, political and technical contexts [49-53] and behaviour,[56] and previous literature on engagement.[57, 58] Questions on demographic characteristics were informed by previous literature.[59-64]

National leads (interviews)

We developed a topic guide for national lead interviews. This included questions about the service, leadership and governance, data and implementation (see *Project website documentation – Study instruments* for topic guide).

Data collection

Staff (survey and interviews)

Staff were asked to follow an online link to complete the survey. The survey began with an information sheet and consent form. Survey sites were asked to keep a record of the number of surveys sent to determine response rates.

Interviews were conducted by one of six postdoctoral researchers (MS, CV, HW, LH, IL, JB); each site had a different lead researcher. Interviews were carried out via telephone or an online platform as preferred by the participant.

Patients/carers (survey and interviews)

Patients were asked to complete the survey in one of two ways: a) if monitored through use of a tech-enabled mode, patients/carers were emailed or texted the link to the online survey, b) if the patient was monitored using analogue methods, they received the survey in the post, together with a pre-paid envelope. Surveys were distributed at onboarding to the remote home monitoring service or discharge from the remote home monitoring service, depending on service procedures. The survey included an information sheet and consent form.

Interviews were conducted by one of six postdoctoral researchers (MS, CV, HW, LH, IL, JB); each site had a different lead researcher. Interviews were carried out via telephone or an online platform as preferred by the participant.

National leads (interviews)

National lead interviews were conducted by four researchers (MS, CV, HW, NJF). Interviews were carried out via telephone or an online platform (e.g. Zoom or Microsoft (MS) Teams) as preferred by the participant.

Data management

Surveys (patients and staff)

Electronic surveys were transferred directly into Research Electronic Data Capture (REDCap). Surveys received via post were returned to Nuffield Trust or UCL offices, stored securely in locked filing cabinets and inputted into REDcap by members of the research team. Data were securely stored on Data Safe Haven.

Interviews (national lead, patients/carers and staff)

All interviews were audio-recorded (with consent), transcribed verbatim, anonymised and stored securely.

Analysis

Site characteristics

Sites were characterised with respect to their population size,[65] the proportion in urban versus rural areas,[66] the proportion in the most and least deprived areas (with respect to national quintiles),[67] and ethnicity.[68] For sites based on CCG areas we calculated these characteristics using publicly available data at lower super output area (LSOA) level mapped to CCGs,[69] while for trust-based sites we used data derived from inpatient HES admissions during the financial year 2019/20, in addition to web searches for the trust catchment populations.

Surveys (patients/carers and staff)

Survey data were analysed using descriptive statistics, multivariate and univariate analyses on Statistical Package for the Social Sciences (SPSS, version 25). Participating sites were provided with a report on the patient survey responses from their site compared with overall findings.

Interviews (national lead, patients/carers and staff)

Data collection and analysis was facilitated through the use of Rapid Assessment Procedure (RAP) sheets.[70] RAP sheets were developed per site to facilitate cross-case comparisons and per population (to make comparisons between sub-groups). The categories used in the RAP sheets were based on the questions included in the interview topic guide, maintaining flexibility to add categories as the study progressed. RAP sheets were used to develop coding frameworks to explore themes and sub-themes in more-depth and identify example quotes. Further details on analysis methods are reported within each chapter (see *Chapters 4* and *8-11*).

Although our study was rapid, many steps were taken to ensure the transparency, rigour and robustness of our qualitative research methods. For example, our study used purposive sampling to recruit a large number of participants with a range of characteristics. In terms of analysis, our study used both rapid analysis methods (e.g. Rapid Assessment Procedures[70]), together with traditional qualitative analysis methods (e.g. in-depth coding of transcripts and development of themes and sub-themes). Our study involved a range of experienced qualitative researchers, and our analysis was strengthened by continuous team discussions about the interpretation of our data. We also discussed findings with those providing the service and our clinical advisory group to sense check our interpretation. Additionally, our findings were triangulated with quantitative, economic and other qualitative analyses. Our methodological approaches are consistent with previous recommendations on conducting trustworthy, robust and rigorous qualitative research.[71-74]

Integration

Data from all four workstreams were integrated to answer our research questions and to facilitate processes of triangulation. The study team met weekly throughout the study. We included findings from each workstream within our RAP sheet. We produced RAP sheets at site level and also at population level (including for sub-groups of staff and patients). For example, findings on local barriers and facilitators to implementation and patient and staff experiences helped the interpretation of findings on outcomes, service use and costs. Quantitative data on resource allocation were understood in relation to qualitative data on staff experiences of planning and delivering services. Data from the case studies were used to explain the survey findings (representing experiences and trends at a national scale). In addition, emerging findings from this study were discussed in relation to those from the two other evaluation partners (Imperial and IAU).

Deviations from protocol

We planned to undertake a cost-utility analysis of the COVID-19 remote home monitoring services but in the absence of any impacts on mortality or hospitalisation, as demonstrated by the effectiveness analysis (see *Chapters 5* and *6*), the economic analysis only included the costs of setting up and running services (see *Chapter 7*).

We intended to conduct 'think alouds' with patients who had used tech-enabled data submission from the four sites selected for in-depth analysis of tech-enabled platforms. However, patients did not have access to the platforms after discharge and recall of the use of these platforms during their illness was poor. Consequently, the 'think aloud' methodology was discontinued for patient interviews.

Patient and public involvement

Members of the study team met with service user and public members of the BRACE PPI group and Health and Care Panel and patient representatives from RSET in a series of workshops. These workshops informed study design, data collection tools, data interpretation and to dissemination for Phase 2. For example, patient-facing documents, such as consent forms, topic guides, patient survey and patient information sheets were reviewed by this group. Additionally, PPI members helped to pilot patient surveys and interview guides with the research team. We also asked some members of the public to pilot the patient survey.

Dissemination and formative feedback

Throughout the project, we regularly shared feedback with stakeholders on emerging findings and lessons learned. The study will inform clinical practice for COVID-19, but will also inform the use of remote monitoring models in other conditions and areas of the NHS. Dissemination has been facilitated through various existing and new networks. Findings have been and will be published in peer-reviewed journals.

Chapter 3. Capturing and informing early stages of design and implementation of COVID-19 remote home monitoring services (Phase 1)

Overview

This chapter draws on two papers by Vindrola-Padros *et al.*, [32, 36] published in *Lancet eClinicalMedicine:* https://doi.org/10.1016/j.eclinm.2021.100965 and https://doi.org/10.1016/j.eclinm.2021.100799. These are open access articles under the term of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits use, distribution and reproduction in any medium, provided the original work is properly cited (see https://creativecommons.org/licenses/by/4.0/).

What was already known

- Previous research has explored the use of remote home monitoring models for non-COVID-19 conditions.
- COVID-19 remote home monitoring services were implemented rapidly around the world, but implementation processes were rarely documented.

What this chapter adds

- The COVID-19 remote home monitoring services varied in relation to the healthcare settings and mechanisms used for patient triage, monitoring and escalation.
- Good communication within clinical teams, culturally appropriate information for patients/carers and the combination of multiple approaches for patient monitoring (app and paper-based) were considered facilitators in implementation.
- We could not reach substantive conclusions regarding patient safety and the identification of early deterioration due to lack of standardised reporting and missing data.

Aims of the Phase 1 evaluation

In July 2020, we began a rapid mixed-methods evaluation to identify the key characteristics of COVID-19 remote home monitoring models operating during the first wave of the COVID-19 pandemic, explore the experiences of staff implementing these models, understand the use of data for monitoring progress against outcomes, document variability in staffing and resource allocation, document patient numbers and impact, draw out lessons learnt for the development of models for the 2020-2021 winter period and identify areas for further research. In order to achieve these aims, Phase 1 was divided in two main workstreams: a rapid review of the literature and a rapid mixed-methods evaluation to document implementation and identify the lessons learnt during wave 1 of the pandemic. Findings from both these phases have been published,[32, 36] so we provide a summary here.

A rapid systematic review of the evidence

Remote home monitoring models have been implemented in the United States (US), Australia, Canada, the Netherlands, Ireland, China and UK, with some variation in the frequency of patient monitoring, modality (a combination of telephone or video calls and use of applications or online portals), patient admission criteria, staffing used for patient monitoring and level of clinical oversight and use of pulse oximetry. However, there is limited published literature on the models of care developed to implement remote home monitoring across different healthcare contexts during the COVID-19 pandemic, the experiences of staff implementing these models and patients receiving care, the use of data for monitoring progress, resources required, as well as the impact of these models on clinical, process and economic outcomes. The aim of this review was to analyse the implementation and

impact of remote home monitoring models for confirmed or suspected COVID-19 patients, identifying their main components, processes of implementation, target patient populations, impact on outcomes, costs and lessons learnt.

Methods

Design

We followed an established rapid review method.[48] This method uses an adapted systematic review approach, with the aim to reduce time taken to carry out the review (e.g. using a large multidisciplinary team to review abstracts/full texts and extract data, having a percentage of excluded articles reviewed by a second reviewer, and using software for data extraction).[48]

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.[75] The protocol was registered with PROSPERO (CRD: 42020202888, registered 6 August 2020).

Search strategy

We used a phased search approach.[48] This involved gradually adding search terms based on the keywords used in the identified literature (see [32] for search terms). We used the following databases: MEDLINE, CINAHL PLUS, EMBASE, TRIP, medRxiv and Web of Science (searches carried out by CV on 9 July 2020 and updated on 21 August 2020, 21 September 2020 and 5 February 2021). To identify additional publications, we manually screened reference lists of included articles. We removed duplicates.

Study selection, inclusion and exclusion criteria

One researcher (CVP) screened titles, with researchers cross-checking exclusions in abstract (KS) and full-text phases (KS/MS). Disagreements were discussed until consensus was reached. To be included, studies needed to: 1) focus on monitoring of confirmed or suspected patients with COVID-19, 2) focus on pre-hospital monitoring, monitoring after Emergency Department (ED) presentation and step-down wards for early discharge, 3) focus on monitoring at home (excluding monitoring done while the patient is in healthcare facilities), and 4) be published in English.

Data extraction and management

We analysed articles using a data extraction form developed in REDCap. We extracted data on design, populations, process, clinical outcomes and economic impact. The form was independently piloted by two researchers (CV/KS) and finalised. Data extraction was checked by three researchers (TG/CSJ/ST).

Data synthesis

The information entered in free text boxes was exported from REDCap and analysed using framework analysis.[76] We did not assess quality of studies.

Results

We present a summary of findings below (see [32] for further information).

Search results

The initial search yielded 902 articles. After screening, 155 articles remained for full-text review. After full-text review (n=11), identifying additional references from reference lists (n=3) and updated searches (n=13), 27 articles met the inclusion criteria (see Supplementary file 3 [32] for PRISMA flow chart).

Characteristics of included remote home monitoring models

Remote home monitoring models were implemented in different countries, including the US (n=11), UK (n=9), Canada (n=2), Netherlands (n=2), China (n=1), Ireland (n=1), Brazil (n=1), Australia (n=1). Different study designs were used (descriptive studies (n=12), evaluations (n=6), observational studies (n=7), feasibility study (n=1), news feature (n=1). See [32] for further details.

Aims and designs of remote home monitoring models

The primary aim of remote home monitoring models was to enable early identification of deterioration for patients self-managing COVID-19 symptoms at home (including those who had not been admitted to hospital as well as those who had been discharged).

A secondary aim of the models was to reduce the rate of hospital infection and demand for beds in the acute care sector (including preventing admitting those suitable for home management and discharging those admitted to hospital earlier with care from a remote team).

Most of the remote home monitoring models were led by teams in secondary care (n=23), with some led by primary care (n=3) and some led by both primary and secondary care (n=2). Thirteen of the models functioned as pre-admission wards (preventing admission of patients to hospital) and five were designed for patients admitted to hospital who could be discharged and monitored at home (step down wards), and 10 were both (with separate pathways).

Patient populations appropriate for remote monitoring

Most of the models established broad criteria for patient eligibility, defining the patient group as adult (over 18 yrs.) patients with COVID-19 symptoms (suspected and confirmed cases). Some models limited referrals to confirmed cases. Some models excluded certain groups e.g. patients over 65 with significant comorbidities, or pregnant women. The size of patient cohorts varied considerably (ranging from 12 patients to 6853) (see [32] for further details).

Stages of remote home monitoring

The articles described five main stages in remote home monitoring for COVID-19: 1) referral and triage to determine eligibility (including recording patient demographics, clinical variables, health data for risk assessment and vital signs data, and in some cases a risk assessment), 2) onboarding of patient to remote home monitoring service (provision of information to patient and/or carer on monitoring process, mechanisms for escalation and self-care), 3) monitoring (including recording of observations, communication of the information via a paper-based system and telephone or digital technologies such as apps or online forms, inclusion of pulse oximetry (in some cases), assessment of the information by the medical team), 4) escalation (if required according to pre-established thresholds), and 5) discharge from the pathway (once their symptoms improved or patient opted out of the pathway).

Expected outcomes

Outcomes of remote home monitoring models were grouped in three main categories: 1) process outcomes related to the remote home monitoring pathway (e.g. time from swab to assessment, time to escalation, ambulance attendance/emergency activation), 2) process outcomes related to secondary care (e.g. length of stay) and 3) patient outcomes (including clinical outcomes such as ED attendance/reattendance, hospital admission, ICU admission, readmission, mortality, ventilation needs and experience e.g. patient satisfaction).

Impact on outcomes

It was difficult to carry out an analysis of the impact of remote home monitoring across all examples because not all articles reported data on the same outcomes. In terms of clinical outcomes, mortality rates were low, admission or readmission rates ranged from 0 to 29%, and ED attendance or reattendance ranged from 4 to 36%. Six of the models reported data on patient feedback, and indicated high satisfaction rates.

Information about remote home monitoring process outcomes was limited (n=6 articles), but time, from swab to assessment ranged from 2 to 3.7 days and virtual length of stay from 3.5 days to 13 days (see [32]).

Economic impact

Very few of the selected studies for this rapid review provided a descriptive form of economic analysis. The amount spent per patient on remote monitoring varied by country and type of costs included in the analysis.

Strengths and limitations of review

The last search was carried on 5 February 2021, so any articles published after this date were not included. However, the inclusion of preprints helped to mitigate this. Although we employed multiple broad search terms, it is possible that we missed articles that did not use these terms. Due to the variability in study designs and the descriptive nature of the articles we did not assess these for quality using standardised tools for assessment. However, we feel it is important to note that we found several cases of missing data and inconsistencies in the reporting of evaluations that would lead to low quality ratings.

Future research areas identified

The review highlighted that further research should focus on exploring patient experience, implementation, outcome evaluation and cost effectiveness.

A rapid mixed-methods evaluation of the early implementation of remote home monitoring services

A number of remote home monitoring models were set-up during the first wave of the COVID-19 pandemic in England with a high degree of variability in relation to the mechanisms implemented for patient assessment and triage, monitoring and escalation.

Despite previous research on the use of remote home monitoring models for other conditions and their widespread use during the COVID-19 pandemic, studies on their implementation and impact are rare. This study aimed to: identify the key characteristics of these services, explore staff experiences, understand the use of data for monitoring progress against outcomes, and document variability in staffing/resource allocation.

Methods

Design

A multi-site mixed methods study that combined qualitative and quantitative approaches to analyse the implementation and impact of remote home monitoring models during the first wave of the COVID-19 pandemic (July to September 2020) in England (see [36]).

Sample and recruitment

We recruited staff with experience delivering these models across eight pilot sites in England. We purposively recruited sites to represent a range of characteristics including the type of remote home monitoring service, different population sizes, areas of the country and monitoring approaches (see [36]).

Data collection

We conducted interviews with 22 staff. Most of these interviews were carried out by pairs of researchers. Interviews were conducted using a topic guide, were audio-recorded and lasted 30-60 minutes.

We also collected data on staffing models and resource allocation (number of staff, their function/seniority, the number of hours worked, all other resources used in setting up and running pilots and associated costs).

Data analysis

Detailed notes from interviews were added to Rapid Assessment Procedure (RAP) sheets.[70] Multiple researchers cross-checked data to ensure consistency. The team met weekly to discuss emerging findings and develop themes. Set up costs were reported as mean cost per site, and for running costs, mean costs of patient were calculated for the pilot period (see [36]).

Findings

We present a summary of findings below (see [36]).

Models implemented

The models varied in relation to the healthcare settings and mechanisms used for patient triage, monitoring and escalation. The main components of models were: triage, admission to service (including provision of pulse oximeter), patient provides readings through phone calls or app, medical team monitor observations and escalate cases and discharge at 14 days or when symptoms have improved.

Barriers and facilitators to implementation

Staff described high levels of patient engagement.

Implementation was embedded in existing staff workloads and budgets.

Implementation facilitators included: good communication within clinical teams, culturally appropriate information for patients/carers and the combination of multiple approaches for patient monitoring (app and paper-based).

Barriers to implementation included: unclear referral criteria and processes, difficulties carrying out non-verbal assessments over telephone, lack of culturally appropriate patient information, lack of administrative support and workforce availability.

Cost

The mean cost per monitored patient varied from £400 to £553, depending on the model. Mean costs were higher in pre-hospital than early discharge from hospital model.

Strengths and limitations

The study was limited in the sense that we could not determine the effectiveness of these models due to lack of comparator data.

Future research areas identified

We identified the sustainability of the models and patient experience (considering the extent to which some of the models exacerbate existing inequalities in access to care) as future areas of research.

Dissemination and use of findings

The findings from the rapid review and the rapid mixed-methods evaluation on the implementation of COVID-19 remote home monitoring models across eight sites in England were disseminated widely

and used to inform decisions in relation to the roll-out of services during autumn/winter 2020-2021. The main channels for the dissemination of findings included journal articles,[13, 32, 36] blogs,[77-79] a slide set [80] and presentations (see Project website documentation – Dissemination).

Impact

A senior director at NHSEI provided the following feedback on how findings from Phase 1 of our evaluation influenced the national roll-out of COVID-19 remote home monitoring services in England:

1. Setting very simple entry criteria (65 and over OR clinical extremely vulnerable [CEV]).
2. Ensured that we didn't go down a tech-only or tech-first route.
3. Produced translations of all the patient facing guidance and an easy-read version at the outset. It's possible we may have missed the importance of this.
4. National SOP was focused on patient self-escalation and our workforce calculations were informed by this work.
5. Created a minimum standard for out-of-hours to ensure that the links were clear.
6. We required services to be established within 2 months and had confidence that we could encourage all CCGs to set up by 31 December.
7. Ensured that we were able to get pulse oximeters out to CCGs within 3 working days.
8. Provide CCGs with a feed of patients that have tested positive and identify people within the cohort (65 and over or CEV).

Informing Phase 2 of the evaluation

The findings from Phase 1 of the evaluation were also used to inform the design of Phase 2, including the selection of outcome measures, cost analysis and identification of key areas of focus such as: the sustainability of these models during the second and third waves of the pandemic, patient and carer experiences with the services and how these varied according to the type of model (including analogue vs. digital models), factors that could have created or exacerbated inequalities in health and access to care and the costs involved in delivering these services.

Chapter 4. The development and implementation of COVID-19 remote home monitoring services (Phase 2)

Overview

What was already known

- COVID-19 remote home monitoring services were implemented internationally during wave 1 of the pandemic.
- During our Phase 1 evaluation (wave 1 of the pandemic), some facilitators and barriers to COVID-19 remote home monitoring services were identified.
- It is important to explore local variation in order to fully understand implementation and to identify factors that might explain variation in effectiveness and cost outcomes across service models.

What this chapter adds

- Rapid development of national remote home monitoring services took place in three phases: i) Local development, ii) National development and roll-out, and iii) Local implementation.
- Patient enrolment to COVID-19 remote home monitoring services across England was lower than expected.
- There was large variability in the models implemented for COVID-19 remote home monitoring services.
- Variation was influenced by patient, workforce, organisational and resource factors, and the rapid and evolving COVID-19 situation.
- These factors might help to explain variation in outcomes/effectiveness of different service models.

Introduction

It is important to understand the impact of local factors on adoption when implementing national policy initiatives [82-84] as evidence suggests local factors affect service design,[85-87] ability to meet service aims,[88] sustainability of the service and can also hinder the accurate assessment of efficacy and cost-effectiveness.[57, 82, 84, 85, 89]

To increase our understanding of how local conditions affect rapid implementation of national policy during a public health crisis [93-96] and support future development and implementation of services,[97-100] it is necessary to explore the development, enrolment rates and implementation of COVID-19 remote home monitoring services (see *Research question 6, Chapter 1*).

This chapter provides:

1. An overview of the development of COVID-19 remote home monitoring services including the national roll-out and the enrolment rates of the services.
2. A description of how services have been implemented and used locally.
3. An analysis of the local factors that help explain why the services varied across sites.
4. A back-drop for findings presented in *Chapters 5-11*.

Methods

A summary of the methods is provided below; further details can be found in *Chapter 2/Supplementary file 1*.

Design

This study draws upon findings from all four workstreams (Figure 4).

Effectiveness (workstream 1)	Economic analysis (workstream 2)	National survey (workstream 3)	In-depth case studies (workstream 4)
• National data used to explore enrolment to COVID-19 remote home monitoring services.	• Data on number and type of staff collected as part of the cost analysis was used to inform how services have been implemented locally.	• National lead interviews used to inform findings on the development and roll-out of services. • Staff and patient survey data used to describe how services have been implemented locally.	• Staff and patient interviews used to describe how services have been implemented locally. • Staff interviews used to understand the local influences that explain why services varied across sites.

Figure 4. A summary of how data from each of the four workstreams contributed to this chapter.

Sample and recruitment

Twenty-eight sites were recruited to our study. Sites were included from all regions across England, represented CCGs and trusts, varied in urban/rural, deprivation scores, ethnicity, and size (see *Chapter 2/Supplementary file 2*).

Data collection

To identify when new services started and to estimate the proportion of new diagnosed cases who were onboarded (enrolment rates), we drew on a selection of data sources (see *Supplementary file 1*), including Kent, Surrey and Sussex AHSN data (see *Chapter 6*), bespoke onboarding data, and data on diagnoses of COVID-19 provided by PHE (now the UK Health Security Agency).

To describe the development and roll-out of services we conducted interviews with national leads (see *Chapter 2*). To explore implementation, we conducted a documentary analysis of service documentation, surveys with patients and staff and interviews with patients, carers and staff and a cost survey (see *Chapter 2*).

Data analysis

Survey and interview data

Inductive thematic analysis was used to analyse interview data inputted into RAP sheets.[70] Survey data were analysed using descriptive statistics (using SPSS , version 25). To allow for comparison, quantitative and qualitative data sets were mapped against the SOP components (referral/triage/onboarding/monitoring/discharge).

National data on enrolment

For the CO@h programme, we defined rates of enrolment as the proportion of new cases diagnosed who were onboarded. For each CCG, we estimated these rates by dividing the numbers onboarded each fortnight by the number of new cases of COVID-19 diagnosed in the same fortnight. We could only do this for CCGs where the onboarding data were judged to be complete, and to make this judgement we used a combination of management information provided by the programme and data collected by our own costing survey (see *Supplementary file 1)*.

For the CVW programme, data quality issues left us unable to use NHS situation reports (SITREPS) data on the number of COVID patients discharged from hospital to virtual wards. We were able, however, to carry out a limited analysis of enrolment rates for seven hospital trust-based sites by comparing the number of patients monitored on a post-discharge pathway (as reported in our costs survey, see *Chapter 7*) to the number of COVID-19 patients discharged alive, according to national Hospital Episode Statistics Admitted Patient Care (HES APC) data.

Findings

Within this section, the following findings are presented: 1) a summary of interview and survey data (n=28 sites), 2) an overview of the development of COVID-19 remote home monitoring services (including a) development of these services, and b) coverage of these services nationally and rates of enrolment) , 3) a description of the different typologies and implementation of services between sites, and 4) factors influencing the implementation of these services.

Participant characteristics

We received 292 staff surveys (39% response rate) across 28 sites and 1069 patient and carer surveys (18% response rate) across 25 sites (see *Supplementary file 2* for demographic characteristics). Interviews were conducted with: national leads (n=5), staff (n=58 across 17 sites) and patients or carers (n=62 across 17 sites) (see *Supplementary file 2* for demographic characteristics).

An overview of the development of COVID-19 remote home monitoring services including the national roll-out and the uptake/coverage of the resultant service

Within this section, we first present an overview of the three phases of development and implementation of these services. Secondly, we present the uptake/coverage of the final service.

a) *Development of COVID-19 remote home monitoring services*

The development of COVID-19 remote home monitoring services occurred rapidly, in three stages: i) Local development and implementation, ii) National development and roll-out, and iii) Local implementation (Figure 5 for timeline and key groups involved in each phase).

Wave 1 of pandemic   **Wave 2 of pandemic**

COVID oximetry @home and virtual wards

Local development and implementation: Developed & used in local teams / services

National development: National planning and development of Standard Operating Procedures

National roll-out: The organisations involved in orchestrating the roll-out of CO@h and virtual wards

Local implementation: The organisations involved in delivering the services at local level

Supported by:
Community of practice
NHS Futures
Local leaders within CCGs and secondary care trusts
NHSX supported tech-enabled platforms in some pilot sites

Supported by:
National Incident Response Board
NHSEI
NHS Digital
Community of Practice
PPI
NHS @Home
PHE

Supported by:
NHSEI
Regional AHSN – patient safety collaborations
Programme Board
Patient Safety Groups
National Deterioration forum
COVID Pathway group
Regional clinical leads (n=7)
Local groups (inc regional medical directors, Senior Responsible Officer, care homes)
NHSX

Supported by:
Local programme and clinical leads
Community trusts
Primary care
CCGs
Local authorities
Public health teams
Voluntary organisations
National learning network and AHSNs – patient safety collaborations
Community of practice
NHSX

Figure 5. Development of COVID-19 remote home monitoring services.

i.   Local development and implementation – wave 1 and the first use of pulse oximetry in patients' homes

Local development and implementation

The use of oximetry to monitor COVID patients in their home began in wave 1 as several, initially disconnected, local services were established, motivated by attempts to mitigate silent hypoxia (very low oxygen saturations, often without breathlessness). Pulse oximetry was initially used to monitor patients in the community.[36] During Phase 1, local clinical leaders within CCGs and secondary care trusts had identified a need for this service and were integral in facilitating the initial development, set-up and implementation of services, and instigated the development of an informal community of practice. NHSX supported a few of the pilot sites to use tech-enabled models by putting them in touch with tech companies. The local development and implementation of services gained interest from national stakeholders.

An evaluation of Phase 1 was commissioned and conducted by researchers from NIHR RSET and NIHR BRACE (see *Chapter 3*). The purpose of this evaluation was to provide lessons for the ongoing development/roll-out of the services.

Supporting local implementation

Two learning communities were set up prior to the national roll-out, to support local implementation: a community of practice and a national learning network.

The community of practice was an informal group, led by key national clinical and policy leads and attended by national and local clinical leaders for local services adopting these pulse oximetry services. The community of practice held regular online meetings (every couple of weeks) to share best practice quickly from national leads to local teams, and between local teams, offering mutual support and leadership. This community of practice grew rapidly.

A national learning network (the National Deterioration and COVID forum) was set up by the AHSN Patient Safety Collaboratives to support clinical leads and provide resources to facilitate implementation of these services. The set-up of the national learning network was prompted through NHS @home [17] (via the national team and regional medical directors). Additionally, regular webinars were held to share learning.[101] The learning network was hosted within the Future NHS collaboration platform (an online platform designed to help services to co-develop services, share materials and work together).[102]

The conversations and shared learning from both of these networks played a key role in shaping the basic pathway underpinning these services. These communities were set up to support local clinical leads and share experiences.

ii.   National development and roll-out

National development

Between wave 1 and 2, there was a period of gathering evidence (research and clinical consensus), discussions around how services should be developed and development of safety netting guidance. This evidence included our evaluation findings from Phase 1 (see *Chapter 3*).

During the summer and autumn of 2020, NHSEI began to develop SOPs for CO@h, with leadership and governance from the NHS @home team. The NIRB approved operationalisation and national roll-out of the CO@h service as the appropriate next step.

The SOP for CO@h[38] (see *Appendix 1, Table 24*) that emerged was informed by the learning gained from previous services which provided care at home, experience gained from managing wave 1 in the community including the various pilots, and case studies. It was shared through the NHS Futures website [102] and the pre-existing evidence base.[32, 36] It was intended that services would be inclusive by design and enabled by, but not dependent on, technology (to remain accessible to the most vulnerable patient groups).

In January 2021, a SOP for CVW (early discharge from hospital) was published and these services were rolled out.[39] Virtual ward models were designed to be run by acute trusts, with responsibility for services being with secondary care services[39] (see *Appendix 1, Table 24*).

National roll-out

Following service development, the AHSNs were commissioned through the AHSN's Patient Safety Collaboratives to facilitate regional roll-out.[101] A programme board with all key stakeholders was established and met weekly to discuss a number of workstreams including data management, workforce/training, patient safety, operations, pathways, evaluation and oximeter distribution. The programme was monitored via comprehensive data collection for CO@h which aimed to track how the programme was developing/performing with a focus on using the data as shared learning. As part of this process any safety incidents were recorded, using patient safety groups where appropriate.

National roll-out of CO@h and virtual ward services was supported by 20 highly-attended regional launch events, which included question and answer sessions. To support national roll-out, national clinical leads and seven regional clinical leads were funded to support local implementation. NHSEI agreed to purchase pulse oximeters. NHSEI purchased 706,000 oximeters across waves one and two. These pulse oximeters were CE marked (as recommended by MHRA guidance)[37] and were available to local sites within three days through an ordering system set out in the SOP. NHS Digital supported data management.[103] NHSX were a partner in the roll-out and implementation of tech-enabled platforms within COVID-19 remote home monitoring services. NHSX committed to supporting (funding) up to 50 organisations to use a tech-enabled model for CO@h and/or virtual ward models during wave 2 (sites bid for this funding and then chose and procured the platform they wanted to use). CO@h and virtual ward services were rolled out between November 2020 and February 2021.

iii.   Local implementation

NHSEI were integral in supporting the local implementation of COVID-19 remote home monitoring services, including providing financial support for primary care to establish and implement these services,[40] resourcing NHS digital to supply data to service providers to identify people who may benefit from these services [41] and the commissioning and funding of AHSN support.

National leads described the importance of local leads assuming responsibility and accountability for their services, guided by the SOPs for CO@h and CVW.

Whilst there was some variation in responsibility and accountability, local CCGs were primarily responsible and accountable for delivery of CO@h and secondary care trusts were responsible and accountable for delivery of CVW. Each local service had its own local governance and management structure, which were expected to minimise national input and allow local services to be more

responsive to and reflective of the needs of local populations. This local governance was overseen and supported by the AHSNs. NHSX managed data reporting on tech-enabled deployment.

With local services responsible for the day-to-day running of CO@h and CVW, services allocated resources, designed staffing models, and distributed equipment and educational materials. The management teams particularly of integrated services (i.e. where CO@h was combined with CVW) consisted of colleagues drawn from across multiple settings including primary and secondary care, but also the ambulance service, mental health trusts, care homes, and patient safety collaboratives. The precise mix depended upon the scope of services within the local environment. Regional 'clinics' were established by the local AHSNs to facilitate regular engagement and support the initial set-up. Two-way relationships were developed between policymakers and strategic management and front-line NHS workers as a way of sense-checking the work completed. Significant support and buy-in from senior management within acute trusts and across CCGs helped to set up COVID-19 remote home monitoring services. But, there was a need to have supportive local authority and public health teams to integrate CO@h and CVW services with existing ways of data sharing.

Supporting local implementation
Throughout the national roll-out, local services were supported by the community of practice and the national learning network (as described earlier).

b) *National coverage of COVID-19 remote home monitoring services and enrolment*
COVID Oximetry @home
We judged that the national onboarding data for CO@h were complete for 37 of 135 CCGs (see *Supplementary file 1*), so our analysis of coverage and enrolment was restricted to these areas.

The dates sites within each of the 37 CCGs started onboarding patients are plotted in Figure 6. Three of these CCGs were onboarding patients in October and all 37 were onboarding patients in the fortnight beginning 11 January 2021.
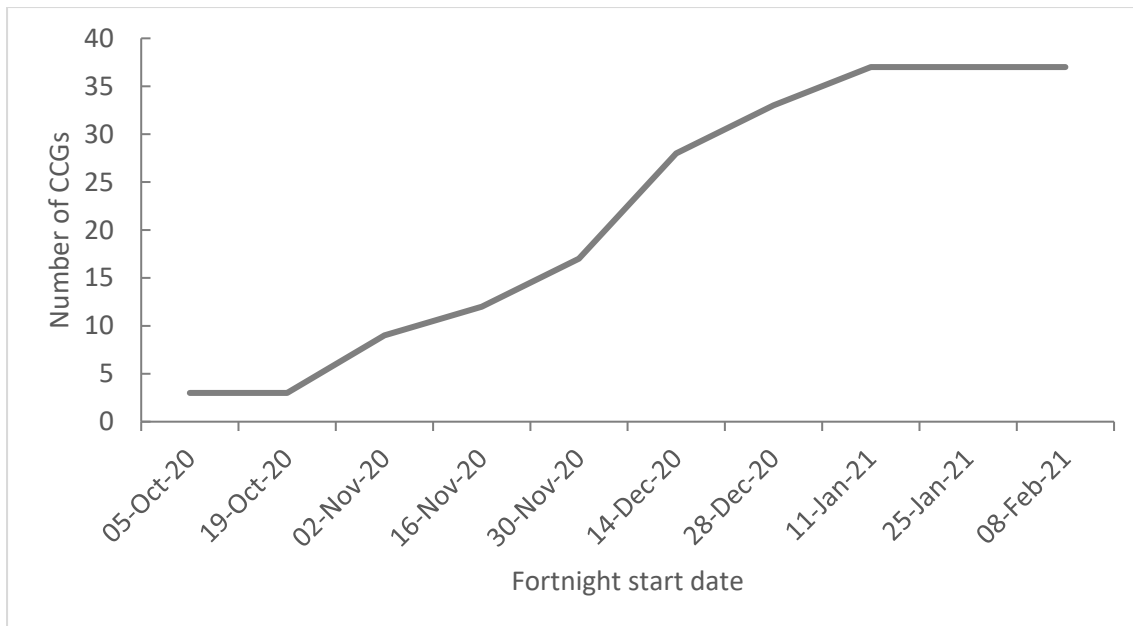
Figure 6. Number of CCGs with sites operating the CO@h programme by fortnight (data for the 37 CCGs where the onboarding data were assumed to be complete).

Once services started operating and up until 4 April, enrolment across the 37 CCGs among people aged 65 or over is shown in Figure 7. The CCG with the highest enrolment rates had values that were more than twice the next highest. Twenty-two CCGs (59%) enrolled fewer than 10%. The overall enrolment rate over the period for this age group across all 37 CCGs was 8.7%.
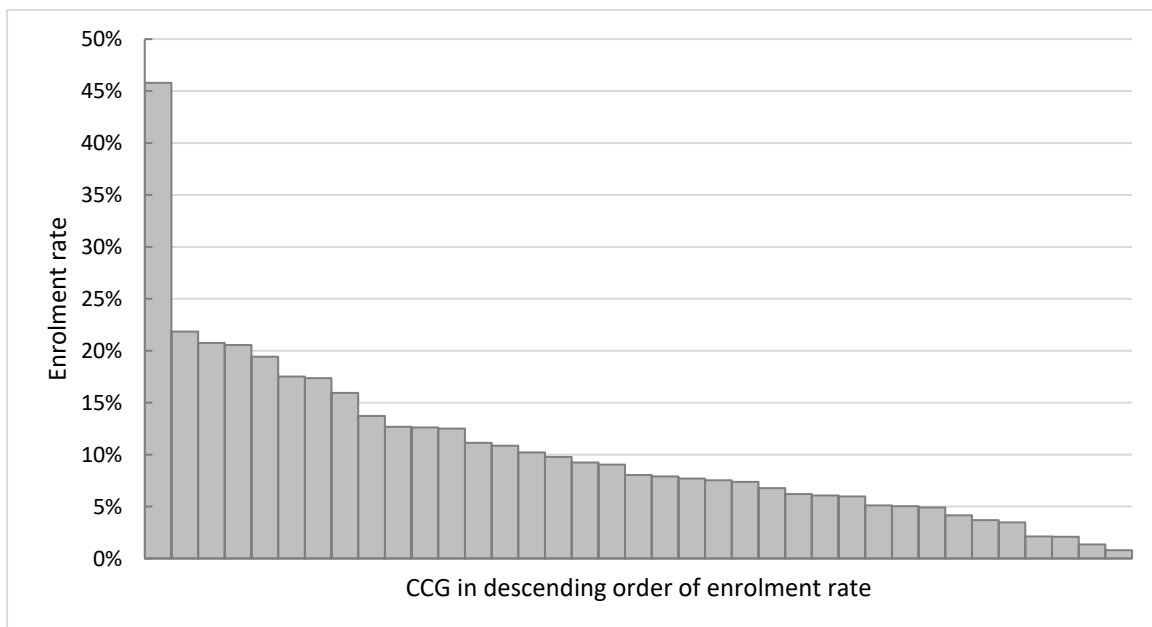
Figure 7. Enrolment of CO@h services among people aged 65 or over by CCG after implementation started up until 4 April 2021.

(Enrolment is defined as the ratio of numbers onboarded to new cases over the period and calculated from 19 October 2020 for any services in operation before then).

Virtual wards

Dates acute trusts opened their virtual wards are plotted in Figure 8. A majority of services (62%) launched in January and February 2021. For seven trust-based sites included in our costs survey (see *Chapter 7*), we were able to estimate an approximate enrolment proportion: that is, the proportion of COVID-19 patients discharged who were monitored on a virtual ward. Two sites had fewer than 10% of patients monitored, one site had 20%, and four had more than 50% (but below 65%) of patients monitored. Otherwise, with national SITREPS data not useable because of data quality issues, we had no further information on virtual ward enrolment.
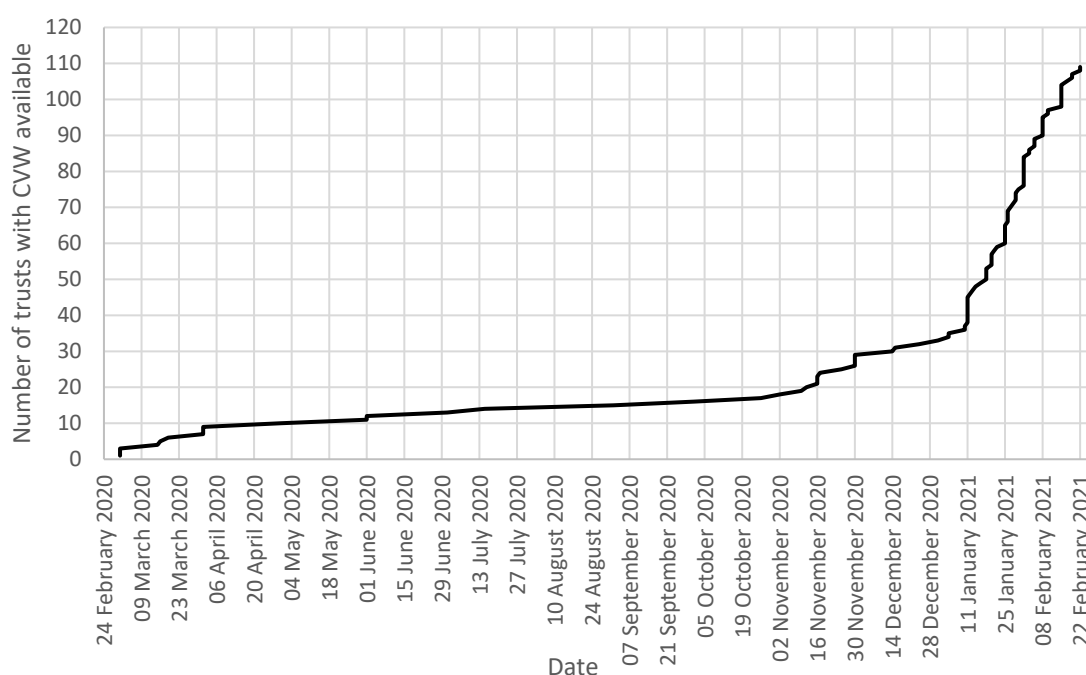
Figure 8. Start dates of CVW services in England's non-specialist acute hospital trusts (n = 123 trusts). Fourteen trusts had no CVW by 22 February 2021.

A description of the different typologies and implementation of services between sites

We created a typology (classification system) and categorised sites according to seven domains (Table 1): 1) type of model (CO@h/CVW/Integrated), 2) sector leading services (primary care/secondary care/both), 3) type of monitoring (analogue-only (paper and telephone)/tech-enabled and analogue), 4) admission criteria (age and clinical vulnerability), 5) workforce (number and type of staff), 6) date service started, and 7) enrolment rates within the CCGs where the sites were located. As above, enrolment rates were defined as the ratio of patients onboarded to new cases among people aged 65 or over by CCG after implementation started up until 4 April 2021. It was calculated from 19 October 2020 for any services in operation before then.

Different models of COVID-19 remote home monitoring services were implemented across the 28 local sites. Below, we describe variability in relation to the stages of services outlined in the national SOPs[38, 39] (see *Supplementary file 4*).

Table 1. Summary of the typology of COVID-19 remote home monitoring services included in our evaluation.

			All models (n=28)	CO@h models (n=13/28)	CVW models (n=4/28)	Integrated models (n=11/28)
1.	Type of model	CO@h (referral from community providers, e.g. GP, hot hub, emergency department)	13	13		
		CVW (referral through early discharge from hospital)	4		4	
		Integrated model (community and early discharge referrals)	11			11
2.	Sector leading the service	Primary/community care	15	11	1	3
		Secondary care	5	0	3	2
		Both	6	1	0	5
		Not specified	2	1	0	1
3.	Method of monitoring	Analogue only (paper and telephone)	7	1	2	4
		Tech-enabled and analogue	21	12	2	7
4.	Admission criteria a. Age*	18+ years old	13	8	2	3
		50+ years old	11	4	0	7
		65+ years old	1	1	0	0
		Did not use age as a criterion	3	0	2	1
	b. Risk factors	Yes	25	13	2	10
		None specified	3	0	2	1
5.	Workforce a. Number of staff	Setting up (range across 26 sites)**	2-20+ staff members	2-20 staff members	2-20 staff members	2-20+ staff members
		Running (range across 26 sites) ***	2-70+ staff members	2-70+	2-10	2-60
	b. Type of staff involved in monitoring	Clinical staff only	15	5	4	6
		Clinical and admin staff	10	7	0	3
		Not known	3	1	0	2
6.	Month started	Before November 2020	11	6	1	4
		In November 2020	12	5	2	5
		After November 2020	5	2	1	2
7.	Enrolment rates within CCGs where sites were located (population age 65 or over – COVID Oximetry @home models only)	> 30%	1	0		1
		20% - 30%	1	1		
		10% - 20%	4	3		1
		< 10%	6	3		3
		Incomplete****	11	5		6

*Age criteria changed throughout the service for many sites. E.g. some sites were initially 65+ but then amended to include adults of younger age categories throughout the service.

** Number of staff involved in setting up the service not known for 2 sites.

*** Number of staff involved in running the service not known for 2 sites.

**** One CCG providing incomplete data had more than one study site. Because one site was integrated, we mapped the CCG to the 'integrated' category and the total number of CCGs providing exclusively CO@h models is 12.

Entry criteria

In terms of entry criteria, most services used age criteria of either 18 years or over, or 50 years or over, rather than the age criteria recommended within the SOP of 65 years or over. Many sites adapted and reduced their enrolment age throughout the period. Most sites used risk factors alongside age to enrol patients, but each site varied in the risk factors used.

Workforce

As shown in Table 1, there were large differences across sites with regard to the number of staff involved in setting up (n=2-20+) and running (n=2-70+) the service, and with regard to the type of staff involved in monitoring. Most sites used clinical staff only to support monitoring.

Triage

As recommended by national guidance, most sites had processes in place for patient triage (n=24/25). However, interview findings indicate that triage processes varied across different models (e.g. in terms of who checks against admission criteria, and the processes used). See *Chapter 11* for a description of models categorised by risk-stratification.

Onboarding

In line with national guidance, all of the sites provided patients with oximeters. However, their means of distribution varied, including delivery (n=27 sites), giving to patients at GP/hospital (n=9 sites), patients/family members collecting oximeters (n=7 sites). Some patients described difficulties in collecting oximeters due to their poor health and isolation.

In line with national guidance, most sites provided patients with information (n=22/25). Most sites provided patients with written information or provided information over the telephone.

Monitoring

Sites differed in the type of options they offered for patients submitting data (e.g. tech-enabled and/or analogue) and the level of interaction with staff (see *Appendix 2, Table 25*). Most services were tech-enabled with telephone options offered when tech-enabled modes of submission were not possible. Members of staff were involved in taking and reporting readings at all sites; none of the services solely asked all of their patients to self-monitor and self-escalate care (see *Appendix 2, Table 25*). However, interview findings indicated that two sites offered some of their patients (exact number not known) a self-monitoring option. Self-monitoring is defined as patients or carers (where appropriate) monitoring their readings and escalating their own care as necessary (see Supplementary file 4).

Escalation

Escalation processes varied, with some tech-enabled solutions identifying patients for escalation (with the addition of phone or face-to-face assessment in some cases) and some escalation processes being manually initiated (with the addition of phone or face-to-face assessment in some cases) (see *Supplementary file 4*).

Discharge

In line with national guidance, many but not all sites had explicit processes in place for patient discharge (n=19/25). Our findings on the flexibility of discharge were in line with the SOP, in that most sites reported patients were discharged after 14 days, but that patients could be discharged earlier or kept on if needed. However, only 73.4% (n=769) of patients were aware of discharge processes (range across sites: 33.3%-90.9%). Oximeter return processes were also not apparent at every site with only 69% of patients being asked to return the oximeter (range across sites: 21.5%-100%).

Factors influencing implementation of COVID-19 remote home monitoring services

We observed differences in the design and delivery of services between local sites and between the national guidance and local implementation. Implementation may have been influenced by a number of site-specific factors relating to patients, staff, the organisation delivering the programme, and the resources at their disposal (see *Supplementary file 4*).

Patient-related factors

Patient factors relate to demographic characteristics, disease prevalence, digital access, and patient engagement. Sites were charged with responding to the needs of local populations and the degree to which they did so was shaped by the specific needs of the local population, influenced by factors such as socio-economic status, ethnic and cultural background, prevalence of co-morbidities, the ability of patients to access or utilise digital technologies and their level of engagement with the programme (see *Box 1*). However, sites varied in the time and resources dedicated to attempt to engage with the vulnerable and disadvantaged groups disproportionately affected by COVID-19.

Though all of our sites used telephones to collect readings, some sites would also use these calls to offer comfort and reassurance to isolating patients or otherwise signpost them to other services or community groups. Some sites reported that staff would visit patients in-person if particularly concerned about their wellbeing or if the patient was visually impaired. This additional support was at the discretion of sites and not prescribed by the national guidance.

Box 1. An example of patient-related factors influencing implementation.

> **In Site O, they developed materials in a range of languages. They also utilised community-based partnerships and voluntary organisations to help onboard and monitor patients. Patients were drawn from a range of vulnerable populations leading them to successfully target minority ethnic groups, those who were morbidly obese and members from the local homeless population.**

Staff factors

A number of staff-related factors influenced the way in which services varied between sites. These related to their level of training and experience, whether they worked remotely or in a shared workspace with more direct clinical oversight, and the overall workload they experienced (see *Box 2*). For example, those that were redeployed to services tended to be nurses working in secondary care, whereas those asked to take on the responsibility of delivering these services alongside their current roles tended to be drawn from primary care.

The knowledge, skills and confidence of the staff charged with delivering services varied between sites, and these differences in confidence and knowledge were particularly evident when services relied on non-clinical staff. Across many sites, the routine availability of senior clinical oversight was deemed important.

Box 4. An example of staff-related factors influencing implementation.

> **In Site M, where staff worked remotely from other staff, they described how their training was minimal and this gave rise to a number of concerns. These included their ability to use the software through which they managed their caseload, but also more fundamental issues around their lack of experience of tele-consultations, remote monitoring, or respiratory conditions and how this left them uncertain about whether they were offering the correct advice to patients or their non-clinical colleagues with patient-facing roles.**

Organisational factors

A range of organisational factors impacted on the design of individual services including staffing models, the culture and work practices that supported the learning of individuals and/or the organisation,[104] and the engagement of senior staff in changing practice and supporting innovative delivery.[105] The timing of the introduction of remote home monitoring services in each local area may have influenced variation in services observed between sites. The SOP produced in November 2020 contained the caveat that those that had already established a service would not be expected to adhere to the national guidance.

A key factor in shaping services was the level of successful collaboration between the organisations involved at each site (see *Box 3*). The importance of robust communication pathways between senior managers at local sites was recognised, as was the value of collaborating with other teams and specialities, particularly in refining and improving services and for supporting patients with additional needs (e.g. those with existing health conditions or requiring mental health support).

Box 7. An example of organisations working together across sectors.

> **In Site K, there was close collaboration between different sectors. Their service was run by primary care and secondary care organisations together with each organisation/sector operating within clearly defined roles (identification of patients, running hot hubs/assessments, monitoring). Staff within this service reported a history of integrated working relationships between secondary, primary care and voluntary/community sectors. These long-standing relationships were felt to better facilitate the implementation.**

Resource factors

Resource factors related to the availability of reliable pulse oximeters and the availability and functionality of the software used to support the service. One major investment in these services was the provision of pulse oximeters by NHSEI. However, the perceived quality of these oximeters reportedly varied and not all sites had the links with the voluntary sector that many used to deliver the instruments (in workable order) to patients in the community.

The tech-enabled platforms selected by local systems varied across regions and local systems, with each possessing various levels of functionality and interoperability. The more readily service data could be integrated with existing databases the more effective the programme could operate. In its absence, valuable information on patients would be unavailable, for example, current medications, prior history of respiratory illness, or susceptibility to anxiety. Several sites reported that technology platforms were not always ready for use at the onset (due to the speed at which services were developed and implemented). This meant switching mid-pandemic without the necessary time for training or familiarisation (see *Box 4*).

Box 10. An example of resource factors influencing implementation.

> **At Site J, the site originally used [Platform 1] but this did not meet their requirements to automatically send three reminders to patients per day. Therefore, midway through the second wave the service switched over to [Platform 2]. However, this presented its own challenges of moving from one system to another whilst the service was under enormous pressure and they had to temporarily return to using [Platform 1] due to fears that some patients were being omitted.**

Discussion

Key findings

The rapid development of COVID-19 remote home monitoring services in England took place in three phases: i) Local development and implementation (in wave 1 and 2), ii) National development and roll-out (in wave 2), and iii) Local implementation. The proportion of new diagnosed cases who were onboarded on to these services was lower than expected. The implementation of services varied between sites and from national guidance. A range of service typologies emerged across our evaluation including noticeable variation in relation to enrolment rates, the nature of onboarding, referral criteria, monitoring processes, and discharge and pulse oximeter return procedures. Patient factors (e.g. needs of the local population), staff factors (e.g. workload and work environment), organisational factors (e.g. staffing models and collaboration) and resource factors (e.g. software) influenced implementation and enrolment.

How findings relate to previous research

The implementation of COVID-19 remote home monitoring services in England can be seen as an example of major system change or 'large system transformations', defined as "coordinated, systemwide change affecting multiple organizations and care providers, with the goal of significant improvements in the efficiency of healthcare delivery, the quality of patient care, and population-level patient outcomes" ([106]; p. 422). A conceptual framework proposes five main stages of major system change: i) decision to change influenced by drivers to change, governance and leadership of decision making, ii) decision on which model to implement, iii) the implementation approach, iv) implementation outcomes, and v) intervention outcomes.[107] There are different ways of implementing major system change (top-down and bottom-up approaches). Previous research suggests that a combination of both top-down and bottom-up approaches may be beneficial.[108] Our findings indicate that rapid implementation processes may follow a bottom-up (local services make decision to change and which model to implement), top-down (national service makes decision to change and provides guidance on which model to implement), then bottom-up process (local services interpret guidance from national service and decide which model to implement) (as described in *Chapter 4*). Therefore, rapid implementation may vary from major system change in non-rapid contexts (e.g. [107]). However, our findings support previous research which indicates that this combination of approaches may impact on consistency of implementation approach and uptake.[109]

Prior to this evaluation, there was limited evidence regarding how these services have been implemented. Our findings indicated that most remote home monitoring services studied had low rates of enrolment and that there was considerable variation in which model was implemented and how, according to local context. These findings support previous research demonstrating likelihood of variation when implementing national services generally [82-84, 93-96] and in response to the COVID-19 pandemic.[90-92] Previous research has highlighted differences in the models implemented and the ways in which services are implemented must be considered when interpreting effectiveness and cost-effectiveness of services.[57, 82, 84, 85, 89]

Strengths and limitations

This study used mixed-methods data from a wide range of sources, including national quantitative data, cost data, national surveys and case study interviews. Additionally, this evaluation is a large rapid scale evaluation, including 28 healthcare services throughout England. Therefore, the findings provide a comprehensive picture of the development, coverage and implementation of COVID-19 remote home monitoring services through Phase 2 of the pandemic.

Given the rapid implementation of services, we are unable to say whether the degree of variation we witnessed is a result of the rapid roll-out or whether it would have been observed if lengthier implementation processes had been followed.

Different data sources were triangulated to analyse the findings presented in this chapter. Sometimes, different data sources or respondents disagreed, and consensus needed to be reached. For example, across several sites, more than one clinical lead/service manager completed the staff survey and there were several instances of responses being inconsistent (to overcome this problem, we sought further information from services as necessary and selected one clinical lead per site using relevance of job title).

Our assessment of service enrolment within CCGs relied on their onboarding data being complete. To judge completeness, we relied on assessments made by individual CCGs, although as they were not necessarily the service providers, and therefore removed from the data entry process, we were not sure about the accuracy of this information in all cases. We were able to cross-check against the data provided by the 28 study sites themselves and found a reasonable match for most but not all, and we were unable to verify the data from the CCGs that were not study sites in the same way.

Implications
Our findings have implications for interpretation of quantitative outcomes of the evaluation. Our findings on low rates of enrolment and variation in implementation can be used to help interpret findings relating to effectiveness and cost of the services (as we discuss in *Chapters 5-7*). However, we were not able to look at how specific variation linked with particular service outcomes or enrolment more generally.

Several valuable lessons for service development have emerged from our work. Findings indicate that when developing and rapidly implementing national roll-out of services, service planners must consider the context and priorities of local organisations (for example their patient population characteristics and resources). It may be helpful to consult with patient groups to ensure that strategies to ensure reach are appropriate and feasible, and that services meet the needs of the local population. Flexibility of workforce is needed for those delivering the service.

Future research
Future research should explore how similar nationally-implemented programmes vary from their intended design when not implemented at such speed and the degree to which local variation acts favourably in sustaining the service. Further evidence is needed on self-monitoring models of remote home monitoring for COVID-19, including the groups of patients that this might be appropriate for and whether its use would enable services to onboard more patients. Further research is needed to explore why enrolment was lower than expected, and how to improve enrolment to these services in future.

Conclusions
Local and national leadership were integral in the development and implementation of COVID-19 remote home monitoring services. Enrolment to these services was lower than expected. There was large variability in the models implemented and that variation may have been influenced by patient, workforce, organisational and resource factors. Together, low enrolment and variation in implementation indicate that it is difficult to evaluate the true extent of effectiveness of COVID-19 remote home monitoring services.

Chapter 5. The impact of COVID Oximetry @home on mortality and the use of hospital in-patient services

Overview

This chapter draws on a manuscript by Sherlaw-Johnson *et al.*[110] published in *Lancet eClinicalMedicine (2022):* https://doi.org/10.1016/j.eclinm.2022.101318. This is an open access article under the term of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits use, distribution and reproduction in any medium, provided the original work is properly cited (see https://creativecommons.org/licenses/by/4.0/).

What was already known

- Previous quantitative studies have mostly assessed remote oximetry monitoring services for COVID-19 patients at individual sites and focused on their safety.
- There is some existing evidence that remote monitoring of COVID-19 patients can be locally effective, particularly among higher risk patient groups. However, effectiveness of national programmes has been little studied.

What this chapter adds

- We have found no evidence that national implementation of pre-admission home monitoring of older people diagnosed with COVID-19 impacts on mortality, hospital admission rates, in-hospital mortality or length of hospital stay.
- Missing data and lower than expected enrolment of patients to services may have influenced our results, and the effectiveness of some local programmes could have been lost among the analysis of national data.
- Future implementation requires better data collection strategies and effective learning from areas that have achieved higher patient enrolment.

Background

Among the aims of remote monitoring of the CO@h service was the reduction in mortality through earlier identification of deterioration. Furthermore, it was hypothesised that if fewer COVID-19 patients were admitted to hospital with advanced disease and critically low oxygen levels, there may be a reduction in the use of critical care facilities, fewer deaths within hospital and shorter lengths of stay. The anticipated impact on numbers of hospital admissions was less certain since the aim of the programme was not to reduce admissions, but to make sure people who needed to be in hospital were admitted sooner. However, any consequence on the number and mix of patients admitted with COVID-19 would be useful to understand as remote monitoring may have different impacts on different types of individuals.

Earlier studies of the use of oximetry for remote monitoring within England during the country's first wave focused on aspects of safety and implementation, but were unable to establish reliable comparators for measuring impact.[32, 111]

This chapter presents findings from the clinical effectiveness workstream of the study addressing the specific research questions:

1. What was the impact of CO@h on mortality?
2. What was the impact of CO@h on the incidence of hospital admission for COVID-19 or suspected COVID-19 and on the characteristics of those admitted?

3. For these admissions, what was the impact on in-hospital mortality and length of stay?

Our evaluation was requested by NHSEI alongside two other evaluations of clinical effectiveness which were intended to complement each other.[43, 45, 55] Our approach used combinations of unlinked, aggregated population-level data and hospital administrative data. In doing so we were able to undertake a rapid analysis that worked alongside the other evaluations and provided valuable insight in the future evaluation of similar programmes implemented at scale.

Methods
Our methods are described in *Chapter 2* and *Supplementary file 1*.

Results
Data completeness and patient enrolment
As we mentioned in Chapter 2, because of the design of our study we were only able to evaluate services within 37 CCGs where we judged there was complete data on numbers of people enrolled on to services (onboarded) between 2nd November 2020 and 21st February 2021. The study population included anyone aged 65 or over with a laboratory-confirmed positive test for COVID-19 and any hospital admission within that age group for COVID or suspected COVID.

The included CCGs had no notable differences in mean age, proportions of non-White population or proportions resident in most deprived areas when compared to the remaining 98 that were not included, although included CCGs had a lower incidence of positive test results (Table 2). There were also regional differences: no CCGs from the East NHS Region were included, and only one from the North East and Yorkshire (Figure 9). The South West, North West and Midlands were the best represented regions.

Table 2. Characteristics of the populations resident within the CCGs included in the analysis compared with those that were excluded (samples are the proportions and rates observed within each CCG).

	Included CCGs (n=37)		Excluded CCGs (n=98)		
	Mean	*(Standard error)*	Mean	*(Standard error)*	P-value for difference between groups*
Mean proportion aged 65 or more	18.1%	*(0.7%)*	17.9%	*(0.5%)*	0.77
Mean proportion aged 80 or more	4.8%	*(0.2%)*	4.8%	*(0.1%)*	0.91
Mean proportion in non-White ethnic groups	17.3%	*(2.7%)*	17.7%	*(1.8%)*	0.97
Mean CCG-level IMD	22.7	*(1.3)*	22.6	*(0.8)*	0.96
Incidence of laboratory-confirmed COVID-19 per 1000 people					
All ages	41.9	*(1.7)*	46.8	*(1.4)*	0.03
Age 65 or over	30.4	*(1.3)*	35.0	*(1.2)*	0.01

*Two-sample T-tests. Mann-Whitney test for ethnic groupings.

Data sources:

Ethnicity – NHS digital: https://digital.nhs.uk/data-and-information/publications/statistical/mi-ethnic-category-coverage/current.

Deprivation – Ministry of Housing, Communities and Local Government:

https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019.

Ages – NHS Digital: https://digital.nhs.uk/data-and-information/publications/statistical/patients-registered-at-a-gp-practice/november-2020.

Incidence of COVID-19 – Public Health England (now UK Health Security Agency).
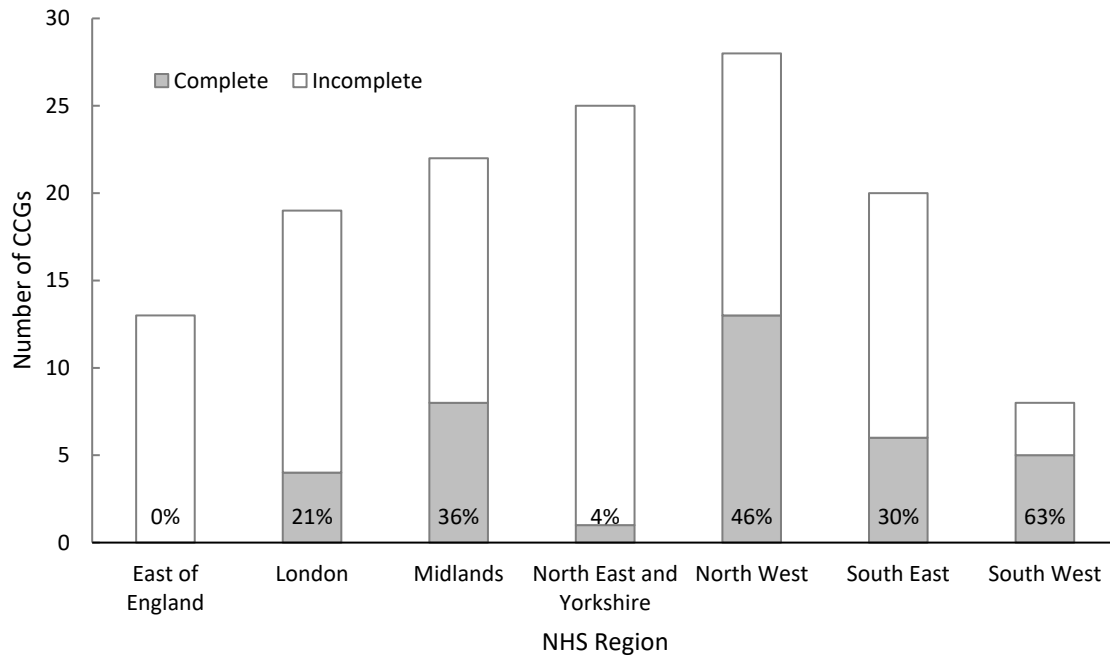
Figure 9. Number of CCGs with complete data by NHS region (% complete shown in each bar).

Fortnightly patient enrolment to CO@h among people aged 65 or over within the 37 CCGs is shown in Figure 10. Rates were particularly low earlier in the period because many sites had not commenced implementation. The numbers of CCGs where there were sites onboarding patients within each fortnight is shown along the horizontal axis. Sites within nine (24%) CCGs were operating services in the first fortnight, which had risen to 33 (89%) within the fortnight beginning 28 December 2020. Services were operating within all CCGs during the fortnight beginning 11 January 2021. The median enrolment rate only exceeded 10% in the final fortnight, although, from the end of November 2020, the maximum was consistently above 30%, with one or two CCGs each fortnight achieving much higher rates than the rest. The overall enrolment rate over the period across all 37 CCGs was 5.9%. If we exclude fortnights during which services were either not operating or operating for only part of the fortnight, the overall enrolment rate was 8.7% with only one CCG averaging a rate of more than 30%.
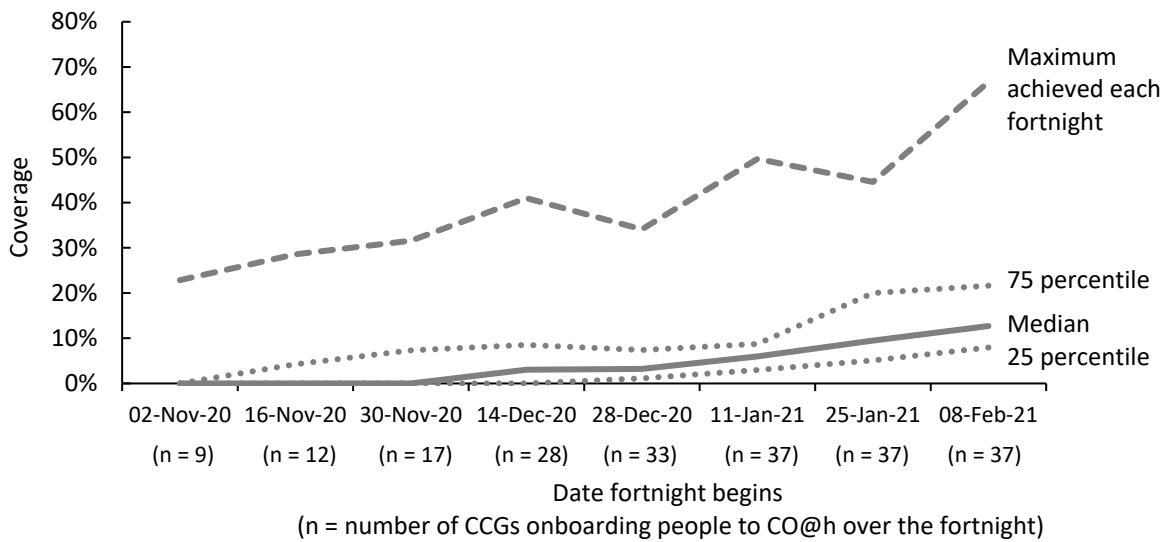
Figure 10. Variation in enrolment rates of CO@h among people aged 65 or over with laboratory-confirmed COVID-19 across the 37 CCGs included in the analysis.

Summary data and outcomes

Summary data and outcomes for the period from 2 November 2020 to 21 February 2021 for the 37 CCGs by age band are shown in Table 3. Although there were many more positive tests recorded among the under 65s, there were approximately half as many deaths and equivalent numbers of hospital admissions. Enrolment rates after implementation was low across both age groups and highest among those aged 65 to 79.

Table 3. Outcomes across the 37 CCGs included in the analysis between 2nd November 2020 and 21 February 2021.

	Age band		Both age groups
	65 to 79	80+	
Positive tests and onboarding over the whole period			
Number of new positive diagnoses	41,437	27,944	69,381
Number onboarded to CO@h*	2,734	1,382	4,116
Enrolment rate	6.60%	4.95%	5.93%
Positive tests and onboarding since implementation**			
Number of new positive diagnoses	26,507	18,636	45,143
Number onboarded to CO@h*	2,610	1,320	3,930
Enrolment rate	9.85%	7.08%	8.71%
Mortality			
Number of deaths	4,269	8,699	12,968
% of new diagnoses over the period***	10.30%	31.13%	18.69%
Hospital admissions			
Number of hospital admissions	12,351	12,128	24,479
% of new diagnoses over the period***	29.81%	43.40%	35.28%
Number of hospital admissions (excluding readmissions within 28 days)	10,895	10,683	21,578
% of new diagnoses over the period***	26.29%	38.23%	31.10%
Within hospital outcomes			
Number of in-hospital deaths	2,748	3,948	6,696
In-hospital deaths per admission	22.25%	32.55%	27.35%
Median LOS in days *(Interquartile Range (IQR))*	8 *(3 to 15)*	9 *(4 to 17)*	8 *(4 to 16)*
Number staying 2 weeks or more	3,489	4,134	7,623
Proportion staying 2 weeks or more	28.25%	34.09%	31.14%

Onboarded numbers aggregated from fortnightly counts at CCG level rounded to the nearest 5 or given the value 4 if between 1 and 7.

**Only includes fortnights for which a service was implemented within the CCG over the whole period.*

***Ignoring lags between new diagnoses and deaths/admission.*

Time series plots of numbers of newly diagnosed cases and numbers onboarded to the programme within the selected 37 CCGs over the study period (2nd November 2020 and 21 February 2021) are shown in Figure 11 and Figure 12. New diagnoses peaked in the fortnight straddling the new year, whilst onboarding peaked in the following fortnight.
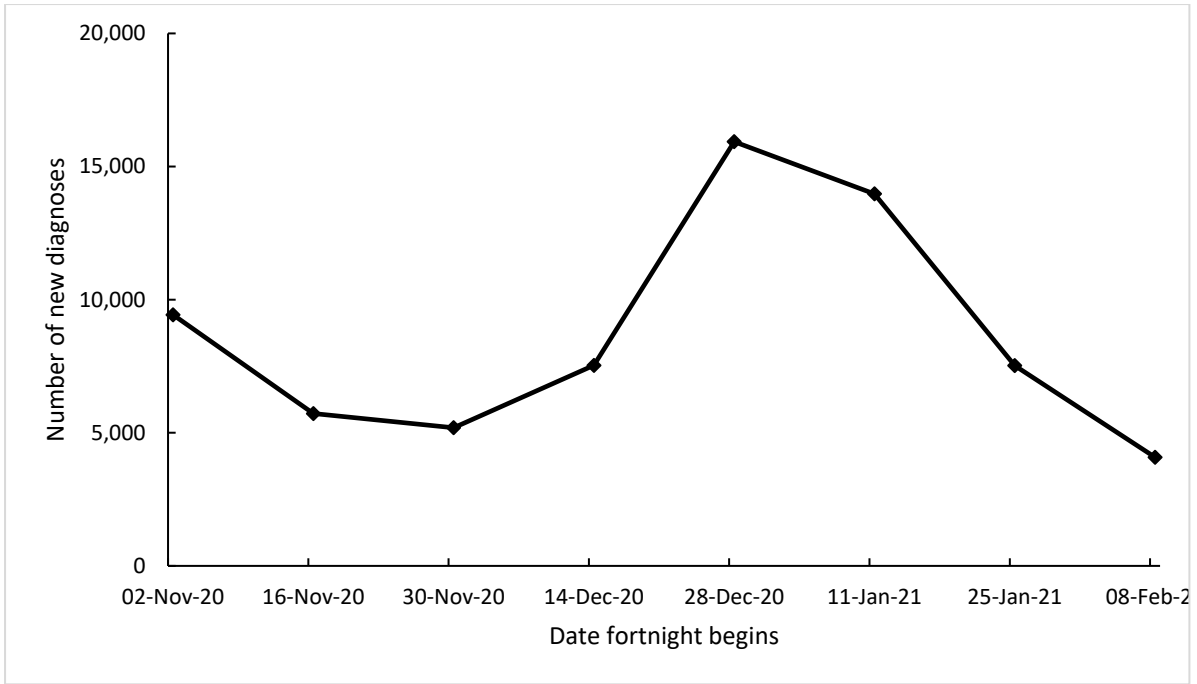
Figure 11. Numbers of new diagnoses of COVID-19 by fortnight. Data for the 37 CCGs included within the analysis.
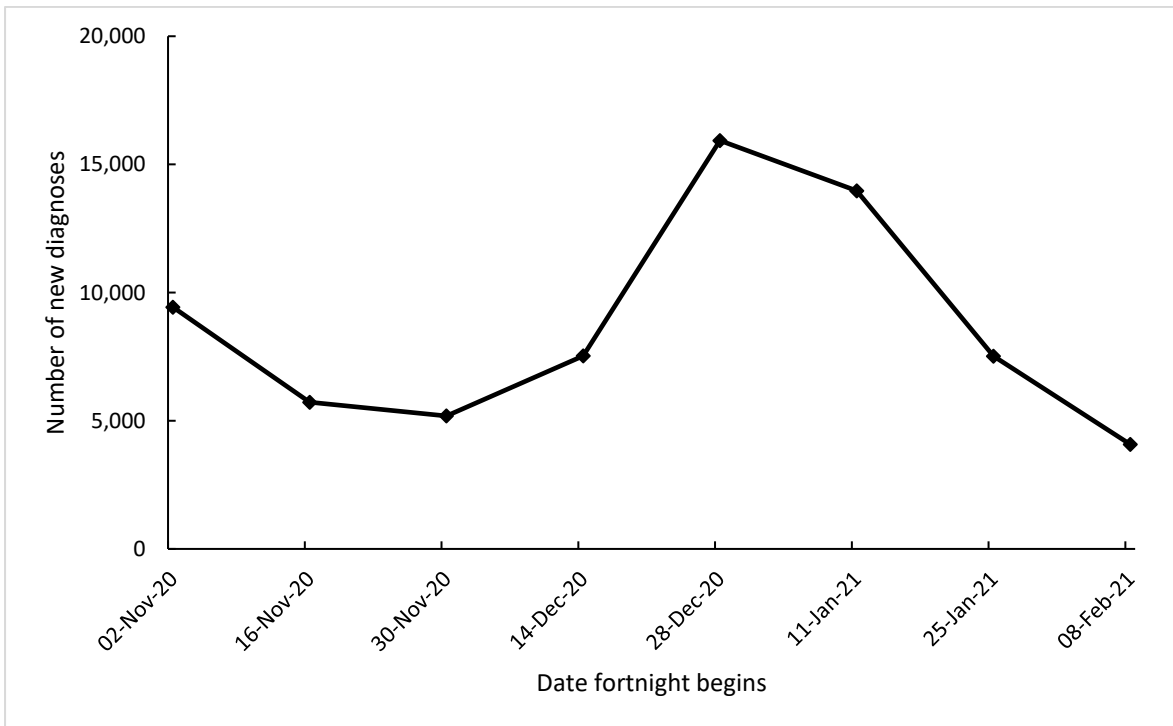
Figure 12. Numbers of people onboarded to the CO@h programme by fortnight. Data for the 37 CCGs included within the analysis

Profiles of all COVID-19 deaths and admissions for confirmed or suspected COVID-19 are shown in Figure 13 and Figure 14.
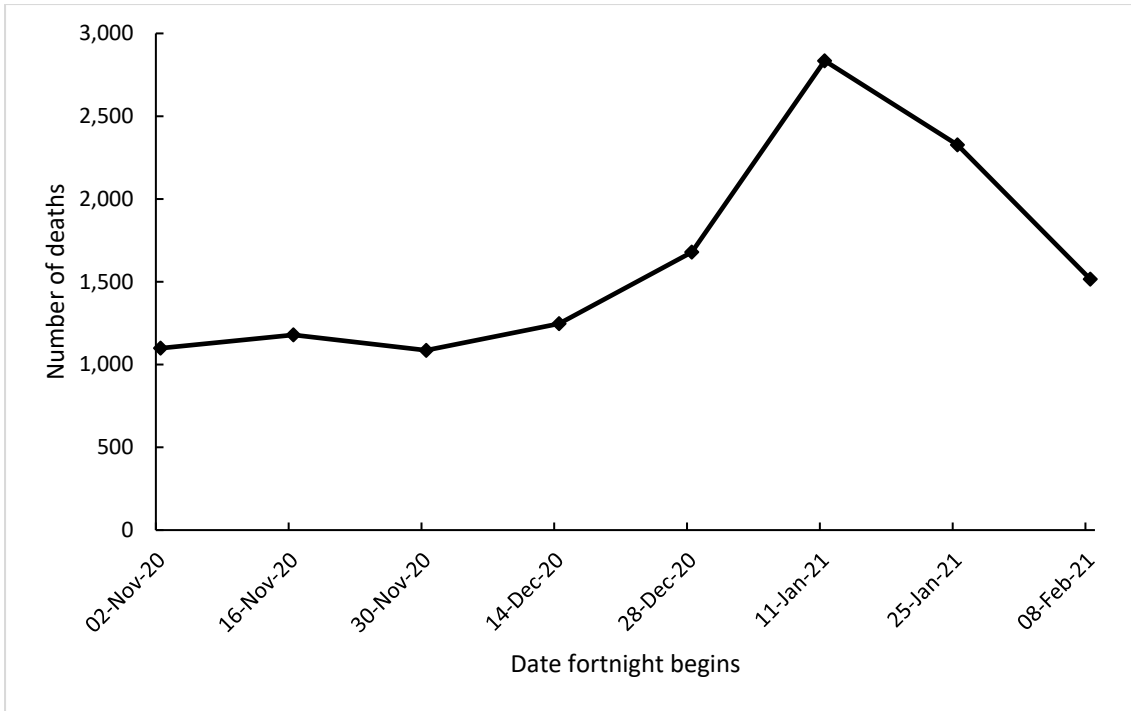
Figure 13. All deaths from COVID-19 by fortnight within the 37 CCGs included in the analysis.
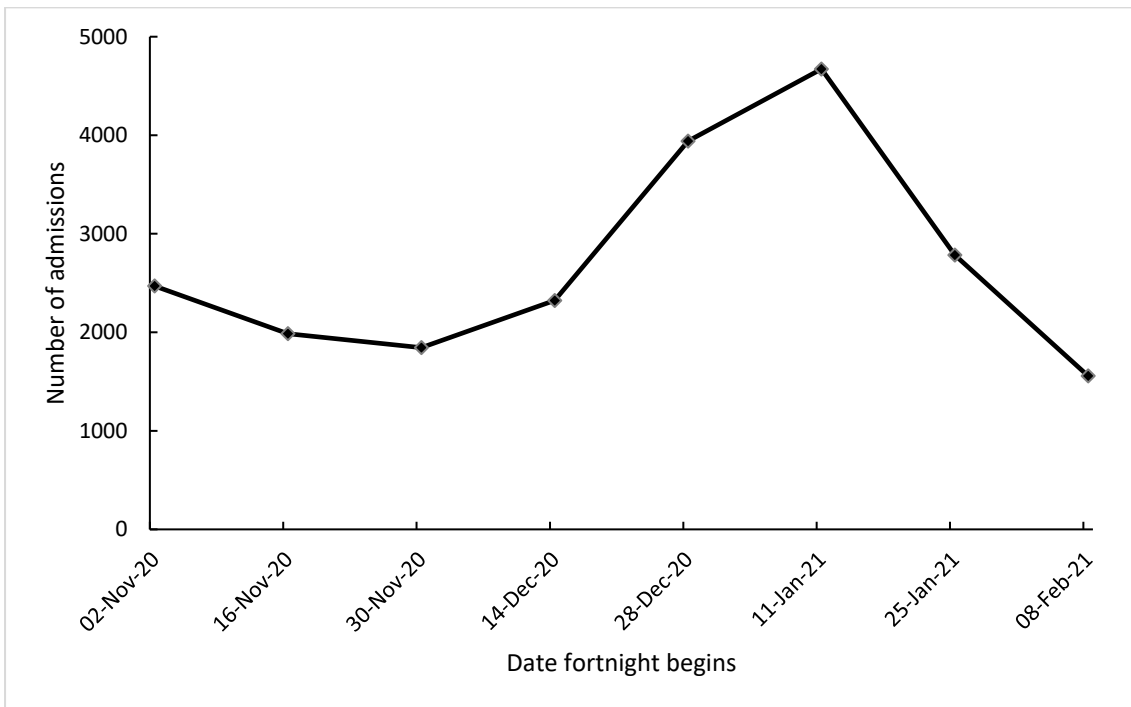
Figure 14. Hospital admissions for confirmed or suspected COVID-19 by fortnight within the 37 CCGs included in the analysis.

Rates of in-hospital mortality and median lengths of stay for patients admitted to hospital with confirmed or suspected COVID-19 are shown in Figure 15 and Figure 16. Mortality rates peak at

approximately 30% over the time of the New Year and decline thereafter to around 21%. Median lengths of stay decline from the end of November 2020 while admission numbers increase.
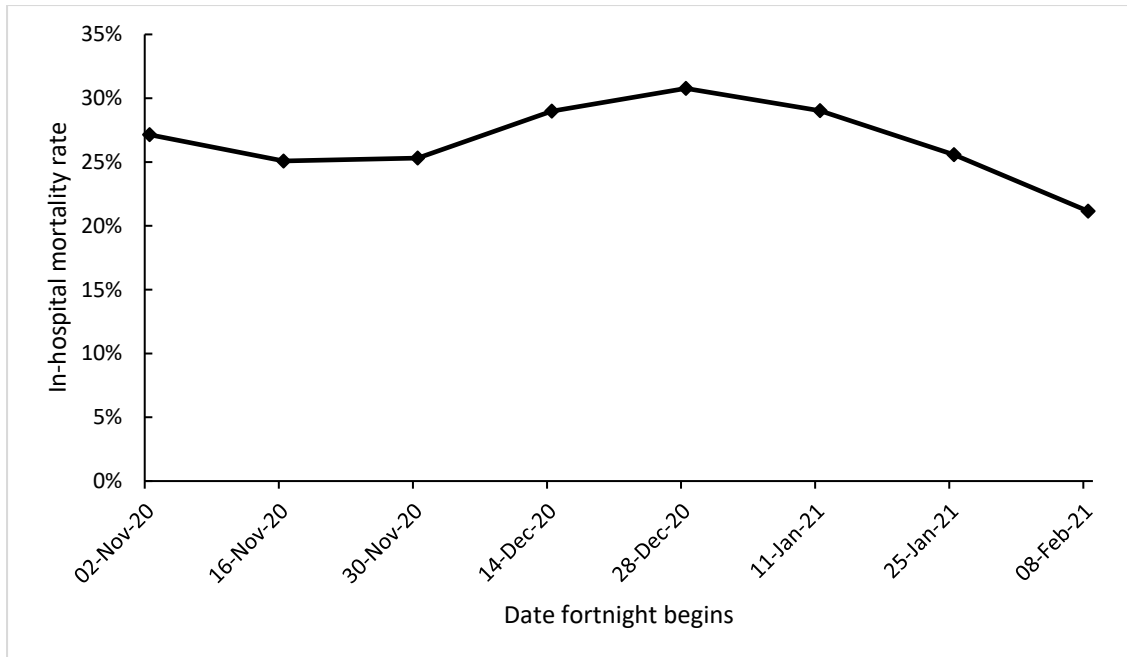
Figure 15. In-hospital mortality by fortnight for patients resident within the 37 CCGs and admitted with confirmed or suspected COVID-19.
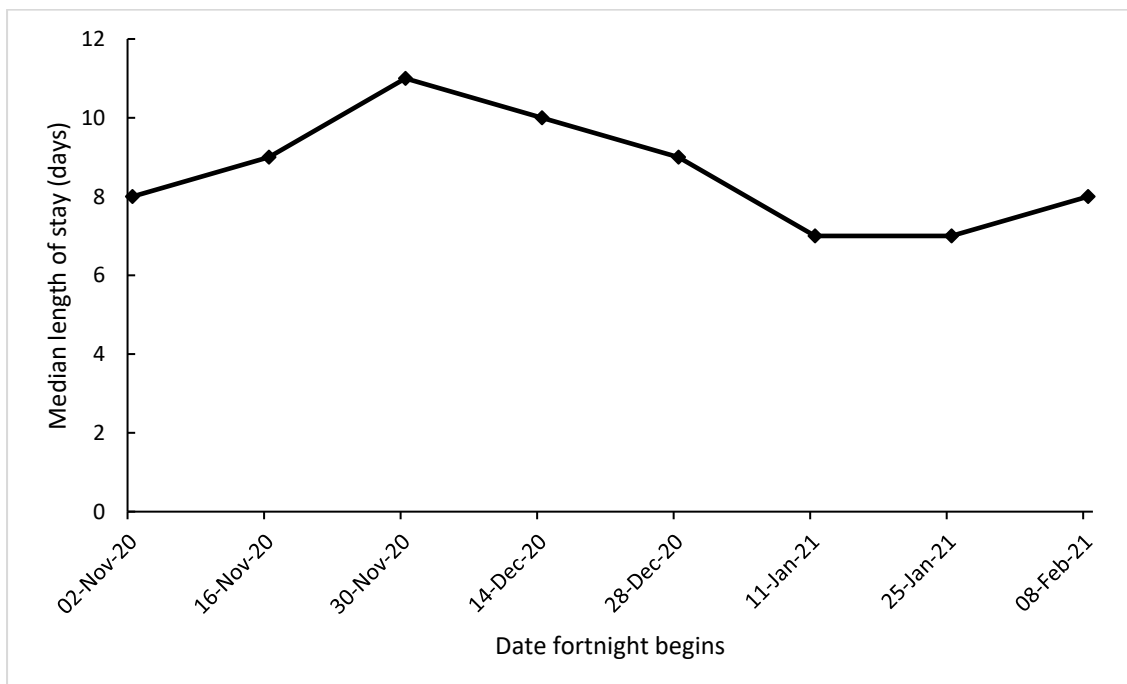
Figure 16. Median length of stay by fortnight of admission for patients resident within the 37 CCGs and admitted with confirmed or suspected COVID-19.

The characteristics of patients admitted with confirmed or suspected COVID-19 over the study period are shown in Table 4.

Table 4. Characteristics of patients admitted with confirmed or suspected COVID-19 over the study period within the 37 included CCGs and values of other explanatory variables on admission.

Explanatory variable	Value	Number of patients	%
Ethnicity	White	19,811	88.99%
	Non-white	2,450	11.01%
Charlson Index	5 or less	19,442	79.42%
	Greater than 5	5,037	20.58%
Sex	Male	12,807	52.32%
	Female	11,672	47.68%
Deprivation	Most deprived quintile	5,295	21.75%
	Excluding most deprived quintile	19,053	78.25%
Age	65 to 79	12,351	50.46%
	80+	12,128	49.54%
Virtual ward active on admission	Yes	9,537	27.98%
	No	13,562	28.94%
COVID bed occupancy on admission	< 15%	5,932	24.23%
	15 - 22%	6,131	25.05%
	22 - 29%	5,944	24.28%
	> 29%	6,472	26.44%
Weighted enrolment	< 5%	15914	65.01%
	5 - 10%	4182	17.08%
	> 10%	4383	17.91%

Mortality and hospital admissions

Results from our models for mortality and hospital admissions are shown in Table 5, Figure 17 and Figure 18. For every 10% increase in enrolment, mortality fell by 2% (relative risk = 0.98, 95% confidence interval: 0.96 to 1.01) and admissions increased by 3% (relative risk = 1.03, 95% confidence interval: 0.99 to 1.07), but neither result is statistically significant. There is, however, a significantly higher risk of mortality and admission among the older age group (p < 0.001) and higher risk of mortality in the months following November 2020 (p < 0.001 for each month in comparison to November).

We also found no significant relationship between rates of enrolment to CO@h and the ethnicity, sex, deprivation or health status of patients admitted to hospital with COVID-19 or suspected COVID-19 (Table 6). The impact on age is of borderline statistical significance with each 10% increase in enrolment associated with a reduction of nearly 4 months (95% confidence interval: -7.9 months to 0.2 months, p = 0.07).

Table 5. Results of the multivariate analysis for mortality and hospital admission: relative risks associated with each factor in the model.

Variable		Relative risk of death *(95% confidence interval)*		Relative risk of hospital admission *(95% confidence interval)*	
Enrolment	Every 10% increase in enrolment	0.98	*(0.96, 1.01)*	1.03	*(0.99, 1.07)*
Age	80+ vs. 65 to 79	3.06	*(2.94, 3.17)*	1.55	*(1.48, 1.63)*
Month	Dec 2020 vs. Nov 2020	1.25	*(1.17, 1.34)*	1.06	*(1.01, 1.11)*
	Jan 2021 vs. Nov 2020	1.24	*(1.14, 1.34)*	1.03	*(0.97, 1.11)*
	Feb 2021 vs. Nov 2020	1.40	*(1.27, 1.55)*	0.97	*(0.88, 1.07)*
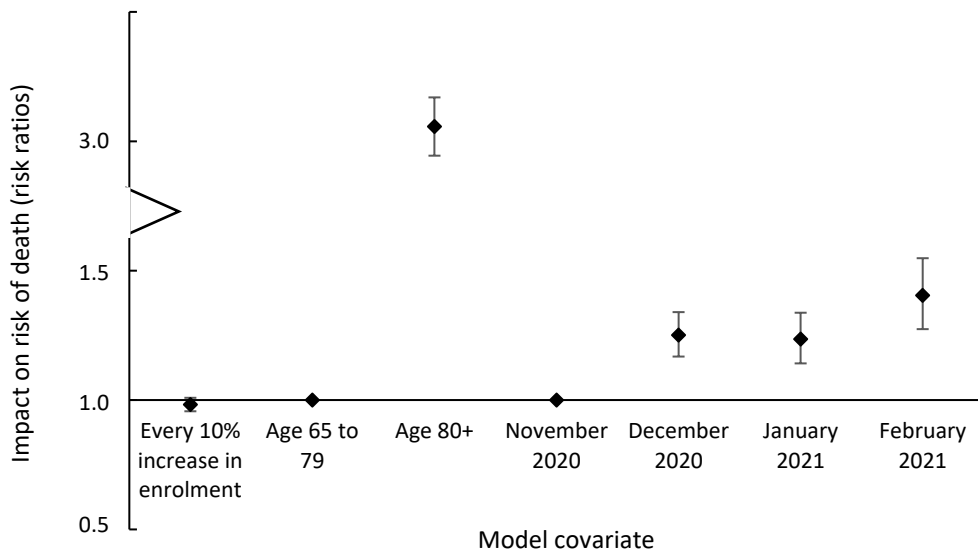
Figure 17. Impact of each variable used in the multivariate model on the risk of death (mortality rate ratios).

Error bars denote 95% confidence intervals.
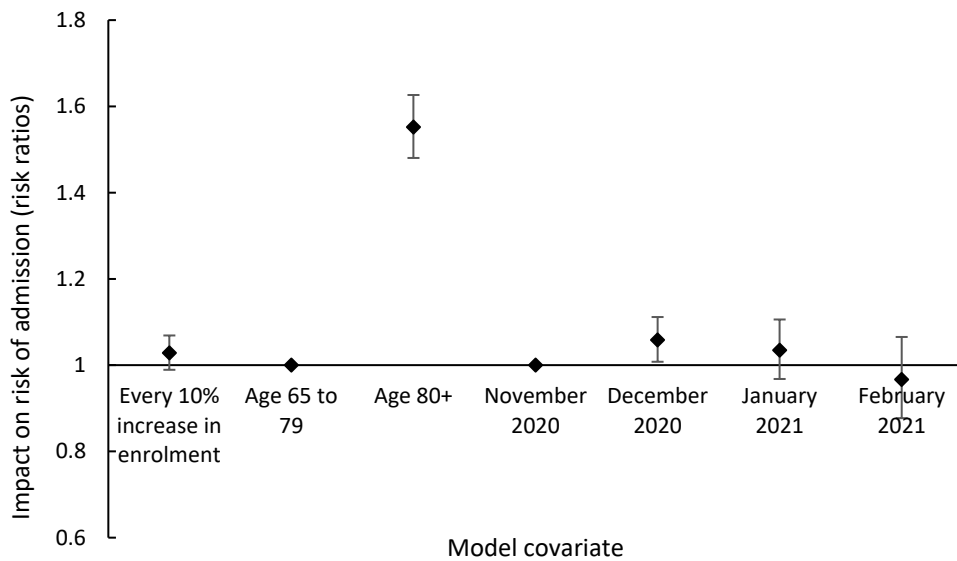
Figure 18. Impact of each variable used in the multivariate model on the risk of hospital admission (admission rate ratios).

Error bars denote 95% confidence intervals.

Table 6. Impact of increases in enrolment to CO@h on the characteristics of people admitted to hospital with COVID-19 or suspected COVID-19.

Characteristic	% change with each 10% increase in enrolment (95% confidence interval)	
Proportion non-White ethnicity	0.43%	(-8.99%, 10.82%)
Proportion female	0.07%	(-1.93%, 2.11%)
Proportion resident in most deprived areas (by quintile)	0.30%	(-7.19%, 8.41%)
Proportion with Charlson scores > 5	-2.75%	(-6.37%, 1.00%)

	Change in mean age with each 10% increase in enrolment (95% confidence interval)	
Mean age	-3.9 months	(-7.9, 0.2)

In-hospital outcomes

The results of our analysis of in-hospital outcomes are shown in Table 7, Figure 19 and Figure 20. For every 10% increase in patient enrolment, in-hospital mortality fell by 3% (relative risk = 0.97, 95% confidence interval: 0.92 to 1.03) and LOS increased by 1.8% (95% confidence interval: -1.2% to 4.9%). Again, neither result is statistically significant. Non-White ethnicity and existing COVID bed occupancy on admission were both associated with shorter lengths of stay.

Sensitivity analysis

Results from sensitivity analyses are shown in *Supplementary file 1*. None of the changes we made in our assumptions affected our findings with respect to the association between coverage of remote oximetry and outcomes.

Table 7. Results of the multivariate analysis for in-hospital mortality and length of stay. Effects of each factor on the odds of mortality and proportionate change in LOS.

Variable		Odds ratio associated with in-hospital mortality *(95% confidence interval)*		Relative change in LOS *(95% confidence interval)*	
Enrolment	Every 10% increase in enrolment	0.97	*(0.92, 1.03)*	1.8%	*(-1.2%, 4.9%)*
Age	80+ vs. 65 to 79	1.73	*(1.63, 1.84)*	6.5%	*(3.1%, 9.7%)*
Month	Dec 2020 vs. Nov 2020	1.27	*(1.14, 1.42)*	-4.2%	*(-9.5%, 1.5%)*
	Jan 2021 vs. Nov 2020	1.12	*(1.00, 1.26)*	-11.5%	*(-14.9%, -8.1%)*
	Feb 2021 vs. Nov 2020	0.88	*(0.76, 1.03)*	-19.7%	*(-27.4%, -11.1%)*
Sex	Female	0.71	*(0.66, 0.76)*	2.5%	*(0.0%, 5.0%)*
Charlson score	Greater than 5	2.14	*(1.96, 2.33)*	1.1%	*(-2.2%, 4.6%)*
Ethnicity	Non-White ethnicity	1.24	*(1.07, 1.42)*	-12.0%	*(-16.2%, -7.6%)*
Deprivation	Lowest IMD quintile	0.98	*(0.89, 1.07)*	0.0%	*(-3.0%, 3.1%)*
Has a virtual ward		0.96	*(0.88, 1.04)*	1.0%	*(-6.5%, 9.1%)*
COVID bed occupancy in the trust on admission	Every 10% increase in occupancy	1.04	*(0.97, 1.11)*	-5.2%	*(-7.6%, -2.7%)*
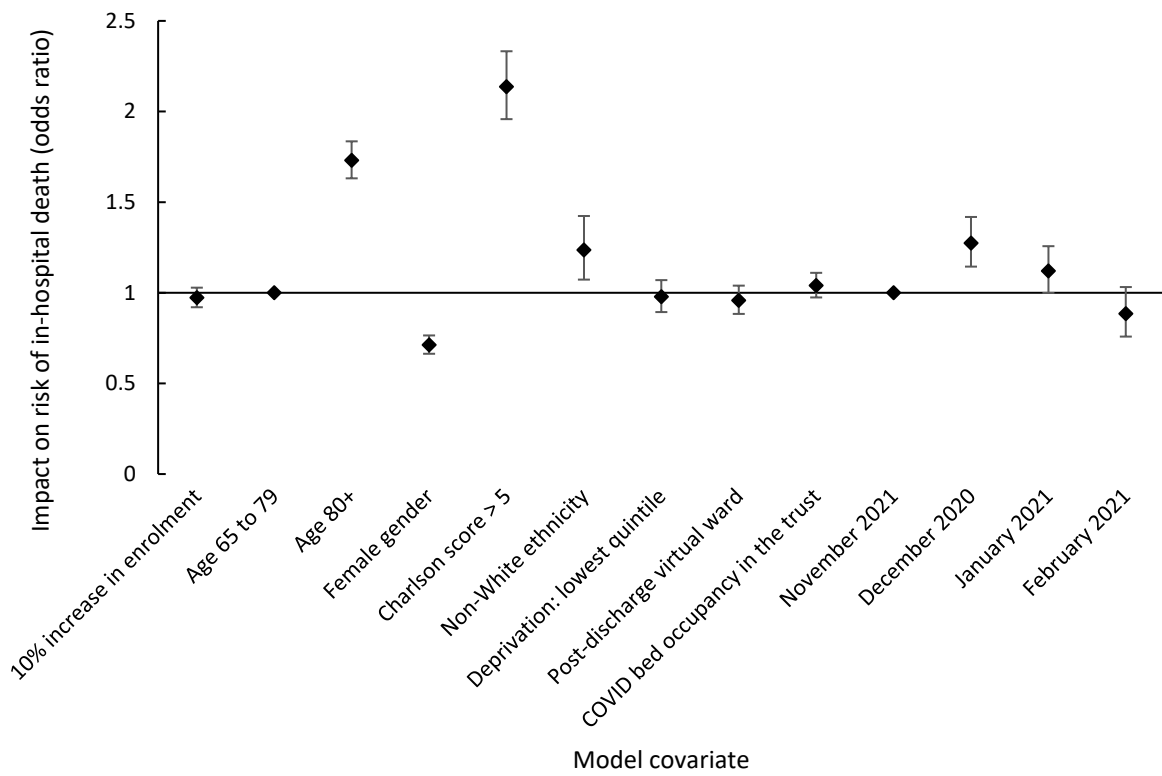
Figure 19. Impact of each variable used in the multivariate model on the risk of in-hospital mortality for people admitted with confirmed or suspected COVID-19 (OR).

Error bars denote 95% confidence intervals.
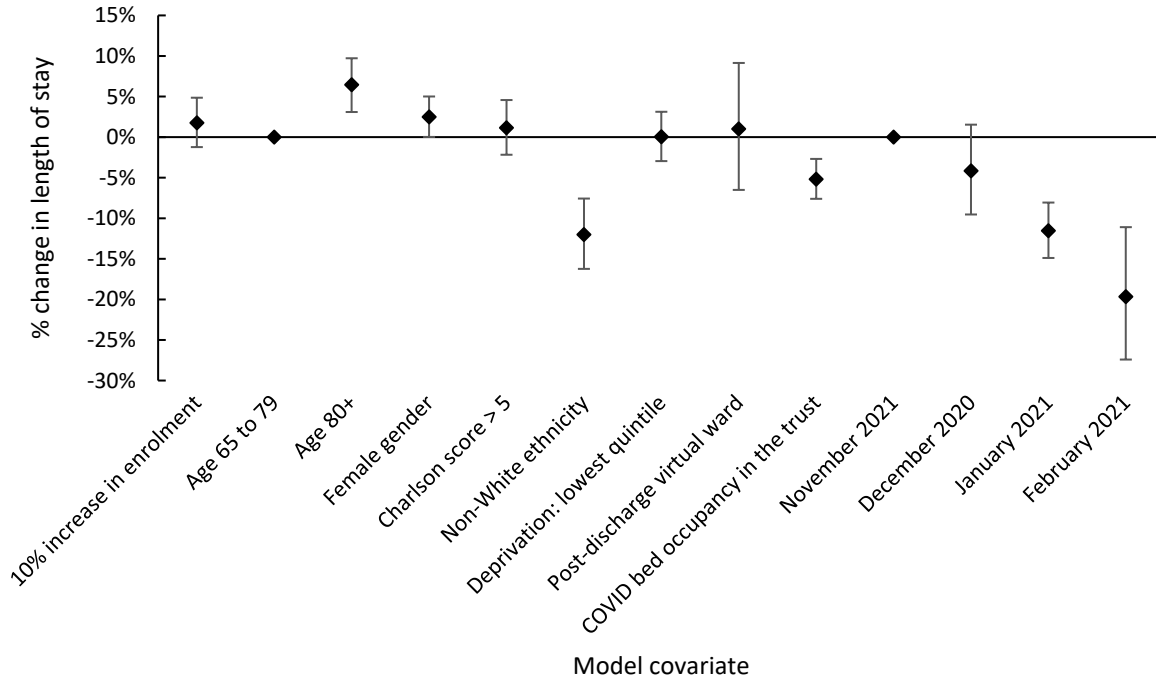
Figure 20. Impact of each variable used in the multivariate model on LOS for people admitted with confirmed or suspected COVID-19 (% change).

Error bars denote 95% confidence intervals.

Discussion

Summary of findings

In this study we have found no significant association between rates of patient enrolment to the CO@h programme, and COVID-associated mortality or COVID-associated admission to hospital. For such hospital admissions, we found no significant relationship to in-hospital mortality or LOS. Also, for COVID-associated admissions, there appears to have been no associated change in the patient characteristics we have tested.

Interpretation

There are several possible explanations for these results, and it would be premature to conclude that the CO@h programme has had no impact. Firstly, limitations in data completeness meant that we were only able to analyse onboarding data for one quarter of CCGs across England. This, combined with lower than expected patient enrolment within these CCGs, meant that our ability to detect any possible impact was smaller than anticipated. This also meant that some areas of the country were under-represented. Secondly, individual level associations may not have been seen at the aggregate level. Thirdly, qualitative findings from our wider study revealed that CO@h was implemented in a variety of ways by different services within CCGs, some of which may have had more impact on outcomes than others (see *Chapter 4*). The possible impact of the intervention on hospital admissions was always uncertain, since the aim of the programme was to ensure people who needed hospital treatment were admitted at the right time. Also, once in hospital, the determinants of LOS are complex and multifactorial, and may have varied during the time course of the second wave of COVID-19 infection in England.

Strengths and limitations

The anticipated value of our approach with aggregated data was that it would complement the other two simultaneous quantitative evaluations of CO@h,[43, 45] could be carried out more rapidly and, if COVID-19 continues to stretch national health services, it could be more readily repeated as new data become available, provided the right information is routinely collected at source.

We were able to handle small number suppression and the rounding of aggregate data by multiple random sampling throughout the range of possible values and it was encouraging to discover that this uncertainty did not have a large impact on results.

Using aggregated data has some limitations because it does not enable us to trace direct links between the onboarding of an individual and their outcomes. There may also be an ecological fallacy, where individual-level effects are not observable in the aggregated data.[112] However, obtaining linked individual-level data is a complex and potentially long process that may not always be feasible when there is a need to provide rapid feedback to a developing programme and where resources are stretched. Unfortunately, however, our ability to provide rapid feedback was compromised by delays in obtaining onboarding data which proved an understandable challenge for local services in the midst of a pandemic.

The wider mixed methods study has added insight into some of our findings and provided locally collected bespoke data against which we could verify information we received centrally about patient enrolment and data completeness. However, these checks could only be made against the 28 study sites and we were not able to verify the data from the other CCGs in the same way. Findings from surveys and interviews have helped interpret what we have found and, conversely, our data analyses have helped provide a context against which to understand the relative importance of the qualitative findings (see *Chapters 4* and *8-11*).

The qualitative study has also shed light on the different ways that the services had been implemented. However, with just 12 of the 28 study sites being among the 37 included in our analysis, in combination with low enrolment, it was not possible to undertake a quantitative study of the relative performance of the different types of services implemented.

We anticipated that finding a suitable comparator group during the national implementation of a programme was likely to be problematic, and we therefore avoided this problem by treating the relationship between rates of enrolment and outcome as a dose-response. However, the power to detect any impact in such an analysis depends on the level of enrolment which, in practice, was lower than we hoped. This approach also assumes any selection bias with those being enrolled is negligible.

During the period of our analysis the vaccination programme was starting and by the end of our study period 88% of people aged 65 or over had had at least one dose.[113] Although this study investigates outcomes of people after being diagnosed with COVID-19, there is evidence that vaccination changes the subsequent risks of mortality and hospital admission [114] which could have had a confounding effect on our analysis.

In the context of fortnightly data, we assumed a minimal lag between the diagnosis of COVID-19 and onboarding to CO@h. However, there was evidence from sites that they sometimes encountered delays in identifying positive cases,[115] although the overall impact on this assumption is uncertain.

Comparison with other studies

Prior to this study, very little was known about the quantitative impact of the use of pulse oximeters for COVID-19 remote home monitoring. One of the other evaluations of the CO@h programme in

England also found no significant impact on mortality or health service utilisation.[43] However, the study did find reductions in mortality and increases in hospital attendance (yet with lower use of critical care) among people enrolled on to the programme after attending the Emergency Department (ED).[42] A study of 4,384 high risk patients receiving home monitoring of vital signs, including pulse oximetry, in one region of Galicia, Spain, found lower admissions, lengths of hospital stays and in-hospital mortality when compared with other local regions.[116] A retrospective cohort study from South Africa evaluated the use of pulse oximetry for home monitoring of people diagnosed with COVID-19 and, as with the Spanish study, deemed to be of high clinical risk.[117] They found a significant improvement in mortality but no impact on admissions to hospital; the reduction in mortality being explained by earlier admission. A recent study of CO@h carried out at one site in England demonstrated reductions in 30-day mortality and lengths of stay among people admitted to hospital over the second wave.[118] The control group in this study were patients admitted with COVID-19 who were not on the CO@h programme and it is not clear whether that would be an inherently higher risk group. In another study implemented in the UK during the first wave, patients with suspected COVID-19 attending ED were discharged home with an oximeter. They observed a reattendance rate of 4.7% compared to 22.7% among a retrospective control group.[119] However, this was a younger cohort (median age 41 years) and the absolute numbers of reattendance were small (nine in all). Other studies have reported on the safety of similar programmes, but have lacked comparators.[28, 111, 120-122, 43]

Implications and further research

At the start of this study we anticipated the services would have higher rates of patient enrolment and complete data would be available from more CCGs. Although the use of aggregated population-level data can enable more rapid evaluation of a new service, these two elements had an influence on the power of the analysis to detect an impact. The resulting shortfall in expected data reflects the challenges of trying to centrally manage a bespoke data collection while services are already stretched. However, sufficient quantities of data are vital to determining whether a service is effective, so it is important to understand how this can be improved, for example, by concentrating data collection in a few sites and using routinely collected data wherever possible.

Furthermore, low patient enrolment raises questions about capacity of both staff and resources in the midst of high infection rates and how it is possible to secure the best value from such a service under the circumstances. The fact that at least one CCG managed to achieve reasonably good rates of enrolment indicates the possibility for learning from others.

Other studies, as described above, have provided evidence of positive impacts on high-risk cohorts, and similar findings may follow from focusing evaluation of the CO@h programme in the same way.

Conclusions

This study provides an evaluation of the national implementation of remote home monitoring of pulse oximetry for people diagnosed with COVID-19 across the English NHS. Although we detected no significant impact on outcomes, there are potential explanations for this finding that are unrelated to the effectiveness of the programme. Taking due account of populations that may respond less well to oximetry, there is no evidence that future implementation of similar programmes would be unsafe. However, the challenges of providing sufficient data so that effectiveness can be adequately measured need to be overcome.

Chapter 6. Impact of COVID Virtual Wards on hospital activity

Overview

This chapter draws on a manuscript by Georghiou *et al.*[123] published in *Lancet eClinicalMedicine (2022):* https://doi.org/10.1016/j.eclinm.2022.101441. This is an open access article under the term of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits use, distribution and reproduction in any medium, provided the original work is properly cited (see https://creativecommons.org/licenses/by/4.0/).

What was already known

- Post-hospital discharge virtual wards have been found to have a positive impact on patient outcomes when focused on patients with specific diseases, for example those with heart disease. There has been less evidence of impact for more heterogenous groups of patients.
- There has been little evidence thus far that post-hospital discharge virtual wards (using pulse oximetry monitoring) have helped to reduce the LOS of hospitalised COVID-19 patients, or change rates of subsequent readmissions for COVID-19.

What this chapter adds

- This national-scale study has found no evidence that the roll-out of post-hospital discharge virtual ward services for COVID-19 patients in England reduced lengths of stay in hospital, or impacted rates of readmission.
- While there is currently an absence of evidence of positive impacts for COVID-19 patients discharged to a virtual ward, our study emphasises the need for quality data to be collected as part of future service implementation.

Introduction

There has been a long-standing ambition in the NHS in England to develop remote monitoring services to better support people with long-term conditions out of hospital.[18] Virtual ward models have been proposed as one way of easing the transition of patients being discharged home, and there is some evidence that such models (distinguished from less intensive telemonitoring) may help to reduce mortality and readmissions, especially where the intervention is focused on patients with a specific disease, for example heart failure.[124]

In facilitating the national roll-out of CVW services in January 2021, NHSEI stated that "CVWs have been proven to reduce admissions/bed occupancy and improve length of stay", and so could act to mitigate the pressure on hospital beds, which was severe at the time.[6] However, evidence of the impact of such services on hospital activity has been lacking. A US study found a reduction in rates of ED presentation or readmission for a group of 225 patients enrolled on to a post-discharge monitoring programme,[125] and two studies (from the Netherlands, and a case study from England) estimated reduced lengths of hospital stays, but with small patient cohorts and uncontrolled methods.[126, 127] Elsewhere, where outcomes have been reported, these have tended to focus on rates of patient escalation (including readmissions) in the absence of a comparator. Occasionally these are considered against a perceived optimal level (for example, a 10% conversion rate to admissions for ambulatory care pathways),[31] or the reported performance of services elsewhere.[25, 31, 36, 122, 128-130]

Data on which patients were enrolled to CVWs in England were not collected, but information was assembled on launch dates of CVWs at each hospital trust. By late February 2021 the large majority of acute hospital trusts in England had a service available for use. The analysis described in this chapter

aimed to use patient-level admissions data to provide quantitative evidence of the impact of the service, to contribute to future development of post-discharge home monitoring programmes during the remainder of the COVID-19 pandemic, and beyond.

The primary aim of the analysis described in this chapter was to address the following research question:

What was the impact of CVWs on the LOS of COVID-19 hospitalisations, and rates of subsequent readmission for COVID-19?

A secondary aim, in the context of COVID-19s widely reported differential effects on outcomes for groups of patients (for example, by gender, age and ethnicity),[12, 131] was to reflect on associations found between patient characteristics and hospital outcomes.

Methods

A summary of the methods is provided below; further details can be found in *Chapter 2* and *Supplementary file 1*.

We used HES APC data to extract information on patients with a confirmed or suspected primary diagnosis of COVID-19 (ICD-10 codes U071 or U072) who were discharged alive between 17 August 2020 and 28 February 2021 (during England's second COVID-19 wave). We limited our analysis to 123 acute hospital trusts for which there was a known CVW service start date (from a dataset collected by Kent, Surrey and Sussex AHSN).

Using patient-level (pseudonymised) data, we developed multivariate models to examine the impact of the availability of CVW (the primary independent variable of interest) on two outcomes: the LOS of the COVID-19 inpatient stay, and on subsequent readmissions for COVID-19. Factors included in our models are shown in Table 8.

Table 8. Factors included in multivariate models, and sources of data.

Modelling Factors	Categories assigned to each COVID-19 patient discharge	Source
Age at admission	0-17, 18-49, 50-64, 65-79, 80s+	HES APC
Gender	Male, Female	HES APC
Ethnic group	Asian, Black, White, Mixed, Other, Unknown	HES APC
Charlson comorbidity index category [54]	0, 1, 2, 3, 4, 5, 6+	HES APC (activity during two years prior to discharge)
Whether the stay was the person's first COVID-19 hospital stay	Yes, No	HES APC
Whether the inpatient stay was an emergency admission	Yes, No (elective)	HES APC
Deprivation quintile IMD (2019)	1 – most deprived to 5 – least deprived, with a sixth category for unknown area	UK Ministry of Housing, Communities & Local Government, linked via LSOA in HES APC
Time period of the discharge date	14 categories, each covering a 14-day period starting from 17 August 2020	HES APC
Proportion of all acute beds occupied by COVID-19 patients	A trust- and week-specific continuous measure (mapped to week of discharge)	HES APC
Availability of CVW	Yes, No	Kent, Surrey and Sussex Academic Health Science Network (KSS AHSN) bespoke data collection

For our main analyses negative binomial regression was used to examine the relationship between independent variables and LOS, and logistic regression was similarly used for occurrence of any readmission. To account for clustering at the level of the hospital trust, generalised estimating equation (GEE) approaches were used. Descriptive statistics and a number of sensitivity analyses were also carried out.

Results

Participants

We found 139,619 discharges between 17 August 2020 and 28 February 2021 where the patient had a primary diagnosis of COVID-19 recorded during their inpatient stay, and had not died in hospital. These discharges belonged to 129,461 individuals. Table 9 shows characteristics of these COVID-19 patient discharges.

Table 9. Characteristics of COVID-19 patient discharges, also split by CVW availability.

	All COVID-19 discharges, N (%) N = 139,619 (100 %)		CVW availability				P value of difference [a]
			Discharges with no CVW available, N (%) N = 81,174 (58.1%)		Discharges with CVW available, N (%) N = 58,445 (41.9%)		
Gender							0.127
Male	75,429	(54.0%)	43,714	(53.9%)	31,715	(54.3%)	
Female	64,190	(46.0%)	37,460	(46.1%)	26,730	(45.7%)	
Age band							<.0001
0-17	2,041	(1.5%))	1,242	(1.5%)	799	(1.4%)	
18-49	30,076	(21.5%)	17,647	(21.7%)	12,429	(21.3%)	
50-64	39,776	(28.5%)	22,620	(27.9%)	17,156	(29.4%)	
65-79	38,140	(27.3%)	22,384	(27.6%)	15,756	(27.0%)	
80+	29,586	(21.2%)	17,281	(21.3%)	12,305	(21.1%)	
Ethnic group							<.0001
Asian	16,360	(11.7%)	9,089	(11.2%)	7,271	(12.4%)	
Black	6,002	(4.3%)	3,172	(3.9%)	2,830	(4.8%)	
Other	4,969	(3.6%)	2,501	(3.1%)	2,468	(4.2%)	
White	93,688	(67.1%)	56,357	(69.4%)	37,331	(63.9%)	
Mixed	1,394	(1.0%)	779	(1.0%)	615	(1.1%)	
Unknown	17,206	(12.3%)	9,276	(11.4%)	7,930	(13.6%)	
IMD 2019 quintile of residence							<.0001
1 (most deprived)	38,247	(27.4%)	23,848	(29.4%)	14,399	(24.6%)	
2	31,794	(22.8%)	18,413	(22.7%)	13,381	(22.9%)	
3	26,391	(18.9%)	14,975	(18.4%)	11,416	(19.5%)	
4	22,697	(16.3%)	12,859	(15.8%)	9,838	(16.8%)	
5 (least deprived)	19,354	(13.9%)	10,367	(12.8%)	8,987	(15.4%)	
Unknown	1,136	(0.8%)	712	(0.9%)	424	(0.7%)	
Charlson comorbidity score							0.402
0	47,904	(34.3%)	27,858	(34.3%)	20,046	(34.3%)	
1	15,012	(10.8%)	8,667	(10.7%)	6,345	(10.9%)	
2	23,403	(16.8%)	13,658	(16.8%)	9,745	(16.7%)	
3	14,677	(10.5%)	8,528	(10.5%)	6,149	(10.5%)	
4	9,538	(6.8%)	5,587	(6.9%)	3,951	(6.8%)	
5	8,585	(6.1%)	5,056	(6.2%)	3,529	(6.0%)	
6+	20,500	(14.7%)	11,820	(14.6%)	8,680	(14.9%)	
First COVID-19 admission?							<.0001
Yes	129,041	(92.4%)	75,948	(93.6%)	53,093	(90.8%)	
No	10,578	(7.6%)	5,226	(6.4%)	5,352	(9.2%)	
COVID-19 admission - emergency?							<.0001
Yes	136,643	(97.9%)	79,642	(98.1%)	57,001	(97.5%)	
No	2,976	(2.1%)	1,532	(1.9%)	1,444	(2.5%)	
COVID stay discharge date (from date)							<.0001
17/08/2020	541	(0.4%)	488	(0.6%)	53	(0.1%)	
31/08/2020	619	(0.4%)	512	(0.6%)	107	(0.2%)	
14/09/2020	1,561	(1.1%)	1,354	(1.7%)	207	(0.4%)	
28/09/2020	2,952	(2.1%)	2,625	(3.2%)	327	(0.6%)	
12/10/2020	4,767	(3.4%)	4,188	(5.2%)	579	(1.0%)	
26/10/2020	7,872	(5.6%)	6,661	(8.2%)	1,211	(2.1%)	
09/11/2020	10,014	(7.2%)	8,246	(10.2%)	1,768	(3.0%)	
23/11/2020	9,135	(6.5%)	7,119	(8.8%)	2,016	(3.4%)	
07/12/2020	8,696	(6.2%)	6,452	(7.9%)	2,244	(3.8%)	
21/12/2020	14,214	(10.2%)	10,274	(12.7%)	3,940	(6.7%)	
04/01/2021	24,578	(17.6%)	15,410	(19.0%)	9,168	(15.7%)	
18/01/2021	25,632	(18.4%)	11,637	(14.3%)	13,995	(23.9%)	
01/02/2021	18,193	(13.0%)	4,600	(5.7%)	13,593	(23.3%)	
15/02/2021	10,845	(7.8%)	1,608	(2.0%)	9,237	(15.8%)	
Proportion of beds occupied by COVID patients at time of discharge							<.0001
0-9.99%	17,370	(12.4%)	13,439	(16.6%)	3,931	(6.7%)	
10-19.99%	34,052	(24.4%)	18,865	(23.2%)	15,187	(26.0%)	
20-29.99%	35,514	(25.4%)	20,173	(24.9%)	15,341	(26.2%)	
30-39.99%	24,841	(17.8%)	13,999	(17.2%)	10,842	(18.6%)	
40-49.99%	16,757	(12.0%)	8,476	(10.4%)	8,281	(14.2%)	
50-59.99%	10,035	(7.2%)	5,550	(6.8%)	4,485	(7.7%)	
60-69.99%	938	(0.7%)	560	(0.7%)	378	(0.6%)	
70-79.99%	112	(0.1%)	112	(0.1%)	0	(0.0%)	

[a] Chi-square test, except for proportion of beds occupied by COVID patients (t test).

The number of COVID-19 patients discharged in this time across England (not limited to the 123 analysis trusts) was 142,216. Thus, our analysis includes 98.2% of recorded inpatient stays of patients in England with a primary COVID-19 diagnosis, discharged alive.

Table 9 also shows the characteristics of the patients split into two key analysis groups: patients discharged where no CVW was available (N = 81,174, 58.1%), and those discharged where a CVW was available (N = 58,445, 41.9%). These two sets of patients were well matched in terms of gender and comorbidities. Patients discharged where a CVW was available were more likely to be in the age range 50 to 64 and members of non-White ethnic groups, and less likely to be from the most deprived areas. As a consequence of the accelerated set-up of CVW services from early January 2021 (Figure 21), discharge dates of patients where a CVW was available tended to take place toward the end of the analysis period, with nearly 4 in 5 occurring on or after 4 January 2021 (compared to 2 in 5 of the discharges where a CVW was not available). Discharges of patients taking place where a CVW was available were more likely to be occurring in the context of higher levels of beds occupied by COVID-19 patients.
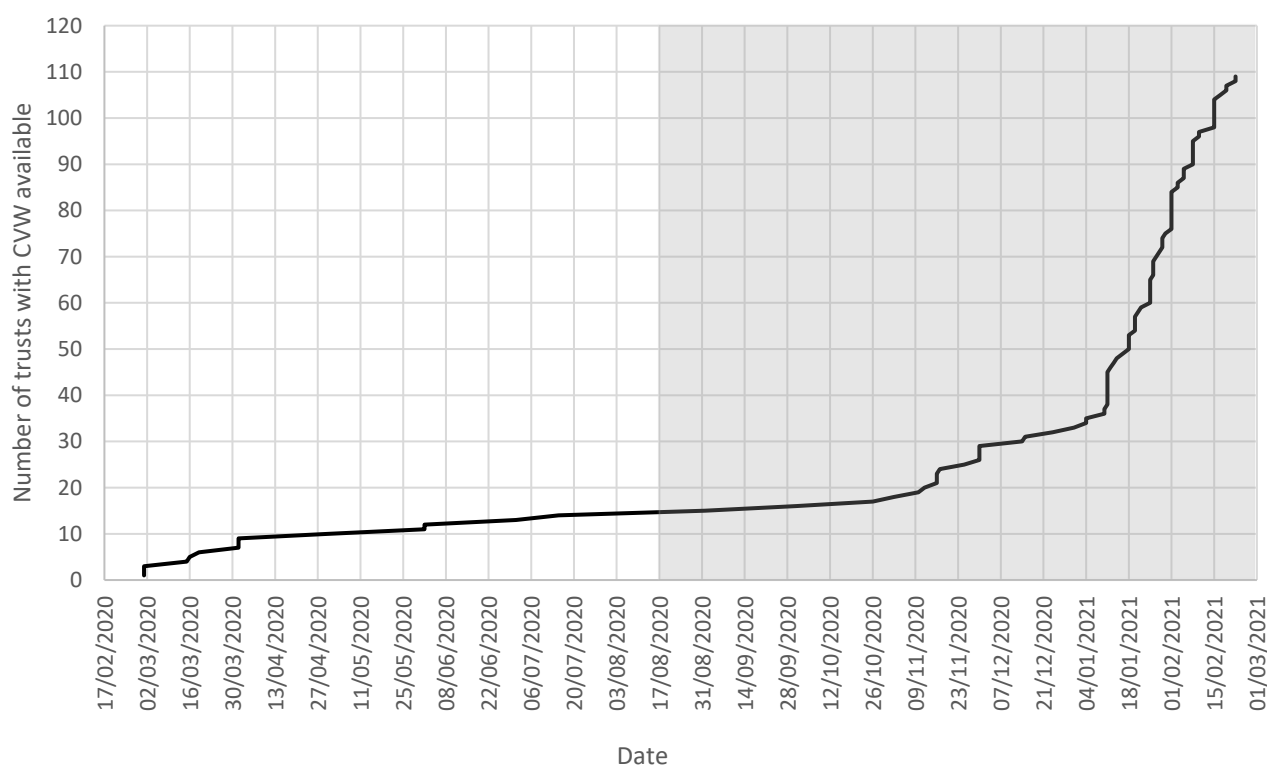
Figure 21. Cumulative start dates of CVW services in England's non-specialist acute hospital trusts (n = 123 trusts). Fourteen trusts had no CVW by 22 February 2021.

The grey box represents the main period of this analysis.

COVID-19 length of stay

The mean LOS for patients discharged where a CVW was available was 10.1 days (standard deviation (SD) 11.3 days), compared to 8.9 days (SD 10.3 days) for patients where a CVW was not available (Figure 22). This was an unadjusted incidence rate ratio of 1.13, or 13% longer for discharges taking place from hospital trusts with a CVW. Distributions of COVID-19 LOSs for patients discharged with and without an available CVW are provided in *Supplementary file 5*.

Categories	Number of discharges	Mean LOS (standard deviation)	Adjusted IRR (log scale)	Adjusted IRR (95% CIs)	P value
Gender					
Male	75,429	9.31 (10.7)		Reference	
Female	64,190	9.52 (10.8)		0.95 (0.94,0.96)	<0.001 *
Age band					
0-17	2,041	2.36 (4.27)		Reference	
18-49	30,076	5.40 (7.23)		2.12 (1.88,2.39)	<0.001 *
50-64	39,776	7.83 (9.22)		2.80 (2.50,3.14)	<0.001 *
65-79	38,140	10.9 (11.5)		3.49 (3.09,3.95)	<0.001 *
80+	29,586	14.1 (12.5)		4.24 (3.74,4.82)	<0.001 *
Ethnic group					
White	93,688	10.3 (11.4)		Reference	
Asian	16,360	6.94 (8.31)		0.89 (0.87,0.91)	<0.001 *
Black	6,002	7.80 (9.29)		0.93 (0.90,0.95)	<0.001 *
Other	4,969	7.59 (8.82)		0.97 (0.94,1.00)	0.027 *
Mixed	1,394	6.96 (8.64)		0.92 (0.86,0.99)	0.026 *
Unknown	17,206	8.32 (9.70)		0.98 (0.95,1.00)	0.091
IMD 2019 quinitle					
1 (most deprived)	38,247	9.35 (10.7)		Reference	
2	31,794	9.28 (10.6)		1.00 (0.98,1.01)	0.623
3	26,391	9.49 (10.7)		0.98 (0.96,1.00)	0.060
4	22,697	9.59 (11.0)		0.96 (0.94,0.98)	<0.001 *
5 (least deprived)	19,354	9.61 (10.9)		0.95 (0.93,0.98)	<0.001 *
Unknown	1,136	6.29 (8.61)		0.79 (0.73,0.86)	<0.001 *
Charlson comorbidity category					
0	47,904	6.09 (7.59)		Reference	
1	15,012	9.02 (9.80)		1.31 (1.28,1.34)	<0.001 *
2	23,403	8.68 (10.0)		1.25 (1.22,1.27)	<0.001 *
3	14,677	11.2 (11.4)		1.46 (1.42,1.49)	<0.001 *
4	9,538	12.5 (12.4)		1.52 (1.48,1.56)	<0.001 *
5	8,585	12.9 (12.5)		1.56 (1.52,1.61)	<0.001 *
6+	20,500	14.1 (13.2)		1.65 (1.61,1.69)	<0.001 *
First COVID admission?					
No	10,578	9.61 (10.6)		Reference	
Yes	129,041	9.39 (10.7)		1.07 (1.02,1.12)	0.002 *
COVID admission - emergency?					
No	2,976	11.6 (15.0)		Reference	
Yes	136,643	9.36 (10.6)		0.73 (0.66,0.80)	<0.001 *
COVID stay discharge date (from date)					
17/08/2020	541	13.9 (17.9)		Reference	
31/08/2020	619	10.1 (15.5)		0.80 (0.69,0.93)	0.003 *
14/09/2020	1,561	5.89 (9.18)		0.49 (0.42,0.56)	<0.001 *
28/09/2020	2,952	6.46 (7.67)		0.54 (0.47,0.61)	<0.001 *
12/10/2020	4,767	6.83 (7.60)		0.54 (0.48,0.61)	<0.001 *
26/10/2020	7,872	7.76 (8.60)		0.61 (0.54,0.69)	<0.001 *
09/11/2020	10,014	9.02 (9.84)		0.69 (0.61,0.78)	<0.001 *
23/11/2020	9,135	10.9 (11.1)		0.81 (0.71,0.91)	<0.001 *
07/12/2020	8,696	11.2 (12.4)		0.84 (0.74,0.95)	0.006 *
21/12/2020	14,214	8.25 (10.5)		0.69 (0.60,0.78)	<0.001 *
04/01/2021	24,578	8.03 (9.69)		0.70 (0.62,0.79)	<0.001 *
18/01/2021	25,632	8.86 (9.78)		0.76 (0.67,0.86)	<0.001 *
01/02/2021	18,193	11.0 (11.2)		0.87 (0.78,0.98)	0.021 *
15/02/2021	10,845	13.6 (13.9)		1.02 (0.91,1.15)	0.682
Proportion of beds occupied COVID pats					
Each 10% point increase				0.97 (0.96,0.98)	<0.001 *
CVW available at discharge?					
No	81,174	8.94 (10.3)		Reference	
Yes	58,445	10.1 (11.3)		1.05 (1.01,1.09)	0.014 *

0.5 1.5 3 5

Shorter LOS ←→ Longer LOS

* statistically significant at 95% confidence

Figure 22. Mean (unadjusted) LOS of COVID-19 hospitalisations, and adjusted Incidence Rate Ratios (IRR), with respect to categories of factors in multivariate model.

Fully adjusting for all covariates, we found an adjusted IRR of 1.05 (95% CI 1.01 to 1.09) for discharges where a CVW was available compared to those where a CVW was not available, indicating that the LOS was 5% longer for relevant COVID-19 inpatient stays where a CVW had been available.

We additionally found strong, generally positive gradients of LOS for increasing age and comorbidity (note that these relationships relate to all 139,619 discharges, and not just those with a CVW-available). Females had shorter lengths of stay than males (adjusted IRR 0.95, 95% CI 0.94 to 0.96), as did all non-White ethnic groupings, compared to the White group (for example, Asian patients had an adjusted IRR of 0.89, 95% CI 0.87 to 0.91, and Black patients an adjusted IRR of 0.93, 95% CI 0.90 to 0.95). Patients resident in the most affluent population quintiles tended to have slightly shorter lengths of stay than those in the most deprived quintile. First COVID-19 inpatient stays were longer than subsequent stays (adjusted IRR 1.07, 95% CI 1.02 to 1.12). The LOS shortened significantly for all time periods after 31 August 2020, until mid-February 2021. As the proportion of acute beds occupied by COVID-19 patients increased, LOS tended to fall: for every ten-percentage point increase in this proportion, the adjusted IRR was 0.97 (CI 0.96 to 0.98).

Model variants carried out as sensitivity analyses marginally altered the resulting adjusted IRR of the CVW-available discharges (see *Supplementary file 5*). Shortening the time period variable to seven days reduced the IRR slightly such that the difference was no longer significant at 95% statistical confidence level (IRR 1.04, 95% CI 0.997 to 1.08), while increasing the period to 28 days increased the adjusted IRR to 1.08 (95% CI 1.04 to 1.13). The addition of earlier (wave 1) data made the two groups effectively indistinguishable from one another (IRR 1.01, 95% CI 0.97 to 1.05). The two alternative LOS outcomes tested had little impact on the adjusted IRRs compared to the base model.

COVID-19 readmission within 28 days

Of the patients discharged from trusts with a CVW available, 13.0% were readmitted with COVID-19 within 28 days, compared to 13.2% from trusts where no CVW was available (Figure 23). Adjusting for all variables, we found a non-significant difference in COVID-19 readmissions within 28 days for discharges where a CVW was available compared to those where a CVW was not available (adjusted OR of 0.97, 95% CI 0.91 to 1.03). Our sensitivity analyses demonstrated the robustness of these findings (see *Supplementary file 5*).

Categories	Number of discharges	Number of readmissions (%)	Adjusted OR (log scale)	Adjusted OR (95% CIs)	P value
Gender					
Male	75,429	10,615 (14.1)		Reference	
Female	64,190	7,715 (12.0)		0.78 (0.75,0.81)	<0.001 *
Age band					
0-17	2,041	215 (10.5)		Reference	
18-49	30,076	2,699 (9.0)		0.78 (0.65,0.94)	0.010 *
50-64	39,776	4,126 (10.4)		0.87 (0.72,1.04)	0.124
65-79	38,140	5,956 (15.6)		1.20 (1.00,1.45)	0.051
80+	29,586	5,334 (18.0)		1.33 (1.10,1.60)	0.003 *
Ethnic group					
White	93,688	12,960 (13.8)		Reference	
Asian	16,360	2,032 (12.4)		1.03 (0.97,1.10)	0.355
Black	6,002	663 (11.0)		0.91 (0.84,0.99)	0.029 *
Other	4,969	547 (11.0)		0.96 (0.87,1.06)	0.411
Mixed	1,394	153 (11.0)		0.95 (0.80,1.12)	0.519
Unknown	17,206	1,975 (11.5)		0.92 (0.87,0.97)	0.003 *
IMD 2019 quinitle					
1 (most deprived)	38,247	4,884 (12.8)		Reference	
2	31,794	4,089 (12.9)		0.99 (0.94,1.03)	0.512
3	26,391	3,552 (13.5)		1.01 (0.96,1.06)	0.767
4	22,697	3,137 (13.8)		1.02 (0.96,1.08)	0.528
5 (least deprived)	19,354	2,609 (13.5)		0.97 (0.90,1.03)	0.317
Unknown	1,136	59 (5.2)		0.37 (0.23,0.60)	<0.001 *
Charlson comorbidity category					
0	47,904	4,363 (9.1)		Reference	
1	15,012	1,693 (11.3)		1.16 (1.10,1.22)	<0.001 *
2	23,403	2,903 (12.4)		1.35 (1.28,1.42)	<0.001 *
3	14,677	2,142 (14.6)		1.48 (1.39,1.58)	<0.001 *
4	9,538	1,630 (17.1)		1.72 (1.61,1.84)	<0.001 *
5	8,585	1,488 (17.3)		1.72 (1.61,1.83)	<0.001 *
6+	20,500	4,111 (20.1)		2.01 (1.90,2.12)	<0.001 *
First COVID admission?					
No	10,578	1,569 (14.8)		Reference	
Yes	129,041	16,761 (13.0)		1.03 (0.96,1.10)	0.391
COVID admission - emergency?					
No	2,976	631 (21.2)		Reference	
Yes	136,643	17,699 (13.0)		0.46 (0.39,0.53)	<0.001 *
COVID stay discharge date (from date)					
17/08/2020	541	39 (7.2)		Reference	
31/08/2020	619	73 (11.8)		1.92 (1.32,2.81)	<0.001 *
14/09/2020	1,561	183 (11.7)		1.99 (1.40,2.83)	<0.001 *
28/09/2020	2,952	291 (9.9)		1.63 (1.18,2.26)	0.003 *
12/10/2020	4,767	606 (12.7)		2.01 (1.49,2.70)	<0.001 *
26/10/2020	7,872	1,091 (13.9)		2.09 (1.52,2.86)	<0.001 *
09/11/2020	10,014	1,298 (13.0)		1.84 (1.34,2.53)	<0.001 *
23/11/2020	9,135	1,161 (12.7)		1.75 (1.27,2.40)	<0.001 *
07/12/2020	8,696	1,206 (13.9)		1.96 (1.43,2.69)	<0.001 *
21/12/2020	14,214	2,024 (14.2)		2.20 (1.61,3.01)	<0.001 *
04/01/2021	24,578	3,517 (14.3)		2.14 (1.57,2.92)	<0.001 *
18/01/2021	25,632	3,556 (13.9)		2.03 (1.47,2.81)	<0.001 *
01/02/2021	18,193	2,151 (11.8)		1.68 (1.22,2.31)	0.001 *
15/02/2021	10,845	1,134 (10.5)		1.48 (1.07,2.05)	0.018 *
Proportion of beds occupied COVID pats					
Each 10% point increase				1.03 (0.99,1.06)	0.103
CVW available at discharge?					
No	81,174	10,749 (13.2)		Reference	
Yes	58,445	7,581 (13.0)		0.97 (0.91,1.03)	0.319

0.2 0.5 1.5 3

←Fewer readmissions   More readmissions→
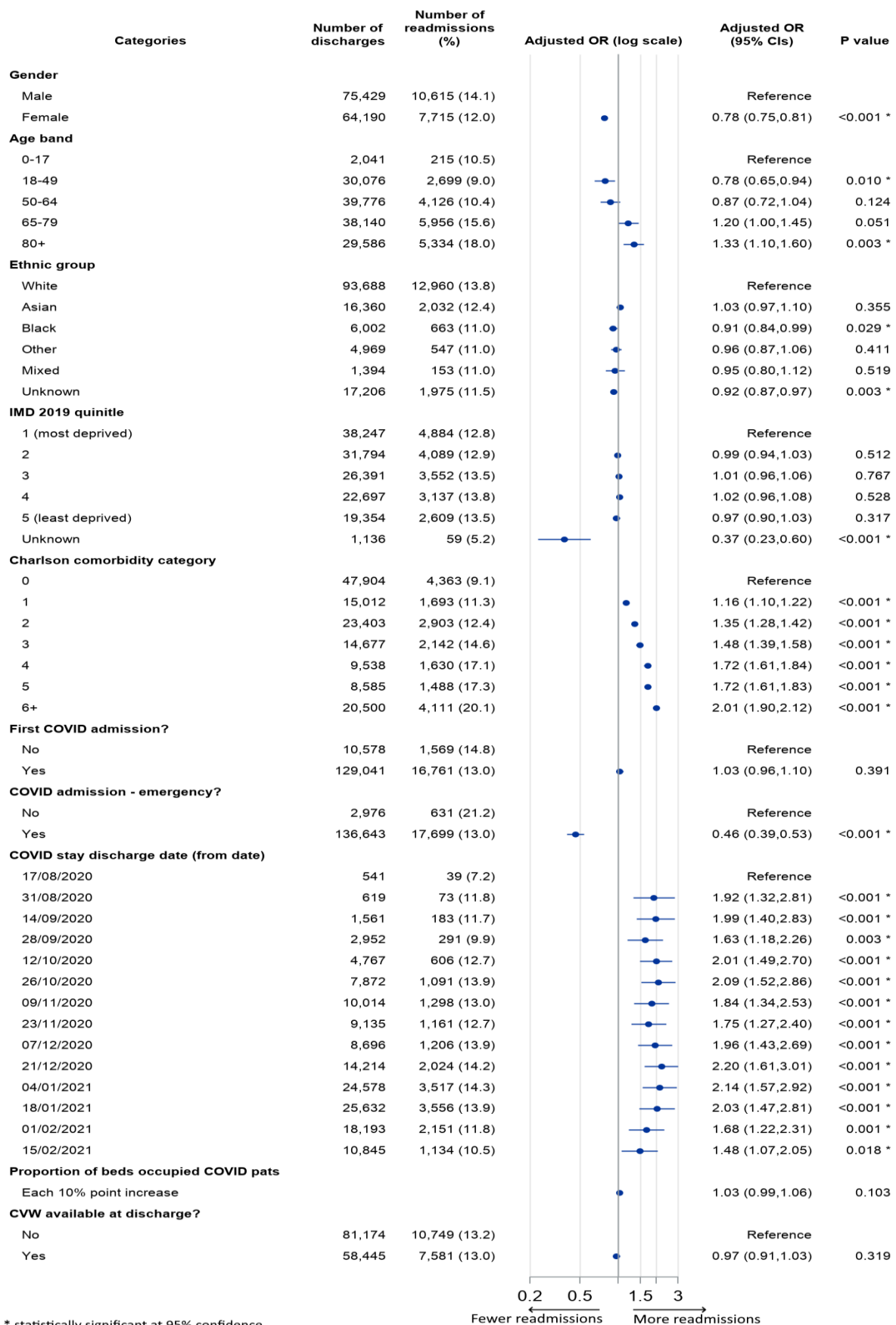
* statistically significant at 95% confidence

Figure 23. Numbers (%) of patients readmitted for COVID-19 within 28 days, and adjusted OR with respect to factors in multivariate model.

As with LOS, we found generally positive gradients of relative odds of readmission with increasing age and comorbidity. Females had significantly lower odds of readmission than males (adjusted OR 0.78, 95% CI 0.75 to 0.81). Black patients had lower odds of readmission compared to White patients (adjusted OR 0.91, 95% CI 0.84 to 0.99), while no other ethnic categories (for patients with known ethnicity) showed similarly significant differences. There were no apparent differences in the odds of COVID-19 readmission for patients resident in less deprived areas, compared to those in the most deprived quintile areas.

For both LOS and readmissions models, adding variables one by one to our multivariate models (an example shown in *Supplementary file 5*) revealed that the addition of the 14-day time period categories, and the clustering by hospital trust had large impacts on the estimated adjusted ratios, but all additional variables (age, comorbidity index, and so on) had relatively marginal additional impacts.

Discussion

Key findings

In this analysis of COVID-19 patients discharged from hospital during the second wave of the COVID-19 pandemic in England, we found no evidence of a relationship between the availability of hospital-based CVWs and subsequent rates of readmission for COVID-19. We did, however, find that the LOS for hospitalised COVID-19 patients was 5% longer where a CVW was available.

Comparisons with other studies

There are few studies available against which we can compare our results. Our finding of no difference with respect to readmissions appears to contrast with that of an analysis of a post-discharge remote monitoring model implemented in five Boston (US) hospitals. This study found that enrolled patients had a reduced odds (OR 0.54, p-value 0.04) of attending ED or being readmitted within 30 days of discharge, compared to those not enrolled.[125] However, given the relatively large confidence intervals in their estimate, ED attendances being much more common than readmissions for the enrolled patient cohort, and those readmissions being for any cause, our findings may not be inconsistent.

Two other analyses have claimed reductions in length of hospitalisation associated with post-discharge models, on a scale of 30-40%. One, related to implementation in a Netherlands hospital, estimated a reduction in the LOS of 5.0 days (with a resulting mean LOS of 10.6 days),[126] and a second, in an English hospital trust, reported a reduced LOS of ten days, against an average of 17 days prior to implementation.[127] Both analyses, however, were based on small patient cohorts with no formal statistical testing. In the first analysis it was not clear how estimates of reductions were made, and in the second there was no attempt made to control for differences between the compared groups.

More generally, there is evidence of non-COVID related post-discharge virtual wards having a positive impact on readmissions when employed as a disease-specific intervention (at least in the case of heart failure), but there is not similar evidence of impact for more mixed groups of high-risk chronic disease patients.[124] Our findings may be consistent with this picture, considering the heterogeneity of COVID-19 patients, and the multi-organ effects of COVID-19 infection.[132-134]

Strengths and limitations

With respect to the analysis of post-discharge COVID monitoring services, our study is currently unique in its scope. We have made use of a national administrative hospital dataset, and have analysed almost 140,000 COVID-19 admissions in an effort to detect an impact of a national-scale roll-out of post-discharge remote monitoring services. We have been pragmatic in our use of the available data, and have controlled for characteristics available to us.

Nevertheless, there are several limitations, and our results should be interpreted with caution. We did not know which patients were enrolled on to a CVW, and so treated all patients as potentially having received the intervention where one was available at a trust. We had no information about important clinical factors, for example, Intensive Care Unit (ICU) admission, clinical readings (including oxygen saturation levels), and specific treatments received. The location to which patients were discharged (home, care home, and so on) was not known, and we also had no information about out-of-hospital deaths (and this during a period in which rates of out-of-hospital deaths had been persistently above long-term norms).[135] We extracted data only on patients discharged alive, and so the impact (if any) of COVID-19 patients who died during their hospital stay has not been accounted for. Our analyses have assumed that these factors – which are likely to have been associated to a greater or lesser degree with eligibility for referral, and/or with risks of readmission and long stays – were well balanced between the two key groupings of patients after having adjusted for model factors, but the extent to which this is the case is not known. However, in terms of at least one of these missing factors, an analysis of a cohort of 419 COVID-19 patients managed on a post-discharge pathway suggests that out-of-hospital deaths may have been relatively rare (<0.1%).[121]

As outlined in Chapter 4, for seven hospital-based sites we were able to estimate a range of 4% to 65% of discharged COVID-19 patients may have been monitored on a CVW. But nationally, we did not know the scale of each trust's implementation and our analysis wasn't able to examine potential dose-response relationships.

We also know that services were implemented with significant differences, depending on the locally adopted models of care. Our analysis treated the intervention as being homogeneous, and was not able to estimate differential impacts by hospital trust, though these may have existed.

Interpretation

We found longer COVID-19 inpatient stays associated with implementation of CVWs; this was not expected for a service that aimed to support the early discharge of patients. One explanation might be that CVW eligibility criteria influenced hospitals' discharge decisions such that patients were kept in a bed for longer than they otherwise might have been. It is not clear whether local pre-hospital (CO@h) services starting at similar times might have affected admissions in such a way that patients were admitted sooner, and stayed for longer. The finding might, in part, also be a consequence of many CVW services launching during the falling (improving) edge of England's second COVID-19 wave, with longer lengths of stay being a consequence of improving bed capacity.

We did attempt to control for the latter effect in our addition of trust-specific weekly occupied beds data, and with our inclusion of a time period variable in our multivariate analyses. In one sensitivity analysis, when we shortened the time period to seven days (from 14), we no longer found a statistically significant difference in LOS at the 95% level (adjusted IRR 1.04, 95% CI 1.00 to 1.08, p-value 0.07). The time factor used in our fully-adjusted models was somewhat arbitrary, and it is not clear that 14 days was better used above seven days. The finding of a longer LOS associated with CVW therefore needs to be considered with some care.

The expected impact of such services on readmissions following discharge is not obvious. These services aimed to detect early deterioration for more rapid escalation to potentially improve ultimate outcomes. It may be the case therefore, that readmissions might have been expected to increase. Unfortunately, with limitations in the available data described above, we were not able to assess any changes in the severity of patients on readmission.

As a result of the limitations in the available data outlined above, there is a strong possibility that any positive impacts - at a local hospital trust level, or for specific versions of the pathway - were not ultimately able to be detected. This limits the extent to which this analysis can contribute to the further development of these, or similar services, and highlights the importance of making routine data collection - appropriate for use in evaluation – an intrinsic part of services' operations.

Briefly, we reflect on observed relationships between patient characteristics and COVID-19 lengths of stay, and readmissions. Positive relationships between age and comorbidities and these outcomes have been observed elsewhere.[136-139] Meanwhile, differences with respect to gender (in this study's case both outcomes were lower for females vs. males) tend to have been absent.[132, 137, 139, 140] We found shorter lengths of stay and lower rates of readmissions for patients belonging to specific ethnic groups with respect to White patients (this was the case for patients belonging to Black ethnic groups for both outcomes, and also Asian, Mixed and 'Other' ethnic groups for LOS). Evidence from elsewhere is mixed, but at least one US study found shorter lengths of stay for hospitalised non-White patient groups.[139] Ultimately, however, care is needed when interpreting findings for specific characteristics separate from the context of the other model variables. It is possible, for example, that non-White ethnic groups (to give one example) may be acting as fine-scale markers of urban or more deprived areas (in addition to the model deprivation categories) and as markers of younger patients (within modelled age bands).

Conclusion

Our analysis has not shown any evidence of early discharges or changes to rates of readmissions associated with the roll-out of CVWs in England. While this may reflect the true impact of the service, it may be, in part, a consequence of the lack of certain data: on which patients were enrolled (or even how many), what COVID-19 treatments were received while in hospital, their clinical observations. It is possible that CVW services had a range of impacts that we have ultimately not been able to reveal.

Chapter 7. Cost evaluation of remote home monitoring services for COVID-19 patients in England during wave 2 from October 2020-April 2021

Overview

What was already known

- Previous economic analyses of remote home monitoring for COVID-19 patients have reported the resources used and the amount spent per patient monitored.

What this chapter adds

- The mean running cost per patient monitored under CO@h services was slightly lower compared with CVW services (£527.5 vs. £599.1).
- For both CO@h and CVW services the mean cost per patient monitored at home was lower in sites using both tech-enabled and analogue modes of data submission compared with the sites using analogue-only modes.
- Mortality rates were slightly higher for the patients under CO@h services in comparison with patients under CVW services (0.9% vs. 0.7% respectively).
- The majority of the staff involved in running CO@h and CVW services were clinical staff. Over 50% of staff (clinical and non-clinical staff combined) were employed at Band 5 or below in the CO@h service, whereas in CVW services there were slightly more staff at Band 6 or above.

Background

While cost analyses have been carried out for remote home monitoring of some conditions,[141] there is a gap in the literature regarding effectiveness, costs, resources and workforce associated with remote monitoring for COVID-19.[36] The aim of this study was to evaluate the costs of implementing remote home monitoring for COVID-19 patients during wave 2 of the pandemic (October 2020-April 2021). Costs related to setting up and running the CO@h and CVW services were identified and measured, and stratified by the mode of technology used for patients' data submission – whether tech-enabled and analogue modes were used, or analogue-only.

The research questions that this analysis addressed were:

1. What were the numbers of patients involved (triaged, monitored, deteriorated, escalated, and number of deaths) in the CO@h and CVW services for the period October 2020 – April 2021?
2. What was the composition of the workforce involved in providing these services, and did this vary between tech-enabled and analogue and analogue-only data submission modes?
3. What were the costs of setting up the CO@h and CVW services and how do these costs vary between tech-enabled and analogue and analogue-only data submission modes?
4. What were the mean costs per patient monitored when running the CO@h and CVW services, and how do these costs vary between tech-enabled and analogue and analogue-only data submission modes?
5. How much time did sites spend on activities required to run the CO@h and CVW services and how did these times vary between tech-enabled and analogue and analogue-only data submission modes?

Methods

Data collection

We gathered retrospective information using a data collection form provided to the 28 sites that was also used for the analyses in Chapters 4, 5 and 6. Designated site leads and data leads at each research site were contacted and asked to complete the form in Microsoft Word, and return it electronically to a member of the research team. During May-June 2021, we collected data for the period 1st October 2020 – 30th April 2021 (see *Chapter 2* for further information). We collected information regarding number of patients involved (triaged, monitored, deteriorated, escalated, and number of deaths), and the number of staff and resources used for setting up and running the sites (see *Project website documentation – Study instruments*).

In order to explore the differences in staff, resources, patients involved and patient outcomes further between tech-enabled and analogue versus analogue-only data submission modes, additional data were collected from four of the 28 sites. All of these four sites were using both tech-enabled and analogue data submission modes. We conducted an in-depth analysis of the time spent per patient for specific activities of the programme and calculated the cost per patient for all the activities. The data collection form for these four sites included additional questions regarding the total number of patients monitored using each data submission mode, staffing (role/band, time spent per patient on every activity) and the frequency of contacts made with patients (see *Project website documentation – Study instruments*).

Data analysis

Patient and staff numbers

Sites were asked to report the number of patients onboarded on to both services (CO@h and CVW), the number of patients whose health deteriorated and were escalated to different pathways, as well as the number of deaths reported among monitored patients (see *Chapter 2* for more detailed information). For sites running both CO@h and CVW services we have summarised the number of patients in each of these services.

We examined the numbers of staff by grade (converted into FTE numbers of staff) during the running of the programme. Staff were grouped into clinical and non-clinical groups. Clinical staff were from a range of backgrounds including medicine and nursing, and non-clinical staff had either an administrative role (e.g. any managerial role, IT assistant, etc.) or other support (e.g. drivers, technical instructors). Clinical staff were divided into three sub-groups (i.e. Bands 5 and below, Bands 6-7 and Bands 8 and above) and non-clinical staff into two sub-groups (Bands 5 and below, Bands 6 and above). In the workforce analysis, sites were stratified into four groups based on the numbers of patients onboarded: very small (200 patients or fewer), small (201-600 patients), medium (601-1000 patients) and large (1001+ patients). Due to data limitations, we assumed that the services were running for the same time period in all sites.

The number of FTE staff involved per site could be affected by other factors such as the type of service, data submission mode and the size of the site. We checked for all these factors and reported on the results of the multivariate regression analysis (we regressed the total number of FTE staff, and FTE staff in different groups, against all of these factors jointly in an ordinary least squares regression analysis).

Costs

We calculated the costs incurred for setting up and running the CO@h and CVW services, also examining the variation by data submission mode (tech-enabled and analogue vs. analogue-only). The

costs of setting up the sites were reported as mean costs per site. Running costs were calculated as mean costs per patient for the period (October 2020 – April 2021) and included: (i) staff that were involved in running the service, (ii) pulse oximeters, and (iii) other monthly expenditures related to the maintaining of the tech-enabled platforms. Staff running costs were based on the information about staff hours and band.[142] We assumed that the unit cost for staff employed at Band 3 and below was equal to that of Band 4 staff.[142] The number of pulse oximeters was based on the number of patients monitored. It was assumed that 70% of pulse oximeters would be returned and reused. This decision was based on the results from the patient and carer survey (n=1069) that showed that 69% of patients or carers had been asked to return the pulse oximeter (range: 21.5%-100% by site). The oximeters were provided by NHSEI, with the unit cost per pulse oximeter varying between £20-£25. However, 15 of the 26 sites purchased all pulse oximeters from alternative sources while 2 of the 26 sites purchased part of them.

The mean running cost per patient could be affected by factors like the type of service, data submission mode, seniority of FTE staff and total number of patients monitored. As above, to investigate the effect of all these factors on the mean running cost, we used an ordinary least square regression model.

Additional detailed information provided by the four selected sites was used to investigate the time spent on different activities per patient associated with each patient data submission mode (see *Project website documentation – Study instruments*).

We adjusted the resources used and costs incurred per patient by applying weights based on the number of patients monitored by each service (CO@h and CVW) and the total number at each site.

Measuring cost effectiveness
In the study protocol we originally planned to undertake a cost-utility analysis of remote home monitoring for COVID-19 patients.[55] In the absence of any impact on mortality or hospitalisation being demonstrated by the primary quantitative analyses (see *Chapters 5* and *6*), a cost-utility analysis was considered uninformative. We therefore focused on the programme costs alone.

Results

Twenty-six out of the 28 sites returned the data collection form, of which 13 provided CO@h services, four provided CVW services and nine both CO@h and CVW (integrated) services.

Patients onboarded and the impact on outcomes

The number of patients triaged for both CO@h and CVW services (26,126 and 1,761 respectively) was higher compared with the number of patients monitored (17,424 and 1,711). The percentage of the monitored patients over total triaged was much higher for CO@h (149.9%) if compared to CVW services (103.3%). This may be because hospitals had a less heterogenous pool of people qualifying for services and had much more prior information about them. The proportion of the patients escalated and deaths over those monitored was higher for the CO@h services compared to the CVW services (16.6% and 10.8% respectively for escalated patients and 0.9% and 0.7% respectively for the number of deaths; Table 10).

Of the 22 sites running the CO@h service, 16 used tech-enabled and analogue modes, and six used the analogue-only mode (see Supplementary file 2). Of the 13 sites running a CVW service, six used the tech-enabled and analogue data submission modes and seven the analogue-only mode. Our results show that from the total number of patients onboarded in the CO@h services 76.8% were followed up using the tech-enabled and analogue data submission mode while in the CVW services 60.8% of patients onboarded were followed up using analogue-only data submission mode.

Table 10. Patients and outcomes by programme.

Throughput and outcome	CO@h service		CVW service	
	No. of patients	% of monitored patients	No. of patients	% of monitored patients
Patients triaged	26,126	149.9%	1,761	103.0%
The average number of patients triaged per site	1,188		135	
Patients monitored	17,424	100.0%	1,711	100.0%
The average number of patients monitored per site	792		132	
Patients deteriorated and escalated	2,898	16.6%	185	10.8%
Deaths	160	0.9%	12	0.7%
Patients deteriorated and escalated	**No. of patients**	**% of deteriorated & escalated patients**	**No. of patients**	**% of deteriorated & escalated patients**
Emergency department	2,240	77.3%	135	73.0%
Admitted to the hospital	1,257	43.4%	161	87.2%
ICU	403	13.9%	7	3.5%
Primary care	1,806	62.3%	73	39.4%

Source: Based on data provided by each site.
Notes: Since some of the patients were not eligible for remote monitoring, the number of patients triaged was higher than the number of patients monitored.

The structure of the workforce involved in providing CO@h and CVW services

The total number of FTE staff involved in running the CO@h service was on average 7.4 per site [range: 1.0 – 39.0] and for the CVW service this was 2.1 per site [range: 0.1 – 4.8]. Staff involved were a mix of medical consultants, ED staff, GPs, nurses, advance nurse practitioners (ANPs) and medical students. Our analysis of the staff employed in running the services showed that there were no clear patterns in the differences in terms of clinical/non-clinical staff or seniority of the staff involved between CO@h and CVW services.

Table 11 provides the mean number of FTE staff by role and band, stratified by type of service and size of site (see *Supplementary file 2* for the total number of FTE staff involved). For both CO@h and CVW services, most of the staff involved in monitoring the patients were clinical (68.4% for CO@h service and 86.7% for CVW service).

Table 11 also shows that for all sites running CO@h services, 53.0% of staff were employed at Band 5 or below (27.1% non-clinical and 25.9% clinical staff). Sites using tech-enabled and analogue modes had a higher proportion of non-clinical staff at Band 5 or below (33.1% non-clinical and 18.6% clinical staff) compared to analogue-only mode (16.8% non-clinical and 38.5% clinical staff).

Across all sites running the CVW services, 51.3% of all staff (50.4% clinical and 0.9% non-clinical) involved were employed at Band 6 and above. A similar trend was observed for the sites using analogue-only mode where 54.1% of all staff involved (53.6% clinical and 0.5% non-clinical) were employed at Band 6 and above whereas for the tech-enabled and analogue mode most staff involved (51.6%; 34.1% clinical and 17.5% non-clinical) were at Band 5 and below.

Our analysis of the effect of other factors (i.e. type of services, data submission mode and size of the site) on the number of FTE staff involved revealed that, as expected, a key determinant was the size

of sites. Note that these findings should be considered with caution due to the small sample size (N=35 sites) (see *Supplementary file 6*).

Table 11. The proportion of clinical and non-clinical staff involved in monitoring patients.

Type of site (by no. patients)	Number of sites*	Mean number of staff (FTE equivalent)	Non-clinical staff (FTE equivalent)			Clinical staff (FTE equivalent)			
			Mean number of non-clinical staff (%)	Mean number of Band 6+ (as % over the total)	Mean number of Band 5 & below (as % over the total)	Mean number of clinical staff (%)	Mean number of Band 8+ (as % over the total	Mean number of Band 6-7 (as % over the total)	Mean number of Band 5 & below (as % over the total)
CO@h service									
The total sample									
Very small sites (0-200 patients)	3	3.7	1.1 (28.7%)	0.6 (16.6%)	0.4 (12.0%)	2.6 (71.3%)	0.1 (2.5%)	0.9 (24.9%)	1.6 (43.9%)
Small sites (201 – 600 patients)	6	4.2	1.3 (31.6%)	0.2 (4.3%)	1.1 (27.3%)	2.8 (68.4%)	1.3 (6.4%)	1.1 (26.3%)	0.4 (10.2%)
Medium sites (601 – 1000 patients)	5	9.7	3.8 (39.1%)	0.6 (5.7%)	3.2 (33.4%)	5.9 (60.9%)	0.6 (5.9%)	2.9 (29.3%)	2.5 (25.7%)
Large sites (1001+ patients)	8	9.8	2.7 (27.4%)	0.2 (2.2%)	2.5 (25.2%)	7.1 (72.6%)	1.1 (22.7%)	3.3 (33.3%)	2.8 (28.6%)
Total sample	**22**	**7.4**	**2.3 (31.6%)**	**0.3 (4.5%)**	**2.0 (27.1%)**	**5.1 (68.4%)**	**0.9 (11.3%)**	**2.3 (30.5%)**	**1.9 (25.9%)**
Tech-enabled and analogue									
Very small sites (0-200 patients)	3	3.7	1.1 (28.7%)	0.6 (16.6%)	0.4 (12.0%)	2.6 (71.3%)	0.1 (2.5%)	0.9 (24.9%)	1.6 (43.9%)
Small sites (201 – 600 patients)	2	4.0	2.8 (69.3%)	0.1 (2.2%)	2.7 (67.1%)	1.2 (30.7%)	0.3 (6.4%)	1.0 (24.3%)	0.0 (0.0%)
Medium sites (601 – 1000 patients)	5	9.7	3.8 (39.1%)	0.6 (5.7%)	3.2 (33.4%)	5.9 (60.9%)	0.6 (5.9%)	2.9 (29.3%)	2.5 (25.7%)
Large sites (1001+ patients)	6	5.9	2.0 (34.7%)	0.2 (3.2%)	1.9 (31.5%)	3.9 (65.3%)	1.3 (22.7%)	2.2 (37.4%)	0.3 (5.3%)
Total Tech-enabled and analogue	**16**	**6.4**	**2.5 (38.8%)**	**0.4 (5.7%)**	**2.1 (33.1%)**	**3.9 (61.2%)**	**0.7 (11.3%)**	**2.0 (31.2%)**	**1.2 (18.6%)**
Analogue-only									
Small sites (201 – 600 patients)	4	4.2	0.6 (13.8%)	0.2 (5.3%)	0.4 (8.5%)	3.7 (86.2%)	1.9 (43.9%)	1.2 (27.2%)	0.6 (15.1%)
Large sites (1001+ patients)	2	21.6	4.6 (21.4%)	0.3 (1.4%)	4.3 (20.1%)	17.0 (78.6%)	0.2 (1.0%)	6.5 (30.0%)	10.3 (47.7%)
Total Analogue-only	**6**	**10.0**	**1.9 (19.3%)**	**0.2 (2.5%)**	**1.7 (16.8%)**	**8.1 (80.7%)**	**1.3 (13.1%)**	**2.9 (29.2%)**	**3.9 (38.5%)**
CVW service									
The total sample									
Very small sites (0-200 patients)	11	1.8	0.2 (11.5%)	0.02 (1.3%)	0.2 (10.2%)	1.6 (88.5%)	0.2 (10.4%)	0.5 (28.4%)	0.9 (49.7%)
Small sites (201 – 600 patients)	2	3.7	0.7 (18.1%)	0.0 (0.0%)	0.7 (18.1%)	3.0 (81.9%)	0.1 (2.9%)	2.9 (79.0%)	0.0 (0.0%)
Total sample	**13**	**2.1**	**0.3 (13.3%)**	**0.02 (0.9%)**	**0.3 (12.3%)**	**1.8 (86.7%)**	**0.2 (8.4%)**	**0.9 (42.0%)**	**0.8 (36.3%)**
Tech-enabled and analogue									
Very small sites (0-200 patients)	5	1.9	0.2 (12.7%)	0.04 (2.0%)	0.2 (10.7%)	1.6 (87.3%)	0.1 (4.5%)	0.6 (34.0%)	0.9 (48.8%)
Small sites (201 – 600 patients)	1	4.0	1.3 (33.2%)	0.0 (0.0%)	1.3 (33.2%)	2.7 (66.8%)	0.2 (5.3%)	2.5 (61.5%)	0.0 (0.0%)
Total Tech-enabled and analogue	**6**	**2.2**	**0.4 (18.9%)**	**0.03 (1.4%)**	**0.4 (17.5%)**	**1.8 (81.1%)**	**0.1 (4.7%)**	**0.9 (42.3%)**	**0.8 (34.1%)**
Analogue-only									
Very small sites (0-200 patients)	6	1.8	0.2 (10.4%)	0.01 (0.6%)	0.2 (9.8%)	1.6 (89.6%)	0.3 (15.5%)	0.4 (23.5%)	0.9 (50.6%)
Small sites (201 – 600 patients)	1	3.4	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	3.4 (100.0%)	0.0 (0.0%)	3.4 (100.0%)	0.0 (0.0%)
Total Analogue-only	**7**	**2.0**	**0.2 (7.9%)**	**0.01 (0.5%)**	**0.1 (7.4%)**	**1.9 (92.1%)**	**0.2 (11.8%)**	**0.8 (41.8%)**	**0.8x (38.5%)**

Source: Based on data provided by each site. Note: *) Please note that nine sites used both CO@h and CVW services and therefore they appear in both services.

The costs of setting-up and running the sites

Table 12 presents detailed information on the mean running cost per patient triaged and monitored over the study period for both CO@h and CVW services (see *Supplementary file 6)*. These data show that most funds during the setting-up phase were spent on non-staff items (e.g. the technology platform, medical and other equipment). Our analysis of running costs showed that the mean cost per patient monitored using the CO@h service was lower compared with the CVW service (£527.5 vs. £599.1). The mean cost per patient monitored was lower for sites using tech-enabled and analogue compared with the sites using analogue-only data submission mode for both CO@h (£515 vs. £561) and CVW (£584 vs. £612) services.

Table 12. Mean cost per patient of CO@h and CVW services.

| | Total Covid Care @home | | | | | |
| | CO@h service | | | CVW service | | |
	Mean cost per patient	10th percentile	90th percentile	Mean cost per patient	10th percentile	90th percentile
Cost per patient triaged	£351.8 (£73.7)	£67.6	£512.2	£581.8 (£139.9)	£74.4	£1,366.8
Cost per patient monitored	£527.5 (£110.5)	£101.4	£768.0	£599.1 (£144.0)	£76.6	£1,407.4
Tech-enabled and analogue mode						
Cost per patient triaged	£343.4 (£83.8)	£78.8	£464.1	£567.0 (£208.1)	£129.0	£1,152.5
Cost per patient monitored	£514.9 (£125.6)	£118.2	£695.8	£583.9 (£214.3)	£132.8	£1,186.8
Analogue-only mode						
Cost per patient triaged	£374.1 (£165.2)	£68.9	£821.1	£594.5 (£204.1)	£130.1	£1,220.9
Cost per patient monitored	£560.9 (£247.8)	£103.2	£1,231.1	£612.1 (£210.2)	£134.0	£1,257.1

Source: Based on data provided by each site.
Note: Standard errors in brackets.

The regression analysis of the effect of factors (i.e. type of services, data submission mode, seniority of FTE staff and the number of the patients monitored) on the mean running cost per patient revealed that, as expected, a key determinant was the number of patients monitored. Another significant factor was the type of service (i.e. CO@h or CVW). Even though the type of the data submission mode and the FTE difference between the senior and junior staff involved were not statistically significant predictors of mean running costs per patient, the direction of their effect was consistent with the descriptive findings. Note that these findings should be considered with caution due to the small sample size (N=35 sites) (see *Supplementary file 6*).

We investigated whether the mean running costs per patient at each site were associated with the total number of patients monitored. *Figure 24* and Figure 25 show a positive relationship (slope coefficient for the CO@h service 0.54 (95% CI 0.19 - 0.89), and for CVW service 2.10 (95% CI 0.16 - 4.03)) between the number of patients monitored and the mean running cost per patient for the CO@h and CVW services, respectively. This suggests that running costs increase as the number of patients monitored increases. However, this finding should be treated with caution for several reasons. First, the number of sites involved in this analysis is small. Second, as evidenced by the two Figures, there are outlying sites in terms of mean costs and number of patients monitored. Third, the Figures are based on running costs only; if set-up costs were included these would fall as the number of

patients monitored increased. Fourth, we do not have data on the maximum patient capacity of sites on which total running costs would be based.

CO@home service
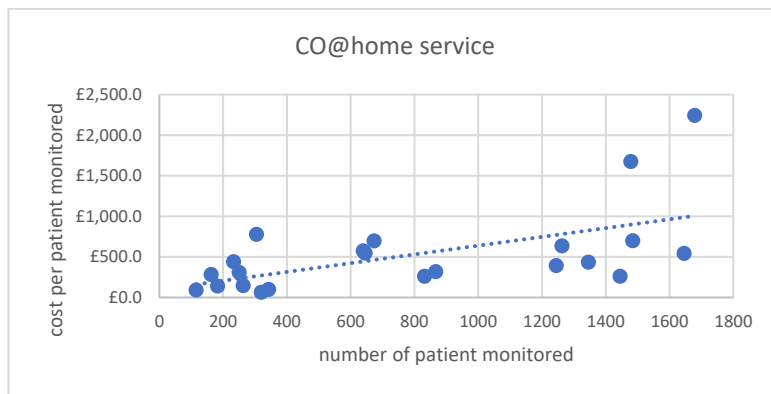
Source: Based on data provided by each site. Twenty-two sites used CO@h services.

Figure 24. The mean cost per patient for CO@h services.

Virtual Wards service
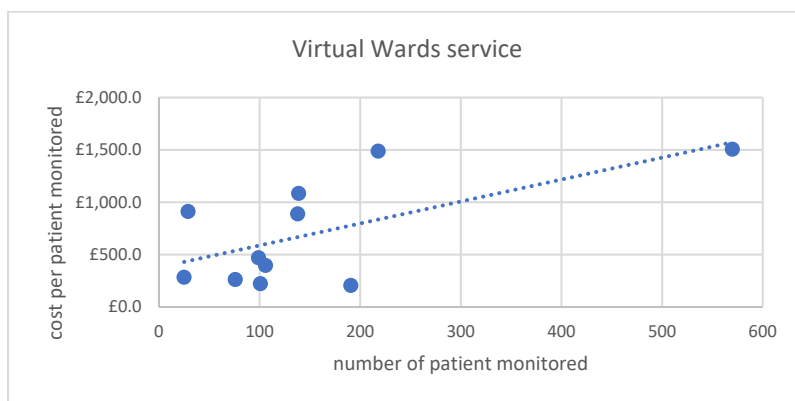
Source: Based on data provided by each site. Thirteen sites used CVW services.

Figure 25. The mean cost per patient for CVW services.

Time spent on monitoring activities

This part of the analysis used data that were available only from the four sites where we undertook a more detailed investigation of the monitoring activities. All four sites used tech-enabled and analogue and analogue-only data submission modes. The total number of patients monitored at these four sites were 3,366, of which 2,824 were monitored using tech-enabled and analogue mode and 542 were monitored using analogue-only mode (see *Supplementary file 2*).

The most time-consuming activity was patient's monitoring, and on average less staff time was spent on this under tech-enabled and analogue mode compared to analogue-only (68.0 minutes vs. 72.5 minutes respectively; note that this activity by staff might be removed in the case of self-monitoring by patients). Based on time spent and staff working on each activity (see Supplementary file 6), we

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calculated the average cost of each activity per patient, for the tech-enabled and analogue and analogue-only modes (£115.1 vs. £98.3, respectively; if the patient monitoring costs were removed, as might be the case in a self-monitoring service with no monitoring by staff, and assuming all other staff inputs/costs remained constant, these costs would fall to £80.0 and £60.8, respectively) (see *Supplementary file 6*). Please note that due to the amount of missing data, these findings should be viewed with caution.

These four sites reported on average 8.7 contacts per patient using tech-enabled and analogue mode throughout the time they were in the CO@h service, and 15.5 contacts per patient using the analogue-only option.

Discussion

Key findings

Twenty six out of the 28 sites contacted provided information for this analysis out of which 13 provided the CO@h service, four provided the CVW service and nine provided both services. In total 17 sites used tech-enabled and analogue and nine analogue-only data submission modes. The mean running cost per patient monitored under the CO@h service was lower compared with CVW service. The main driver of the cost per patient was the number of FTE staff and the grade of staff involved, and this was regardless of the type of service adopted. A comparison with findings from wave 1 (March – August 2020) [36] showed that the mean cost per patient monitored remained fairly constant from wave 1 to wave 2 for the CO@h service (£553 vs. £527) and increased from wave 1 to wave 2 for the CVW service (£400 vs. £598).

The mean costs per patient in the sites using tech-enabled and analogue were lower compared to analogue-only sites, mainly due to shorter time needed to collect patient medical information. However, as other studies have shown, the potential for technology to save costs must be treated with caution unless the digital assessments are shorter in time and they are proven to decrease follow-up and deterioration of symptoms, thus leading to lower commitment of staff time for overall service delivery. [143, 144]

Comparison with other studies

Previous studies have found that remote patient monitoring for conditions other than COVID-19 was associated with improved clinical outcomes and medication compliance and reduced the number of emergency room visits, hospital admissions and patient travel. [145-147] A comparison with data from wave 1 (March – August 2020) [36] showed that escalated patient rates for the period October 2020 – April 2021 was higher for the CO@h service (16.6% vs. 10.0%). Whereas for the CVW service the escalated patients' rates were slightly higher for wave 2 in comparison with March – August 2020 period (10.8% vs. 12.2%). The mortality rates for the period October 2020 – April 2021 were 0.9% for the CO@h and 0.7% for the CVW, slightly lower than the rates previously reported for the period March – August 2020 (1.1% and 0.9%, respectively). [36]

A previous systematic review found that there was no evidence showing that telemedicine and telecare interventions can be cost-effective compared to conventional healthcare. [148] However, it has been also highlighted that cost-effectiveness analysis of remote monitoring of patients for different diseases is often integrated into other home healthcare services making it challenging to isolate and allocate its cost appropriately. [148] The evidence on resources used and costs of remote home monitoring for COVID-19 patients specifically is also very limited. Our previous literature review on similar interventions revealed that very few studies have conducted an economic analysis and in most cases this is limited to describing costs incurred and resources used. [32] In general, previous studies have

stated that similar interventions may be cost-saving by reducing downstream costs (in terms of avoiding hospital admissions and bed days).[31] Our findings are consistent with a recent Australian study where staffing costs were the main contributors to the total costs of monitoring.[149] In other healthcare contexts, the use of telehealth for the provision of healthcare has previously shown to be associated with cost savings, especially in reaching remote areas.[150] However, any potential cost saving of technology relies on the assumption that digital assessment is shorter in time and decreases follow-up contacts and deterioration of symptoms, which may result in new admissions to hospital. Caution is warranted as such assumptions may not always hold.[143]

Strengths and weaknesses

The main strength of this analysis is that we achieved good geographical coverage of sites across England (see *Chapter 4*), obtained primary data on CO@h and CVW services use and distinguished between the tech-enabled and analogue versus analogue-only data submission modes. Additionally, this study fills a literature gap regarding COVID-related remote monitoring services, since it is the first to provide this level of detail about costs, workforce and activities.

There are several weaknesses with this study. First, we were not able to perform a full economic analysis (i.e. cost-utility analysis) as the effectiveness analysis found no evidence of the CO@h service on mortality or downstream hospital utilisation (see *Chapters 5* and *6*). Second, the study design did not allow the use of patient-level data, which means we were unable to examine patient-level variation in service costs. Third, cost- and resource-use data provided by some sites were incomplete. For this reason, the in-depth analysis using the four sites was very limited and the results should be treated with caution. Fourth, the selection of the four sites used for the in-depth analysis was based on purposive and convenience sampling, and this may insert selection bias. Fifth, there was wide variation in service models across sites and much variation in how services were designed and delivered (see *Chapter 4*). Sixth, the generalisation of our findings to all COVID-19 patients is difficult as pre-existing conditions and level of severity were not taken into consideration. Seventh, the limited number of sites which have been used for this analysis does not allow further grouping in terms of their size, considering both the number of patients and the length of time establishing this programme. Finally, any interpretation of results should be taken with caution as we do not have the information on the maximum capacity of the sites and can only observe the current flow of patients. For sites with a higher planned capacity the underutilisation of resources will mean that the cost per patient may go down with the increase in number of patients.

Implications

Our analysis showed a lower cost of remote monitoring per COVID-19 patient during wave 2 of the pandemic in the UK. Our results indicated that the tech-enabled and analogue monitoring was less costly, in terms of mean cost per patient, than analogue-only monitoring. It offers a model for future research in the way it covers a range in the size of sites and raises questions about differential practices within the overall envelope of remote monitoring – differences that are necessarily present in any geographically diverse and large-scale health system.

Future interventions on remote monitoring for other health conditions need to consider their impact on primary and secondary care. Such services may differ in costs, band of the staff involved and worked hours based on the health sector of primary impact. Consideration of the differences between the CO@h and CVW services should also be considered given the different pool of patients they serve and the level of information the staff have on them. Future studies should also gather information on total capacity and how this relates to costs – given the fixed costs in delivering services this may provide a better view on actual costs and also possibly help future planning. Future research, including

more sites, may provide additional evidence and shed light on the areas where the availability of this study's data was poor. Availability of routine data on health outcomes (instead of having to use site questionnaires) would also facilitate future research. Overall, there is pressing scope for seeing remote monitoring within a more holistic view of patients' and staff experiences.

Chapter 8. Staff experiences of delivering COVID-19 remote home monitoring services

Overview
This chapter draws on a manuscript by Sidhu *et al.* [151] currently under review by *Journal of Health Services Research & Policy.*

What was already known
- Remote home monitoring may have some benefits for patients, healthcare systems and staff (for example, flexibility/independence/fast access to clinicians).
- Some challenges and concerns with remote home monitoring have been highlighted (e.g. lack of supportive infrastructure within NHS organisations to facilitate successful implementation and delivery, staff training, treating patients living with a range of long term conditions which may include physical and/or cognitive impairment).
- However, there is a paucity of evidence on staff experiences and the factors influencing delivery of COVID-19 remote home monitoring services.

What this chapter adds
- Delivery of remote home monitoring services for COVID-19 involved delivery of either technology-enabled and analogue services, or analogue-only services. Staff were involved in a range of tasks including monitoring, escalation, and service evaluation.
- Staff generally reported positive experiences of delivering the service, felt that it was easy to deliver and valued support, but staff would have benefitted from further training.
- Factors influencing delivery of remote home monitoring services for COVID-19 included: support for delivering the service, NHS resources and capacity on staff workload, multidisciplinary team dynamics, and patient (dis)engagement.

Introduction
The impact of remote home monitoring services on NHS staff or staff experiences is not yet known.[152-155 36] Delivering remote home monitoring services may affect job satisfaction for staff,[156, 157] i.e. if staff are reluctant to deliver remote services full-time, due to valuing face-to-face interactions with patients [11, 157, 158] and concerns over 'call-centre medicine'.[158] Previous research has indicated that many staff acknowledge benefits of remote home monitoring, including flexibility and independence for staff, fast access to clinicians for patients living with chronic (e.g. respiratory and heart failure) and acute (e.g. COVID-19) conditions,[159, 160] and improved continuity of care and communication of risks between staff and patients.[161] Despite these putative benefits, clinicians have expressed concerns that some patient characteristics, including physical and cognitive impairments, may present challenges for remote home monitoring services.[161] Additionally, staff report concerns about lack of training and the exclusion of some service user groups if alternatives to remote care are not provided.[162, 163]

Despite previous research on remote home monitoring models for other conditions, there is a paucity of evidence on staff experiences of delivering care as part of remote home monitoring services. A range of individual, organisational and environmental factors have been previously proposed to influence healthcare professional behaviours,[164] but the factors (barriers and facilitators) influencing delivery of COVID-19 remote home monitoring services are not yet known.

This study explored staff experience of delivering COVID-19 remote home monitoring services. The study reported in this chapter aimed to answer the following questions:

1. What was the nature of 'work' staff undertake to manage patients with COVID-19?
2. How were staff supported to deliver remote home monitoring services?
3. What factors (barriers and facilitators) influenced delivery of COVID-19 remote monitoring services?

Methods

A summary of the methods is provided below; further details can be found in *Chapter 2* and *Supplementary file 1*.

Design

This chapter draws on data from workstream 3 (staff survey data) and workstream 4 (staff interviews). Data collection for this study took place between February and June 2021.

Sample

Staff who led and/or delivered COVID-19 remote home monitoring services (see *Chapter 2* and *Chapter 4* for site and staff sample details).

Measures

We iteratively developed the survey and semi-structured topic guides specifically for this study (see *Chapter 2, Project website documentation – Study instruments*).

Procedure

We conducted a survey with staff from 28 sites, and interviews with staff from 17 sites (see *Chapter 2* for details).

Analysis

Inductive thematic analysis was used to analyse interview data inputted into RAP sheets.[70] Additionally, a sub-set of transcripts (n=17) were independently thematically coded to validate interpretations from the analysis of RAP sheets.

Survey data were analysed on a complete case basis (excluding participants with missing data) using descriptive statistics (using SPSS, version 25). Open text responses were coded using inductive thematic analysis.

Interview and survey findings were triangulated to compare consistency of findings relating to research questions.[71, 72]

Results

Participant characteristics

Two hundred and ninety-two surveys were received from NHS staff (70 clinical leads/service managers, 222 delivery staff) and 58 interviews were conducted with staff (23 clinical leads, 28 delivery staff, seven data staff) (see *Chapter 4* and *Supplementary file 2* for demographic characteristics).

Findings

The nature of 'work' staff undertake to manage patients with COVID-19 remotely

Staff were involved in remote monitoring services delivered in one of two ways: technology-enabled with analogue services (21/28 sites), and analogue-only services (7/28 sites) (see *Chapter 4* for further details).

Daily, staff would assess the nature of referrals made to the service, monitor data uploaded by patients regarding oxygen saturation, temperature, or breathlessness (as a minimum), and if necessary, determine whether data warranted escalation in patient care (phone call to the patient, sending paramedics to the patient, directing patients to seek emergency acute secondary care).

Staff survey responders reported a range of work-related tasks they had been involved with when delivering their respective services (Table 13). The more frequently cited tasks included monitoring activities (80%) and escalation processes (70%).

Table 13. Number of service managers/clinical leads and delivery staff who reported being involved in different remote home monitoring tasks.

		Service managers/clinical leads (n=70)	Delivery staff (n=222)	Total (n=292)
Aspect of the service involved with n (%)	Development and/or piloting of the service	50 (71)	40 (18)	90 (31)
	Set-up and design	53 (76)	22 (10)	75 (26)
	Service management	54 (77)	32 (14)	86 (30)
	Referring patients	30 (43)	58 (26)	88 (30)
	Triaging patients	29 (41)	112 (51)	141 (48)
	Monitoring	35 (50)	199 (90)	234 (80)
	Escalation	43 (61)	162 (73)	205 (70)
	Discharge	34 (49)	156 (70)	190 (65)
	Monitoring/evaluating the service	50 (71)	61 (28)	111 38)
	Other tasks (e.g. delivering equipment)	3 (4)	15 (7)	18 (6)

The majority of clinical leads and delivery staff felt services they provided had a positive or very positive impact (47%, n=127/266) or neutral impact (32%, n=85/266) on their workload. However, delivery staff and service leads also reported that services increased their workload (21%, n=54/266).

Support and training provided to staff to deliver remote home monitoring services
Service leads reported being supported in many ways by NHSEI and other organisations. For example: obtaining pulse oximeters (54%) and receiving guidance for implementation (43%). Delivery staff (88%) reported that they were adequately supported in their role (Table 14).

Table 14. Summary of staff experiences of delivering COVID-19 remote home monitoring services.

Findings from staff survey		Responses	n (%)
Support in delivering the service	Staff adequately supported in their role (n=221)*	Yes	195 (88%)
		No	9 (4%)
		Not sure	17 (8%)
	Support provided by NHSEI (or other organisations) (n=70)**	Obtaining pulse oximeters	38 (54%)
		Guidance for implementation	30 (43%)
		Setting up and using systems for recording data	18 (26%)
		Training for staff	11 (16%)
		Distributing pulse oximeters	10 (14%)
		Training for patients	5 (7%)
		Other	2 (3%)
Staff reported experience of service	Confidence in carrying out daily responsibilities (n=222)*	Very confident or confident	204 (92%)
		Neutral	15 (7%)
		Not very confident	3 (1%)
	Staff clear about the requirements of their role (n=221)*	Yes	202 (91%)
		No	11 (5%)
		Not sure	8 (4%)
Staff reported experience of tasks*	Remote monitoring of patients (n=201)	Very easy or easy	146 (73%)
		Neutral	47 (23%)
		Difficult or very difficult	8 (5%)
	Escalation processes (n=202)	Very easy or easy	144 (71%)
		Neutral	42 (21%)
		Difficult or very difficult	16 (8%)
	Using IT systems (n=217)	Very easy or easy	144 (66%)
		Neutral	56 (26%)
		Difficult or very difficult	17 (8%)
	Working with other COVID-related services (n=179)	Very easy or easy	97 (54%)
		Neutral	73 (41%)
		Difficult or very difficult	9 (6%)
	Triage processes (n=181)	Very easy or easy	114 (63%)
		Neutral	57 (32%)
		Difficult or very difficult	10 (6%)
Impact of service on workload, job satisfaction and work-related stress	Impact on workload (n=266)	Very positive or positive	127 (47%)
		Neutral	85 (32%)
		Negative or very negative	54 (21%)
	Impact on job satisfaction (n=288)	Very positive or positive	216 (75%)
		Neutral	63 (22%)
		Negative or very negative	9 (3%)
	Impact on work-related stress	Very positive or positive	60 (22%)
		Neutral	152 (57%)
		Negative or very negative	55 (20%)

*Delivery staff only (i.e. responses do not include clinical leads or service managers).

**Service leads or managers only (i.e. responses do not include delivery staff).

In terms of training, 68% (n=200/292) of staff survey respondents (managers/leads and delivery staff) reported having received training or training resources as part of their role. However, the amount and nature of training received was difficult to determine. Delivery staff lacked knowledge of and familiarity with the NHS CO@h competency framework (which sets guidelines for staff training to deliver both services and undertake patient assessment); only 9.5% (n=21/220) reported having completed the framework and 35.5% (n=78/220) were unsure. See *Supplementary file 7* for a training and support summary.

Forty-one per cent (n=28/69) of clinical leads/service managers and 12% (n=26/222) of delivery staff reported that they had further training or support needs (beyond that already received) (See Table 15).

Table 15. Summary of additional training needs reported by staff.

Additional training need	Service managers or clinical leads n (%)		Delivery staff n (%)	
	Clinical role (n=19)	Non-clinical role (n=12)	Clinical role (n=21)	Non-clinical role (n=5)
Clinical pathways	17 (89.5%)	11 (91.6%)	15 (71.4%)	3 (60%)
Processes for triage	12 (63.2%)	7 (58.3%)	7 (33.3%)	0 (0%)
Processes to monitor patients	13 (68.4%)	10 (83.3%)	4 (19%)	0 (0%)
Processes to escalate patients	15 (78.9%)	9 (75%)	8 (38%)	1 (20%)
The IT systems being used	15 (78.9%)	9 (75%)	7 (33.3%)	0 (0%)
Training on conflict resolution	-	-	4 (19%)	0 (0%)
Other	2 (10.5%)	0 (0%)	2 (9.5%) All mentioned ongoing support	1 (20%)

Interview findings highlighted that clinical delivery staff, particularly nurses, raised concerns that training led by senior clinicians largely took the form of shadowing and/or receiving brief overviews on each part of the service. As a result, initially many nurses felt a lack of confidence, especially when communicating risks associated with COVID-19, and remained dependent on senior clinicians. This dependency subsided as their experience grew. During this period, nurses welcomed those senior clinicians who were readily accessible:

> *"[…] you don't need to know everything. You're not a doctor. You just need to get all the information and you can always get a doctor to give them a call. […].So, don't panic. Just, yes, reassure them and if you're unsure, just get a doctor to give them a call." (Site L, interviewee 1 – Healthcare professional delivering the service)*

Factors influencing delivery of COVID-19 remote home monitoring services

Staff knowledge and confidence

Delivery staff reported feeling confident or very confident in their ability to carry out their responsibilities (92%, n=204/222) and were clear about the requirements of their role (91%, n=202/221). Delivery staff reported few difficulties completing tasks as part of delivering services and most staff reported these tasks to be easy or very easy (range between 54% and 73% across tasks).

The most challenging tasks seemed to be using IT systems and working with other COVID-related services – with lower numbers of staff reporting these tasks as easy (see *Table 14*).

Although the survey data indicated that staff felt satisfied with the support and training received as well as confident delivering the service, not all felt this way. Staff reported that the need to develop new knowledge, skills and confidence with regard to engaging with online monitoring platforms and undertaking clinical assessments via telephone, early on in the implementation of these services was a barrier to delivery, as training was not always embedded in a timely way during service implementation. A significant minority of nursing staff felt unsupported and distressed at having to work on a remote home monitoring service. At one site, staff initially "hated [the service] with a passion" with some staff finding the accountability of assessing patient risk remotely and then determining appropriate treatment too stressful and threatened to leave their roles unless changes were made to their training e.g. increasing the number of hours of training, who was providing training, and greater shadowing when staff first deliver the service. Nursing staff, at times felt 'at risk' of potentially making mistakes in relation to monitoring and decisions about potential escalation in the rapid scale-up of services. Often staff were relying on their previous experiences of working with SOPs (in general practice and secondary care) and were unfamiliar with newly established practices when delivering care remotely and hence transitioning to a new remote workplace culture with risk assessment, interpretation, and potential escalation of patient care at its centre was difficult. However, there were a number of exceptions:

> "Working in A&E I can see some really acutely unwell patients and we use kind of an A to E approach where it's kind of a system that we look at looking at airway, breathing, circulation, etc. And then, say, when I'm speaking to a person on the phone, what we are concerned about is the breathing and things, so you're kind of able to transfer that knowledge." **(Site K, interviewee 3 – Healthcare professional delivering the service)**

Influences on staff workload

Members of staff felt their workload was increased more than initially expected (See *Table 15*) as they were often dealing with wider determinants of ill health that were having a substantial impact on patients' well-being. For example, given the nature of COVID-19, staff were supporting some patients who had lost employment, were taking care of others diagnosed with COVID-19, or who also had mental health problems.

Whilst the majority of clinical leads/service managers felt there were enough staff and sufficient capacity to deliver services as intended, delivery staff reported having to balance their role within these services with other roles (Table 16). Redeployment of staff facilitated capacity to deliver services and scale-up when needed, as these staff were often working solely on remote home monitoring services.

Table 16. Number of service managers/clinical leads and delivery staff reporting sharing COVID-19 remote home monitoring role with other roles.

		Service managers/clinical leads (n=70)	Delivery staff (n=222)	Total (n=292)
Sharing COVID remote monitoring role with any other role(s) n (%)	Yes	52 (74)	137 (62)	189 (65)
	No	13 (19)	78 (35)	91 (31)
	Not applicable	5 (7)	7 (3)	12 (4)

Both clinical leads and delivery staff expressed concern that redeployed staff members would not be available during future surges in patient cases.

> *"We delivered on existing staffing. So it was mainly done via bank. We did have bank admin and bank drivers for deliveries and collections.[..] But it was done on existing staffing. So the staff that we already had stepped up, took on extra shifts, it was all done on bank and goodwill."* **(Site F, interviewee 4, Healthcare professional delivering the service)**

Staff reported having discussions within their team regarding which technology-enabled platforms should be used (N=4) and could be easily integrated with existing patient record systems. For example, staff welcomed apps and/or online platforms that could be integrated with existing familiar primary care patient record systems. Technology which could not be integrated meant greater time taken by staff to upload patient data on to multiple databases, which was resource intensive, cumbersome, and increased the risk for potential mistakes. In other sites (N=3), staff did not feel included in decisions on which apps and/or online platforms would be deployed for remote monitoring. The use of these platforms felt imposed and limited early engagement with the technology:

> *"And my honest personal view was at the time I felt like we had a clever little app that we were trying to fit a service for, that was my personal view. And so, I took a little bit of convincing…"* **(Site I, interviewee 2, Service lead)**

Multidisciplinary team dynamics

Where sites adopted a multidisciplinary team model of working, there were at times tensions between professional groups, especially where there was historically a lack of co-working between the groups. This remained problematic until services were more established and roles became more distinguished (e.g. GPs understanding that remote home monitoring services were not replacing their duty to continue doing home visits during the pandemic).

A key facilitator was determining the correct mix of staff that needed to be involved in the delivery of the service. Of the staff survey respondents, 71% (n=206/292) reported their role within services to be clinical, 29% (n=86/292) non-clinical, and 2% (n=5/292) were students/volunteers. In a small number of sites, only clinical staff were involved in monitoring patients, whereas most sites involved a mix of both clinical and administrative staff. Volunteers were also used at two sites to support the administrative duties associated with setting up services.

Implementation was facilitated by good communication between members of the clinical team. Service leads tried to identify staff with the necessary communication skills to undertake remote monitoring consultations via telephone, such as active listening, and picking up cues regarding a patient's current condition without physical examination. Delivery team members, in turn, wanted to make service managers aware that they needed flexibility regarding how each call was made as staff wanted to be able to provide patients with emotional support as well, which, at times meant longer phone calls.

> *"You spend a lot of your time actually reassuring patients that they're doing all right. They're frightened. They're very frightened. And they always know somebody that's been in hospital and has had a really bad experience."* **(Site I, interviewee 4, Healthcare professional delivering the service)**

Staff experiences of patent engagement or disengagement

All staff felt that delivery of remote home monitoring services was facilitated by patients engaging with services and having confidence as well as sufficient digital literacy to send their measurements and readings. Survey staff reported high levels of patient engagement with their service (96%, n=209/219). Delivery staff generally reported that service users experienced few difficulties in using the oximeter to take readings (91% well/very well: n=193/212) and providing readings over the phone (91% well/very well: n=186/205). However, providing readings via an app was reported to have more difficulties (78% well/very well: n=134/172). Staff felt that those patients who were living with a long-term respiratory condition (e.g. COPD) were more comfortable dealing with episodes of breathlessness and therefore were less in need of the advice and exercises provided by nurses for managing COVID symptoms.

Staff also identified specific groups which they felt required more support and found it more difficult to engage (e.g. those who were older, had health difficulties, and lacked sufficient digital literacy), and other groups who were more likely to disengage with services (e.g. younger patients, those who had returned to work following self-isolation, or those with few acute symptoms associated with COVID-19). Often, asking next of kin or family members to provide readings helped maintain engagement which also facilitated effective delivery of the service. In addition, delivery staff felt some patients preferred to provide oximetry readings with the support of a member of the remote home monitoring team over the telephone. There were a number of barriers to delivering remote home monitoring services relating to patient engagement (e.g. having to chase patients who did not submit readings, patients not answering the phone, delays in provision of oximeters or other equipment and patients receiving too little written or oral information).

Discussion

Key findings

Staff were involved in flexibly delivering a range of technology-enabled and analogue remote monitoring models for COVID-19. Staff generally reported positive experiences of delivering the service, felt that it was easy to deliver and valued support. A range of training and support opportunities were provided but staff would have benefitted from further training especially when undertaking clinical assessments remotely, determining how best to escalate care of patients whose condition may be deteriorating from COVID-19, and how best to provide follow up care. Findings also indicated different factors which influenced delivery of remote home monitoring models, including appropriate support and training, staff knowledge and confidence, capacity and workload, multidisciplinary team dynamics, and patient engagement or disengagement.

How findings relate to previous research

Given the rapid transition to using remote home monitoring models and technology to support people living with COVID-19 and long-term health conditions, our findings extend literature on the training needs and experiences of staff asked to use such methods within a wider context of workforce challenges across primary and secondary care.[155] Staff were generally comfortable pivoting away from their usual frontline services during the pandemic; however, the impact on how staff managed this transition varied with some feeling an additional burden while others welcomed greater responsibility and the opportunity to support the NHS's response to the pandemic. For some delivery staff, remote home monitoring brought new challenges especially when completing consultations over the telephone compared to face-to-face. In some cases, such a change led staff to reconsider their professional role, beliefs, as well as capabilities when treating patients. Similar learning has been found in previous reviews, citing nursing staff in particular as being concerned about the impact of digitally-enhanced modes of working on the staff-patient relationship.[165] However, patient experience findings indicated that the staff-patient relationship was not jeopardised by remote monitoring (see

Chapter 9 or [166]). Staff experiences on the modality of COVID-19 remote home monitoring and impact of staff are explored elsewhere (see *Chapter 11*).

Staff received a range of training and support to deliver remote monitoring models as described in our evaluation. Unfamiliarity with nationally designed competency frameworks and a desire for bespoke training to reflect local organisational working meant some staff may have been better equipped to work more independently than others. Frontline delivery staff, in particular, were asked to rapidly transition from usual methods of providing face-to-face treatment to remote ways of working with limited available evidence of the effectiveness, benefits/challenges and staff experiences of remote home monitoring services.[154] Given the speed at which remote home monitoring services were implemented, this left a significant gap between staff skills, competency and confidence.

The nature and quality of training delivered to frontline delivery staff was dependent on those providing senior clinical insight. Consequently, some delivery staff experienced substantial levels of uncertainty about using their own clinical judgement to independently assess and communicate risk. This was, to some extent, later addressed by the development of SOPs and other working materials. This uncertainty may have impacted on the ability of delivery staff to communicate risks effectively with patients, especially those living with multi-morbidities as well as COVID-19 which may have led to patients to revaluate self-management practices. Remote home monitoring may not always remove the need for in-person examinations.[167]

Our findings demonstrated workload differences for those balancing their workload with other commitments versus those who were redeployed. This supports findings from the first wave of the pandemic, in which staff were able to focus on delivery of remote home monitoring services due to cancellation of elective care/other activities, and the redeployment of staff.[36] Delivery staff, particularly nurses, remained committed to taking a patient-centred approach to providing care that took account of the emotional and physical impact of COVID-19 on patients. As with previous research,[153] our findings highlighted that staff were often not directly involved or lacked a level of autonomy with respect to wider organisational change, despite wanting to share views on how models should be implemented locally.

Given the range of skills required to deliver remote home monitoring models, a multi-disciplinary approach is needed for COVID-19 and chronic disease management in general.[168] Previous research from the US showed that team-based care (physicians, nurses, administrative staff) led to more effective implementation of COVID-19 remote home monitoring services and higher patient satisfaction than single practitioner-led models.[130] Similar findings were found in another study with chronic heart failure patients, who expressed a greater desire to speak with a range of health professionals when being digitally monitored using a range of technology enabled devices.[169]

Strengths and limitations

One strength is that we used mixed methods to study staff experiences of COVID-19 remote home monitoring services, and our study included a large sample of participants working across a range of job roles in primary and secondary care. However, variation between case study sites (see *Chapter 4*) made it difficult to synthesise findings, which may limit transferability of findings.

Our findings may not be representative of all staff views and experiences. For example, the response rate for our staff survey was 39%. Therefore, it is possible that staff who were less engaged with services may have been less likely to complete the survey.

Implications for policy and practice

Current levels of training may not be adequate to support both clinical leads and delivery staff to undertake a wide range of 'work' when managing patients with COVID-19. Staff need the opportunity to be better informed for delivering the service; e-resources should be available to staff, that can be accessed as and when required, and staff should receive bespoke training relevant to their service and organisation. Service leads should consider whether they need to introduce formal sign-off mechanisms to ensure staff have been trained adequately and to a required standard. Staff largely felt confident in their ability to deliver remote home monitoring services, but found apps and online platforms difficult to navigate as part of monitoring. It would be valuable, where possible, to involve staff when deciding which apps and/or online platforms to adopt during service development and implementation. Notably, delivery staff lacked confidence when communicating the risks associated with COVID-19 to patients. As a result, organisations implementing remote home monitoring services should promote multi-disciplinary approaches where delivery staff have ready access to clinical oversight, especially when a patient has deteriorated to a stage where escalation is required.

Primary and secondary care organisations need to consider staff capacity for delivering home monitoring services, given redeployed staff will no longer be available as routine healthcare services recommence.

For staff to take a patient-centred approach, staff should be given flexibility within services to discuss wider contextual issues that can contribute to ill health and to provide emotional support to patients experiencing anxiety and other difficulties.

Future research

Further research is needed to explore the following topics: staff experiences of delivering care for COVID-19 and other health conditions using remote monitoring models, the competency and skill set required to deliver remote monitoring services, how training should be designed, and how best to embed training during the set-up and implementation of services across primary and secondary care sectors.

Conclusions

Remote monitoring models can play a crucial role in managing a large number of patients for a range of health conditions; however, the success of delivery is dependent on the right workplace infrastructure for delivering these models of care. While staff in our study show high levels of acceptability for managing patients using remote models, issues remain around confidence when making clinically-informed decisions and a dependency on clinical oversight. Delivery of remote home monitoring services is also influenced by patient engagement or disengagement with these services.

Chapter 9. Patients' and carers' experiences of, and engagement with COVID-19 remote home monitoring services

Overview

This chapter draws on a manuscript by Walton *et al*.[166] accepted for publication in *Health Expectations* (2022). This is an open access article under the term of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits use, distribution and reproduction in any medium, provided the original work is properly cited (see https://creativecommons.org/licenses/by/4.0/).

What was already known

- Remote home monitoring services for COVID-19 patients have been implemented throughout England.
- These services may place more responsibility on to patients/families.
- It is not known how patients and carers experience these services, or how they found engaging with the activities.

What this chapter adds

- Patients and carers found the human contact with staff reassuring.
- Patients with COVID-19 (an acute condition) can engage with remote monitoring services but may require support from staff and family/friends to do so.
- Engagement is conditional on a range of factors including patient factors, support and resources, and service characteristics.
- Burden of treatment may be experienced by patients and families with acute conditions.

Introduction

The shift in healthcare delivery from traditional face-to-face care models [52] towards remote home monitoring models [22, 170] is consistent with recent moves towards self-management and patient activation within healthcare, whereby accountability for care has changed.[171-174] Patients are becoming more involved in self-management, for example, learning how to detect and manage their symptoms, and treatments, and escalation of care associated with their condition, [51, 175-179] and healthcare tasks (e.g. managing medication, organising care appointments, taking measurements).[180] Whilst some patients may welcome this,[181] there have been concerns that self-management and models such as remote home monitoring shift burden (including responsibility, commitment and workload) on to patients and families, rather than facilitating shared care.[172, 181] This may not be suitable for everyone,[182] as some people may be unable to meet expectations and may experience negative impacts from treatment burden,[172] e.g. health consequences faced by patients due to not adhering to treatment and professional, social, emotional and financial consequences.[180] Different individuals may tolerate different levels of treatment burden, and needs should be assessed regularly as tolerance changes over time.[172, 183] As many situational, personal, and structural factors can worsen treatment burden,[180] formal and informal support networks are needed to support patients.[50, 51]

Treatment burden may negatively impact on patient experience and levels of engagement. This is problematic given that patient engagement with remote home monitoring is crucial. Patient engagement has been defined as patients understanding the information they are given ('receipt') and being able to perform the required activities ('enactment').[57, 58] For this service, engagement refers to the behaviours that patients must undertake as part of the service, e.g. reading/listening to and understanding the information given to them by the service, using the oximeter to take readings,

recording and submitting readings and self-escalating care as required. If patients do not engage with these services, they may be at risk of negative outcomes, e.g. silent hypoxia (very low oxygen saturations, often without breathlessness) [13] and/or delayed admission to hospital.[15, 16] Additionally, limited engagement makes it difficult to evaluate whether or not these services influence key outcome measures such as any changes in mortality or hospital use.

Whilst previous research indicates factors which may influence patient engagement with treatment models more generally,[50, 51, 172, 180] there is a lack of research on patient experience and engagement with COVID-19 remote home monitoring services (see *Chapter 3* or [32, 36]). This chapter addresses this gap by evaluating patient experience of, and engagement with COVID-19 remote home monitoring services.

This study aimed to explore what formal and informal support patients received as part of COVID-19 remote home monitoring services, and patient experience of, and engagement with these services. This chapter addressed the following questions:

1. What types of formal and informal support did patients receive as part of COVID-19 remote home monitoring services? What was the burden of treatment on patients and carers in informal support roles?
2. What were patients' and carers' experiences of engaging with COVID-19 remote home monitoring services?
3. What were the factors influencing burden of treatment and ability to engage with COVID-19 remote home monitoring services?

Methods
A summary of the methods is provided below; further details can be found in *Chapter 2* (or [166]).

Design
This chapter draws on data from workstream 3 (patient and carer survey data) and workstream 4 (patient and carer interviews). Data collection took place between February and June 2021 (patient surveys retrospectively included January).

Sample
Patients and carers who had received COVID-19 remote home monitoring services (see *Chapter 2* and *Chapter 4* for site and patient sample details).

Measures
We developed the survey and semi-structured topic guides specifically for this study (see *Chapter 2*, *Project website documentation – Study instruments*).

Data collection
We conducted a survey with patients and carers from 25 sites, and interviews with patients and carers from 17 sites (see *Chapter 2* for details).

Analysis
Survey data were analysed using descriptive statistics (using SPSS, version 25). All cases were analysed (whether carer, patient or unknown). Where data were missing for specific questions, cases were excluded from the analysis and the denominator reported. Open text responses for three questions (434 responses for anything else to say about the service, 61 responses for how carers supported friend/family member while they had COVID-19 and 200 responses for recommendations to improve service).

Inductive thematic analysis was used to analyse interview data inputted into RAP sheets. [70] We then developed a framework based on these themes and sub-themes and one researcher used this framework to extract quotes from all original transcripts.

Survey and interview findings were triangulated.

Results

Participant characteristics

One thousand and sixty-nine surveys were received from patients (n=936) and carers (n=48), and 62 interviews were conducted with patients (n=59) and carers (n=3) (see *Chapter 4* and *Supplementary file 2* for demographics).

Most patients were referred to services via community methods (Table 17). Patients and carers used a range of methods to record and report their readings to the service, including analogue (paper and phone) and tech-enabled methods (Table 17).

Table 17. Summary of patients' remote home monitoring pathway and method of recording and reporting.

		Survey participants (n=1069) n (%)	Interview participants (n=62) n (%)
Pathway	CO@h (referred pre-hospital via community methods)	749 (70%)	44 (71%)
	CVW (referred via early discharge from hospital)	168 (16%)	13 (21%)
	Both	N/A	2 (3%)
	Unknown	152 (14%)	2 (3%)
	Not applicable	N/A	1 (1%)
Method used to record and report readings	Analogue (Paper and phone)	522 (49%)	19 (31%)
	Tech-enabled (such as text, app, weblink or automated phone)	547 (51%)	27 (44%)
	Combination of tech-enabled and analogue	N/A	14 (23%)
	Not known	N/A	1 (2%)
	Not applicable	N/A	1 (2%)

What type of formal and informal support did patients receive as part of COVID-19 remote home monitoring services?

Formal support from staff

The 'care' on offer differed across sites and patients, with variation in the type and frequency of monitoring offered by services (see *Chapter 4*).

The frequency with which patients had contact with a member of staff ranged from several times a day to not at all. Most patients and carers had contact either once a day, or several times a week. A few patients and carers reported not speaking to staff at all (

Table 18). Findings indicate that patients were supported by staff throughout different stages of the service, including providing information, monitoring, escalating care, signposting and comfort and reassurance.

Table 18. Summary of frequency of contact with staff members for survey participants.

Frequency of contact with staff member	Percentage of survey participants n (%)	Percentage range across sites
Several times a day *(n=1060)*	169 (16%)	0%-45%
Once a day *(n=1060)*	276 (26%)	7%-91%
Several times a week *(n=1060)*	270 (25%)	0%-62%
Once a week *(n=1060)*	139 (13%)	0%-31%
Less than once a week *(n=1060)*	142 (13%)	0%-27%
Not at all *(n=1060)*	64 (6%)	0%-27%

Burden of treatment on patients and carers in informal support roles

Survey findings indicated that almost all patients used an oximeter to record readings when receiving the service. Many patients reported completing a diary and providing readings over the phone or using technology-enabled methods. Escalation-related behaviours (seeking further help, checking readings) were reported less frequently by patients (Table 19).

Table 19. Remote home monitoring activities reported by survey participants.

Remote home monitoring activities that patients reported doing	Percentage of survey participants n (%)	Percentage range across sites
Using the oximeter *(n=1069)*	1014 (95%)	81%-100%
Completing a diary *(n=1069)*	555 (52%)	11%-89%
Providing readings over the phone *(n=1069)*	498 (47%)	19%-93%
Providing readings via text *(n=1069)*	309 (29%)	0%-74%
Recording readings in a digital app *(n=1069)*	264 (25%)	0%-89%
Providing readings via email *(n=1069)*	15 (1%)	0%-5%
Seeking further help due to readings being lower than the recommended threshold *(n=1069)*	344 (32%)	18%-71%
Checking over readings for issues *(n=1069)*	215 (20%)	7%-41%

Many patients were supported by family and friends to engage with the service. A quarter of survey respondents needed help to use equipment (25%, range 11%-50% across sites), and more than half of the interview participants were supported by family members.

Most patients and carers reported having informal support to help them use the oximeter and support with taking and recording readings (Table 20). Qualitative findings highlighted that family and friends provided support with many activities, including support submitting readings, monitoring and collecting the oximeter.

However, not all patients had support with using the oximeter (16%) or taking/recording readings (18%). Some patients did not have support due to their family members having COVID-19.

Table 20. Support for remote home monitoring activities as reported by survey participants.

Support for remote home monitoring activities		Percentage of survey participants n (%)	Percentage range across sites
Having someone to help use the oximeter when needed *(n=1058)*	Yes	782 (74%)	50%-100%
	No	169 (16%)	0%-44%
	Not applicable	107 (10%)	0%-22%
Support taking and recording readings if needed *(n=1057)*	Yes	666 (63%)	43.8%-90%
	No	190 (18%)	7%-33%
	Not applicable	201 (19%)	0%-37.5%

What are patients' and carers' experiences of engaging with COVID-19 remote home monitoring services?

Patients mostly had positive views of the services. Ninety-three per cent (n=970/1045) of survey respondents rated services as excellent or good, 90% (n=923/1028) of respondents found the services helpful and 91% (n=944/1037) would recommend the services to their family and friends.

Findings indicated that most patients and carers found the services reassuring and supportive (91% (n=946/1040) of survey respondents). Qualitative findings indicated that patients and carers valued the human contact with staff and found it reassuring due to having someone watching over them, particularly for those who were living alone, had no support nearby or had existing conditions.

> *"Because it's obviously keeping an eye on you, isn't it really? And I was getting the phone calls every day. How are you feeling?, […]. But someone who was on their own, who had no-who was living on their own, you know, it's a bit of a lifesaver isn't it?"* **(Site A, interviewee 4)**

A minority of patients and carers felt that there were gaps in the service, and it was not holistic. Some felt that services were narrowly focused on managing known symptoms of COVID-19 which did not always suit those with other symptoms, health conditions or who required wider support. A few patients reported feeling that services were isolating and unsupportive (e.g. they only received a call about the oximeter drop-off/return, but not for monitoring).

Most patients and carers felt the care provided was appropriate and preferred to be at home instead of being in hospital (given the pandemic context). Reasons for preferring home over hospital included freeing up space for others in need, fears of going to hospital during a pandemic, and communication barriers. However, some patients and carers spoke about preferring to be in the hospital rather than at home, to feel more secure, feeling scared and wanting to be seen face-to-face.

> *"And I didn't feel too embarrassed that I was using up valuable resources because I thought, Well I'm sitting here at home, there's no reason for me to go in Hospital, bother anyone and waste people's time."* **(Site N, interviewee 3)**

A minority of patients and carers spoke about how these services were the only available care and that they would have liked to have received care from other healthcare professionals such as their GP in parallel. Many patients and carers were not aware of these services prior to referral.

Some patients and carers also spoke about how these services helped them to monitor their own improvement and that it potentially improved their outcomes.

Patients and carers reported very positive views of the workforce and that they were helpful and put patients at ease and were professional and potentially even lifesaving. Continuity of staff was thought to be important.

A few patients had negative experiences with individual staff members, e.g. that they were dismissive, did not recognise that they needed help, were not interested or lacked clinical expertise to support patients or answer their queries.

What are the factors influencing burden of treatment and ability to engage with COVID-19 remote home monitoring services?

Findings indicated that patients and carers generally found it easy or very easy to engage with these services and the resulting activities, including understanding information, monitoring using the oximeter, recording readings and providing readings and escalating care (Table 21). Most survey respondents indicated that they did not experience problems with services (72%, n=771/1069) and did not report barriers to engagement with services (80%, n=858/1069).

Table 21. Experience engaging with service activities as reported by survey participants.

Experience engaging with service activities	Percentage of survey participants who reported easy/very easy n (%)
Understanding the information they were given *(n=1040)*	970 (93%)
Monitoring using the oximeter *(n=1049)*	1022 (97%)
Recording readings *(n=949)*	913 (96%)
Providing readings to the remote home monitoring team *(n=1010)*	979 (97%)
Seeking further help (if applicable) *(n=857)*	738 (86%)

Engagement with service activities was not without challenges, with some patients and carers reporting issues with the information provided or needing further information. Some patients found monitoring difficult due to other health conditions, or that monitoring made them feel worried. Some patients and carers wanted more support or found recording burdensome. Finally, some issues related to escalating care were identified in the interviews. The uncertainty of COVID-19, perceptions of hospital as a frightening place and uncertainty around interpretation of readings and thresholds, meant that some patients and carers were hesitant to self-escalate their care, waited for a member of staff to advise them to escalate their care or reported not wanting to go to hospital or seek further support, even when advised to by staff members.

> *"really I should have probably rung when the readings were that bad but I didn't. […]And when I did send them through they said, 'No, get to the doctors now'." (Site C, interviewee 6)*

The most frequent challenges reported within the survey were returning the oximeter, contacting healthcare professionals when needed and seeking further help (Table 22). Whilst many survey respondents discussed problems with the team (35%, n=87/249) or had their problems resolved (33%, n=76/232), over half of these participants said problems had not been resolved (54%, n=126/232).

Table 22. Challenges experienced and the discussion and resolution of problems as reported by survey participants.

		Percentage of survey participants n (%)
Challenges experienced with service activities	Using the oximeter *(n=1069)*	34 (3%)
	Recording readings in an app or diary *(n=1069)*	27 (3%)
	Contacting healthcare professionals when needed *(n=1069)*	56 (5%)
	Seeking further help *(n=1069)*	57 (5%)
	Returning the oximeter *(n=1069)*	136 (13%)
	Other *(n=1069)*	42 (4%)
Discussion and resolution of problems	Discussed problems with remote home monitoring team *(n=249)*	87 (35%)
	Had problems resolved *(n=232)*	76 (33%)
	Did not have problems resolved *(n=232)*	126 (54%)

Findings from the surveys and interviews indicated three overarching themes that influenced burden of treatment and patient's ability to engage, with COVID-19 remote home monitoring services: i) patient factors, ii) wider support and resources, and iii) service factors (see *Supplementary file 8* for example quotes).

Patient factors
Knowledge, memory, physical health, attitudes towards services and having time to complete the required tasks influenced engagement (see *Supplementary file 8*). Interview findings indicated that patients in poorer health (e.g. due to COVID-19, other health conditions) found it harder to engage with the service. Patients and carers who felt they had sufficient knowledge about what they needed to do found it easier to engage (e.g. 55% (n=583/1069) of survey respondents felt that knowing what to do helped them to engage the service). On the other hand, a lack of knowledge on how to complete the activities limited engagement.

Wider support and resources
Support from staff/service, support from family members/friends, accessibility and availability of materials, equipment and technology influenced engagement (see *Supplementary file 8*). For example, support from staff members (e.g. 46% (n=488/1069) of survey respondents) and family/friends (e.g. 25% (n=266/1069) of survey respondents) was crucial in helping many patients to use the service.

Service factors
Monitoring characteristics, service characteristics, scope of service and availability of treatment influenced engagement (see *Supplementary file 8*). For example, some participants felt that the inconsistent timing of calls was a barrier and some felt that calls were too frequent, whereas others felt they were not frequent enough. Additionally, some patients and carers felt that service scope was a barrier to engagement, in that it did not cover wider symptoms of COVID-19 and was not holistic.

Discussion

Key findings

Patients can engage with remote home monitoring services, even when experiencing acute illnesses (e.g. COVID-19). However, many patients required formal input from staff and informal support from family and friends to complete the necessary tasks. Patients and carers had positive experiences receiving remote home monitoring. The human contact from staff provided patients and carers with reassurance and patients reported services were mostly easy to engage with. However, patients' ability to engage with services was conditional on a range of factors, including having support from family/friends and staff, being in good health and receiving clear instructions on what they needed to do and how to do it, and the level of commitment from patients whilst on the service.

How findings relate to previous research

Previous research highlighted that little was known regarding patient experiences of COVID-19 remote home monitoring services in the context of pressured health services and concerned patients (see *Chapter 3* or [32, 36]). These findings extend earlier findings by highlighting patients' and carers' positive views of the service, challenges and concerns relating to engagement with remote home monitoring for acute conditions, and tangible recommendations on how to improve remote home monitoring services (see *Appendix 3, Table 26*), many of which support wider themes reported in patient experience literature (e.g. the importance of information provision).[184, 185]

Previous research outlines concerns relating to remote care and telemedicine and the loss of interpersonal dimensions involved in caring relationships.[171] Findings extend the evidence base by showing that care does not need to take place face-to-face for patients to feel reassured and supported. Patients largely felt care provided at a distance was appropriate and that they were being monitored. This is consistent with previous research indicating that technology may support closer contact with professionals.[171] However, findings may have been affected by the pandemic context in that data were collected during the height of wave 2 of the pandemic, therefore patients may have been more likely to accept remotely-delivered services to help minimise risk to themselves, family members and staff. Patients and carers may feel differently about remote home monitoring and care delivered at a distance in non-pandemic contexts.

New models of healthcare such as COVID-19 remote home monitoring services sought to change the traditional model of in-person care. Instead, within these models, staff engage with patients to share the care burden whilst equipping patients and carers to self-monitor and manage care in the absence of staff members. Our findings demonstrate that concepts of treatment burden and difficulties engaging with healthcare demands [172, 180, 183] also apply to remote monitoring models for COVID-19. Some patients reported problems engaging with remote home monitoring services for a range of reasons, including feeling too poorly, not having enough knowledge on what to do, and lack of support from staff and/or family/friends. Others reported the necessity of support from their family/friends when engaging with the service. This extends knowledge by showing that social networks may undertake self-monitoring tasks on behalf of (potentially very poorly) patients in addition to helping patients cope with burden of treatment [172] and self-management of conditions.[51, 186] Those who feel more poorly (either due to COVID-19 or existing conditions) may require more formal or informal support to manage care. Yet, this increases the caring burden for family/friends. This finding also raises concerns regarding appropriateness of care for those who do not have informal support networks in place.

This chapter builds on earlier research by providing a nuanced interpretation of the factors that influenced engagement with remote home monitoring services for acute conditions such as COVID-

19. Our finding that many non-health related factors influence engagement is consistent with other studies in a range of other conditions and interventions.[51, 180, 187-190] Our findings add to prior knowledge by demonstrating that many factors were exacerbated due to the acute nature of COVID-19 and policy factors surrounding COVID. For example, physical health factors limiting engagement may be worsened by the acute nature of COVID-19 and the severity of symptoms that some patients faced, thus affecting a patient's ability to engage. Furthermore, policy regulations and lockdown restrictions imposed within the UK may have meant that physical social support available to patients may have been limited by members of their support networks living elsewhere. As COVID-19 is easily transmissible, social distancing recommendations were in place, therefore, many patients were distancing from family members living in the same space. Findings demonstrate that despite difficulties imposed by COVID-19, social networks were crucial for many patients in facilitating engagement with services and ensuring that care needs were met. This highlights the need for alternative support where necessary (particularly for those living alone or those who are socially isolated). The reliance on informal support networks has implications for burden of treatment and may not be appropriate for all individuals. These findings support previous theoretical frameworks indicating that social, political and technical contexts influence engagement.[49-52]

Previous research has explored concepts of self-management,[50, 51, 187] engagement [188] and treatment burden [180] in chronic conditions, but little research had been conducted on remote home monitoring and self-management in acute conditions such as COVID-19 in which care needs to be urgently escalated in an efficient and time-sensitive manner. Findings extend earlier work by demonstrating challenges of remote home monitoring models for acute conditions. For example, due to uncertainty of COVID-19, perceptions of hospital being a frightening place and uncertainty around readings and thresholds, some patients were hesitant to self-escalate care and in many cases, patients waited until advised by staff to escalate care. This finding indicates that in situations where there is a need for timely escalation, but concerns around infection transmission from going to hospital, it may be suitable to have formal support from staff members. Together, staff and patients can collaboratively decide when to seek further help, rather than placing responsibility on to patients. This finding contrasts with recommendations within the national SOP for COVID-19 remote home monitoring services,[38, 39] which indicate that pathways should encourage patients to self-escalate care.

Some patients felt that they were able to engage with services due to having manageable symptoms and feeling comfortable with tasks. This indicates different levels of remote monitoring support are needed for different individuals. This supports previous research indicating that the success of telehealth services including remote home monitoring may rely on the fit between individuals' needs and services.[50, 171]

Strengths and limitations
Integration of mixed-methods data helped to provide in-depth perspectives on patient and carer experiences of, and engagement with COVID-19 remote home monitoring services.

Findings may not be representative of all patient and carer groups and experiences, for the following reasons: i) our patient sample was under-representative of some groups (e.g. older patients and ethnic minorities) and over-representative of other groups, when compared with patient onboarding data,[115] ii) survey response rate was only 17.5%, and iii) we were unable to recruit patients who had declined or dropped out of the service, or who did not want to take part in the research.

The focus of our research was on patients' experiences of remote home monitoring services. Therefore, it is possible that we have not captured carers' experiences in detail. However, some carers shared their own experiences during the interviews and in responding to the survey.

Implications

Burden of treatment may not only affect those with multimorbidity or chronic conditions, but can also affect those with acute conditions. Findings indicate that remote monitoring may increase treatment burden for some patients and families.

COVID-19 remote home monitoring services aimed to target patient groups at higher risk from COVID-19, yet many of these groups appear more likely to report difficulties in engagement with these services, e.g. older patients, and patients with health problems. Remote monitoring may not be appropriate for everyone (e.g. those without support). Services need to gauge a person's support network and any concerns surrounding remote home monitoring when assessing eligibility for these services. Services must then tailor the healthcare offer to enable patients to engage (e.g. providing further support for those from at-risk groups or who do not have informal support, or linking patients with care networks if needed). All patients should be given contact details to contact services should problems arise. Face-to-face support (e.g. for monitoring) from staff and families has implications for infection transmission.

These findings may have implications for remote home monitoring services more generally. Service developers should consider the type of condition when designing pathways. For example, services for acute conditions may require support from staff to ensure that patients are escalated for further care as necessary. Services must plan logistics for delivery and collection of equipment, ensure sufficient information provision and that patients know what they need to do and that they feel able to engage with the service. Some patients felt that services offered were too narrow and do not consider wider social, emotional or condition-related needs. Service adaptations may be necessary for those receiving remote home monitoring for acute conditions in addition to care for other chronic conditions.

Future research

Further research is needed to explore: i) experiences of those who decline or disengage from these services, ii) burden of treatment for acute conditions versus chronic conditions, iii) which groups are able to engage with and tolerate burden from remote home monitoring services, and iv) the impact of treatment burden from informal caring responsibilities on families.

Conclusions

COVID-19 remote home monitoring services place a large responsibility on patients and carers in relation to monitoring and escalating care. Whilst patients and carers found services reassuring and a positive experience, many factors influenced their ability to engage. This indicates that services may be conditional on a range of factors relating to the patient (e.g. knowledge and memory), their support and resources (e.g. support from family, friends and staff) and service factors (e.g. service scope and frequency of monitoring).

Chapter 10. Examining disparities relating to service reach and patient engagement with COVID-19 remote home monitoring services

Overview

This chapter draws on a manuscript by Crellin et al. [191] uploaded as a preprint to *MedRXiv*. This is an open access article under the term of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits use, distribution and reproduction in any medium, provided the original work is properly cited (see https://creativecommons.org/licenses/by/4.0/).

What was already known

- Evidence shows COVID-19 has a disproportionate impact on certain population groups, such as ethnic minority groups, older adults and those with comorbidities.
- Literature exploring the effectiveness of strategies to reduce health disparities for remote monitoring services and the impact of remote monitoring services on health disparities is scarce.
- The rapid adoption and spread of remote home monitoring services in England must be accompanied by evaluations at a local level to monitor the impact on health disparities.

What this chapter adds

- Increased understanding of how remote home monitoring services can be designed and delivered to address local population needs to increase accessibility and facilitate engagement with the service.
- We identified a number of local service adaptations, including prioritising vulnerable groups, creating referral pathways, offering translation services, offering non-digital options, and providing face-to-face assessments, and we discuss their potential impact on health disparities.
- We found that despite efforts to adapt services, disparities across patient groups in their experience of, and engagement with, the service were reported (related to age, health status, ethnicity, level of education, employment status and gender).

Introduction

The COVID-19 pandemic has shone a spotlight on existing health disparities in the UK. The pandemic has disproportionately affected the most marginalised communities, particularly people living in more socio-economically deprived areas, those from minority ethnic communities, older adults, people with a learning disability and those residing in care homes, and people in key worker occupations.[12, 131, 192]

The pandemic has also led to changes to the way that health services are delivered at an unprecedented pace,[193, 194] with an acceleration of the move towards remote monitoring models of care. Yet, little is known as to whether and how this shift might affect existing health disparities.[196-198]

The benefits brought about by remote methods of delivering healthcare are not experienced by all: for tech-enabled remote methods, digital exclusion may negatively impact access to or quality of care.[200-202] Other factors may exacerbate disparities in access, engagement or quality of care. Some patient groups are more likely to experience inequities (e.g. older adults, people with coexisting conditions, those with difficulties communicating, and those isolated or experiencing language

barriers, those with lower health literacy or understanding of how health systems work) and may need additional support to engage with services.[203]

Inequities can be introduced at all stages of the planning and delivery of health interventions, including access, diagnostic accuracy, patient uptake and engagement.[199]Given the recent rapid shift towards remote models of care, it is important to explore whether disparities exist in how patients access, engage with and experience services, and to understand whether and how remote services can be designed and delivered to promote inclusion. This study addressed the following questions:

1) Were COVID-19 remote home monitoring services adapted at a local level to increase service reach and patient engagement for different groups?
2) Were there disparities in patients' reports of their ability to engage with the service, and were these moderated by the modality of the service? What were the potential impacts of service adaptations on health disparities according to patients?
3) Were there disparities in patients' reports of their experience of the service?

Methods

A summary of the methods is provided below; further details can be found in *Chapter 2* or *Supplementary file 1*.

Design

This chapter draws on staff and patient/carer surveys and staff and patient/carer interviews. Data collection took place between February and June 2021 (patient surveys retrospectively included January).

Sample

Patients/carers who received these services and staff leading and delivering services (see *Chapter 2* and *Chapter 4* for sample details).

Measures

We developed the survey and semi-structured topic guides specifically for this study (see *Chapter 2* and *Project website documentation – Study instruments*).

Data collection

We conducted a survey with patients/carers from 25 sites and with staff from 28 sites. We conducted interviews with staff, patients and carers from 17 sites (see *Chapter 2* for details).

Analysis

Descriptive statistics were calculated to explore staff survey responses relating to perceived patient groups facing barriers. Open text responses relating to local service adaptations and patient groups facing barriers were analysed; responses were triangulated with service lead interview data, coded and grouped into themes.

For patient survey data, non-parametric univariate analyses (i.e. Mann-Whitney U tests and Kruskal Wallis tests) were conducted to explore patient engagement with services and experience of services across patient characteristics. Where statistically significance differences were detected (at the $p<.01$ level) across more than two groups, post hoc analyses were conducted. For both patient and staff survey responses, where data were missing for specific questions, available case analysis was performed and the denominator reported.

We conducted logistic regression modelling to examine whether modality of the service, age, education, health status and ethnicity were associated with likelihood of patients reporting at least one problem with the service. Patient open text survey responses providing feedback about services and any suggested changes or improvements were triangulated with patient interview data, coded and grouped into themes.

Service lead and patient interviews
To understand whether and how local services were adapted to address health disparities and their potential impacts (RQ1), a thematic analysis was carried out on primary data from service lead interviews.[213, 214] Interview transcripts were coded inductively and organised into higher-order themes.

To examine the potential impacts of adaptations from patients' perspectives, RAP sheets [70] were analysed. Data was deductively coded using the themes from the service lead interviews.

Results

Participant characteristics

Two hundred and ninety-two surveys were received from NHS staff and 1069 surveys were received from patients and carers. We conducted 23 interviews with service delivery leads and 62 interviews with patients/carers (see *Chapter 4* and *Supplementary file 2* for demographic characteristics).

Comparison of the characteristics of patient survey respondents with those of more than 26,000 patients onboarded to CO@h services [115] indicate the survey sample to be relatively representative of patients engaging with the service. However, several differences should be noted. The survey sample is under-representative of patients over 80 years (5% vs. 10%) and under 50 years of age (21% vs. 33%), and over-representative of patients aged 50-80 years (74% vs. 57%). The survey sample comprises a higher proportion of patients from white ethnic groups (91%) compared to those onboarded to services (76%). Finally, our sample is over-representative of patients in the least deprived deciles of the IMD (18% vs. 13%) and under-representative of patients in the most deprived deciles (24% vs. 28%).

Service adaptations to increase service reach and patient engagement

Staff reported their views of patient groups facing barriers to engaging with the service. Thirty-nine per cent (n=113/292) reported patients for whom English was not their first language, 33% (n=97/292) patients with a visual or hearing impairment, 31% (n=91/292) cognitive impairment, 22% (n=63/292) patients with a learning disability, 21% (n=61/292) those who are digitally excluded, 13% (n=37/292) older adults, 7% (n=20/292) ethnic minority groups, and 5% (n=16/292) unpaid carers. Other patient groups that staff reported in surveys or interviews included those living alone without support, patients unable to collect the oximeter, people with mental health problems, asthmatics, pregnant patients, patients whose GP had not engaged with the service, those with difficulty communicating via phone, and patients without a fixed abode.

Two-thirds of service leads (16/24 sites) reported that their service had been adapted at a local level to accommodate specific service user needs or requirements. Examples included providing information in different languages, offering translation services, offering non-digital monitoring options, face-to-face assessments, and flexibility of monitoring. Service lead interviews and survey data indicated there was considerable local variation in the number of strategies adopted by sites. For example, several services made considerable efforts to standardise the coverage of the service, invest

resources into setting up special pathways targeting hard-to-reach, vulnerable or at-risk groups, and monitor uptake. National strategies and local service adaptations reported by staff are set out in *Appendix 4, Table 27*.

Disparities in patients' reports of their ability to engage with the service
In this section, we present findings from patient-reported engagement with these services in terms of the accessibility of information, the achievability of tasks, and problems reported via the survey (drawn from the survey analysis). See *Supplementary file 8* for further details. We also use findings from patient interviews and open-text survey responses (referred to as 'qualitative data') relating to patient experiences of the impact of service adaptations aimed at addressing inequalities.

Accessing the service
In interviews, patients reported being referred to services by many different organisations and pathways. However, sites were not always consistent in the admission criteria applied to access the service and there was sometimes a lack of clarity in how patients were referred to the service; some patients reported inconsistencies across local areas and several patients from sites that used active case finding reported they did not know how they were referred. Collaboration between services was perceived to have facilitated more rapid access to care; several patients highlighted that they were supported quickly because of close liaison between services and their GP practice, hospital or ambulance services. Once enrolled into the service, there were challenges relating to obtaining the appropriate equipment; some patients reported it was difficult to collect the oximeter when they were unwell and relied on family members or friends.

Accessibility of the information about the service
Interviews and survey responses indicated variation across and between sites in the information available to patients and how it was provided. We found evidence of a difference in understanding information provided by services with patient age (p=0.005) and ethnicity (p=0.001). There were also some marginally non-significant differences with health status (p=0.014).

Patients aged 80 years and over reported less ease in understanding information; a lower proportion of patients reported understanding the information to be 'very easy' (40%) compared to all other age categories (60-67%). However, the number of patients aged 80 years and over was small and when 'very easy' and 'easy' responses were combined there was little difference across age categories. Patient ratings of helpfulness of the information was also statistically significantly lower for older patients (p=0.005), with similar patterns of responses to understanding the information. Patients from minority ethnic groups reported less ease in understanding information provided; 81% of patients from minority ethnic groups reported understanding the information to be 'easy' or 'very easy' compared to 96% of patients from white ethnic groups.

Interviews identified several other factors affecting the accessibility of patient information. Several patients noted it was particularly difficult to take on the information when they were unwell, while those with visual impairments would have welcomed written information in a larger font, and several patients would have liked additional information about the service, their condition and recovery (e.g. how to interpret oxygen readings, how to manage their recovery, and where to seek help).

Patients' ability to complete tasks as part of the service

We found evidence of differences in patient-reported ease of completing monitoring activities (i.e. using an oximeter, recording and providing readings) and escalation activities (i.e. seeking further help) with age, gender, health status, ethnicity, and level of education (see *Supplementary file 8* for further details).

Monitoring activities

Overall, our analysis found that most patients reported monitoring activities easy to engage with – the proportion of patients reporting difficulties was low, however some patient groups might require additional support to engage with the service. This is consistent with qualitative data; some patients reported receiving additional support beyond the monitoring protocol or national guidance, such as receiving face-to-face visits.

Survey analysis found evidence of a difference in patient-reported ease of recording readings with health status (p=0.004). Fewer patients with a health problem or disability rated recording readings as 'very easy' (70%) compared to those without a health problem (79%), however when this response option was combined with 'easy' there was little difference between groups. A similar trend was found for health status and providing readings to services, however was marginally non significant (p=0.017).

There was evidence of differences between ethnic groups for recording readings (p<0.001). Fewer patients from minority ethnic groups reported recording readings (91%) to be 'easy' or 'very easy' compared to white groups (98%). A similar pattern was found for providing readings to services however was marginally non-significant (p=0.013). While translated patient materials were available to services, the extent that these were used by services is unclear.

Staff interviews indicated translation services were often needed and not always available for patients for whom English was not their first language. Services often relied on liaising with friends or family to support communication (when translation services were not available) and this was not always possible.

Although not statistically significant, there was some evidence of differences in ease of recording (p=0.022) and providing readings (p=0.016) with age. There was little difference in the proportion of patients reporting tasks as 'easy' or 'very easy' across age categories, however fewer patients aged over 80 years reported recording readings (55%) and providing readings (57%) to be 'very easy' compared to those under 50 years (80%, 79%) and in the 50-64 years age category (77%, 78%). Older patients reported support from friends, family and healthcare professionals was more important for their engagement with services: 26% (n=11/43) of patients over 80 years reported they had support from family and friends to use equipment and 49% (n=21/43) reported support from healthcare professionals helped them to engage with the service. This compares to 21% (n=40/195) of patients under 50 years of age reporting support from family and friends, and 43% (n=83/195) reporting support from healthcare professionals.

A statistically significant difference in providing readings to services (p=0.001) was also identified for gender: fewer male patients reported providing readings (70%) to be 'very easy' compared to female patients (80%). A higher proportion of males (25%, n=97/385) also reported the importance of friends and family in supporting their engagement with services compared to females (19%, n=102/531).

There were no statistically significant differences (at the p<.01 level) in engagement with monitoring activities with employment or living situation. In interviews several patients in paid employment reported that they would prefer to reduce the number of daily readings or that they preferred to receive calls at a specific time each day. Patients living with others reported greater reliance on support networks, friends and family; 10% (n=14/137) of patients living alone reported support from family or friends helped them to engage with the service compared to 23% (n=175/754) of those living with others. Many patients reported the support from family members, friends or carers to take and provide readings, and liaise with the remote monitoring team was crucial. This was particularly important for patients who were tired or more acutely unwell.

Escalation processes
As for escalation processes (i.e. seeking further help when needed), we found evidence of a difference with employment status (p=0.007). Fewer patients who were not in employment reported seeking further help to be 'easy' or 'very easy' (84%) compared to those who were employed (89%). There was also some evidence of differences in ease of engagement with escalation processes across ethnic groups (p=0.015) and with level of education (p=0.015), however these were marginally non-significant (at the p<.01 level). Patients with higher education attainment and those from minority ethnic groups were less likely to report seeking further help to be 'easy' or 'very easy'.

Disparities in patient engagement by the mode of services
Overall, 25% (n=228/936) of patients reported at least one problem completing tasks that were part of services (e.g. using the oximeter, providing or recording readings, or seeking further help). Logistic regression analysis found mode of monitoring was not related to whether patients reported a problem, nor were health status or ethnicity (see *Supplementary file 8*). Increasing age and a higher level of educational attainment were associated with an increased likelihood of reporting a problem. The odds of reporting at least one problem with services were approximately 7.6 times higher for older adults (80 years and over) than younger adults (under 50 years of age), for patients aged 65-79 years the odds were 2.9 times higher and for patients aged 50-64 years the odds were 2.3 times higher compared to patients under 50 years. The odds of patients who were educated to A level or equivalent reporting a problem were 3 times higher than patients who had received no formal qualification.

Disparities in patients' reports of their experience of the service
We found evidence of differences in patient reported experience and helpfulness of services with age and employment status, however reassurance provided did not differ markedly across patient groups.

Older patients reported services to be less helpful (p=0.004); fewer patients aged 80 years and over reported services to be 'helpful' or 'very helpful' (88%) compared to those in the under 50-years (92%) and 50-64 years age categories (92%). Older patients also reported a less positive experience of services (p=0.034), however this was not statistically significant (at the p<.01 level). The less positive experiences of patients aged 80 years and over might be explained by differences in understanding information about services and ease of completing monitoring tasks, however they might also be due to the smaller sample size of the 80 years and over age category.

Patients in employment rated services more positively (p=0.001) and found services more helpful (p=0.003); 96% rated it 'good' or 'excellent' and 93% 'helpful' or 'very helpful' compared to 92% and 87% respectively among patients not in employment. The differences in patient experiences based

on employment status might be related to other factors, such as health status, level of education or age, with older patients more likely to be retired.

Living situation was not identified in the survey data to be a significant factor in patient reported experience, or reassurance provided. However patient interview data indicated living situation and strength of social network as important factors; provided by services was reported to be particularly important for those socially isolated or living alone.

Discussion

Key findings

At a local level many sites designed and adapted their service to be more inclusive to the needs of their local population and to expand their reach. Strategies included: providing information in different languages or formats, offering translation services, offering analogue and tech-enabled options for relaying readings, face-to-face assessments, delivering oximeters, providing additional training or support, flexible monitoring processes, and liaising with family or friends. There was considerable local variation in the adaptations employed by services. The adoption of such strategies was often dependent on local leaders as to how patient groups were approached and supported [94] and on the resources available to deliver the service.

Despite efforts to adapt services to meet local needs, there were disparities across patient groups in their experience of, and engagement with services including age, employment status, ethnicity, level of education, health status, and gender.

How findings relate to previous research

Despite previous evaluations investigating models of remote home monitoring and implementation of such services for COVID-19 patients,[36, 110] to our knowledge, this is the first research that focused on strategies adopted by services to address disparities. Our findings are consistent with previous research of strategies that can be used to reduce disparities in access to and use of health services more broadly,[204, 206, 207, 210] for example, expanding admission criteria and referral routes, and providing information in a range of formats (although support was provided at a national level, not all services provided information in formats accessible to all patients). Our findings extend research by outlining some strategies not previously identified, e.g. staff providing additional support beyond monitoring (linking with social support, or more contact time), amending protocols to patient need and liaising with family/carers. Some possible areas for improvement included the need to routinely collect and analyse data on relevant populations, co-developing platforms with patients and staff (there was limited opportunity due to the rapid implementation), and working with communities to promote the service.

Critiques of remote models of care often focus on possible harms arising from digital exclusion. Having analogue options available as part of COVID-19 remote home monitoring services is, therefore, crucial to prevent increasing health disparities.[219] This is particularly important given the overlap between patient groups at greater risk of severe illness from COVID-19 (e.g. older adults) and those who are at greater risk of digital exclusion. Our finding that mode of service did not impact on patient engagement or experiences might be explained by patient satisfaction or the fact that all sites offered analogue modes (see *Chapter 11*).

Implications

Our evaluation generates a range of recommendations for the design and delivery of remote monitoring services for COVID-19 patients, and other health conditions. Services must consider the needs of their local population and be adapted accordingly, monitor the impact of services on population groups at risk of health disparities and work with existing local systems (e.g. community groups) to engage harder to reach groups.

Given that many of the groups of patients (e.g. clinically vulnerable, older adults, those without support) that services aimed to reach found it more difficult to engage with the service, patients' needs and circumstances should be assessed upon referral in a standardised way and services must be tailored to provide appropriate levels of support for patients and carers (see *Chapters 9* and *10* results and [214, 220, 221]). Examples of appropriate tailoring could include: patient information in a range of formats,[222] additional information, education or support in navigating services [223] and flexible monitoring processes.).

When implementing remote models of care, adequate resources and infrastructure should be provided to allow patients to be involved in the design and implementation. Co-design can help to ensure that services are better suited to patient needs, and facilitate adherence and engagement.[224] Holistic healthcare and collaboration or linking between services have previously shown to be important for reducing inequalities, particularly for those who are unwell or have comorbidities.[220, 224]

Strengths and limitations

The analysis of experience and engagement across patient groups could have been subject to false positives due to the number of comparisons made, although a more stringent p-value was used in reporting significant results ($p<.01$). When making comparisons between patient groups, the sample size of several groups was relatively small (e.g. patients aged over 80 years), limiting generalisability. The planned multivariate regressions investigating whether mode of monitoring and patient characteristics were associated with patient experience of the service were not possible due to the skew within the dependent variable (and therefore insufficient power to detect any differences). The interviews with patients focused on their experiences of services more broadly and not necessarily the identification of inequalities in access or quality of care, so much of our analysis of the latter draws on staff perspectives or patient survey data.

Future research

There is little published literature on the implementation of remote monitoring and health disparities. There are other populations at risk of health disparities that were beyond the scope of this evaluation and should be considered in any future evaluations, for example, the homeless community, people with disabilities, and unpaid carers.

The scope of our evaluation also did not allow us to examine the impact of specific strategies used to increase accessibility or patient engagement, or the impact of specific adaptations made by local services. We are therefore not able to make any conclusions regarding the effectiveness of strategies in relation to health outcomes for particular patient groups. This is an area for future research.

Conclusions

When health services undergo such a rapid transformation, as we have seen with the shift towards remote models of care, evaluations of the effectiveness of such services must include an impact

assessment to ensure services are accessible and available to all patients, and to monitor the impact on health disparities. Addressing health disparities must therefore be a key focus in the planning, design and delivery of remote monitoring models for COVID-19 and other conditions, both nationally and locally, so that remote models of care can be of value to all population groups. Staff and patients from groups typically experiencing disparities in their healthcare must play an active role in service design to ensure their needs, experiences and expectations are accounted for.

Chapter 11. Technology-enabled and analogue models of remote home monitoring care for COVID-19: a rapid mixed-method evaluation of patient and staff experiences

Overview

What was already known

- Patients and staff like remote home monitoring, but there are some barriers to delivery and engagement, and it may not be appropriate for all patient groups.
- The availability of dependable, high-quality, and clinically-useful technology systems that patients and staff can engage with influences implementation of services.
- Few studies have explored patient and staff experience of COVID-19 remote home monitoring services.

What this chapter adds

- Older patients, patients with a lower level of educational attainment and ethnic minorities were more likely to relay symptoms through phone calls with the service.
- Staff considered tech-enabled and analogue models better equipped to manage large patient numbers; but improvements were needed to improve functionality of technology systems to better fit clinical and operational needs.
- Tech-enabled and analogue models were not a substitute for human contact, as phone calls were used in both tech-enabled and analogue services and analogue-only services.

Background

COVID-19 remote home monitoring services have been implemented using a range of technology-enabled and analogue modes ([32, 36] and *Chapters 1, 3* and 4).

In order for patients to engage with remote home monitoring services, previous research has indicated that patients need access to private space, carer support, the necessary digital infrastructures required to engage with remote home monitoring services,[219] a choice of modality and access to technical support.[226]

In order for staff to deliver remote home monitoring services, previous research has highlighted the importance of the accessibility and functionality of technology for meeting the needs of work practices, interoperability with existing data systems and sufficient staffing for monitoring and responding to data.[165, 227-229] Furthermore, the beneficial impacts of technology on work activity can be reduced by technical problems and a lack of technological infrastructure.[230]

Research indicates that patients and staff have emphasised the need to maintain human contact in the clinical relationship to preserve high quality care.[227, 231-233]

Whilst previous research provides an indication of the types of factors that may enable staff and patient use of remote home monitoring services, the experience of patients and staff when using different modes of COVID-19 remote home monitoring have not yet been fully explored. Emerging

evidence indicates that digital apps may facilitate the follow-up of a higher number of COVID-19 patients compared to telephone calls,[32] but might also limit the engagement of older patients.

Within this chapter, we report on patient and staff experiences of engaging with rapidly implemented tech-enabled and analogue models of remote home monitoring with COVID-19 patients. We hypothesise that differences in how patients relay readings in the models may impact on how patients and staff engage with and experience the service. We aimed to answer the following questions:

1) Which models of tech-enabled and analogue COVID-19 remote home monitoring were adopted in the UK?
2) Were there differences in the characteristics of patients using these models?
3) What were patients' experiences of relaying symptom data using tech-enabled and analogue models?
4) What were staff experiences of processing symptom data for large numbers of patients using tech-enabled and analogue models?
5) How did the use of tech-enabled and analogue models affect patients' and staff's experience of the patient-clinician relationship?

Methods
A summary of the methods is provided below; further details can be found in *Chapter 2* or *Supplementary file 1.*

We used the technologies (dependability, functionality and familiarity) and clinical relationship (patient-clinician interaction, knowledge of patient and trust) domains of the Planning and Evaluating Remote Consultation Services (PERCS) conceptual framework to examine the newly established services.[219]

Design
This chapter draws on staff and patient/carer surveys and staff and patient/carer interviews. Data collection took place between February and June 2021 (patient surveys retrospectively included January).

Sample
Patients/carers who received these services and staff leading and delivering services or involved in service data collection/analysis (see *Chapter 2* and *Chapter 4* for sample details).

Measures
We developed the survey and semi-structured topic guides specifically for this study (see *Chapter 2* and *Project website documentation – Study instruments*). Interviews with delivery staff included a 'think aloud' section where staff narrated the process of using the platform.

Data collection
We conducted a survey with patients/carers from 25 sites and with staff from 28 sites. We conducted interviews with staff, patients and carers from 17 sites (see *Chapter 2* for details).

Data analysis
Inductive thematic analysis was used to analyse interview data (relating to patient views/experiences of relaying symptom data, staff processing data and interactions between patients and clinicians), inputted into RAP sheets.[70] The PERCS domains of technologies and the clinical relationship were used as a sensitising lens.[219] Transcripts were reviewed to gain further in-depth data on reasons for adoption of models and knowledge gained from models. Each code's data were checked for

consistency of interpretation and re-coded as necessary. The data were organised into lower- and higher-order themes. We constructed the typology of the models based on two key characteristics: the modality of the technology and human contact between patients and clinicians. Data relating to modality and frequency of human contact were coded deductively.

Survey data were analysed using SPSS (version 25). The following patient data were analysed: socio-demographic information, patient-reported ease of completing activities as part of their care, frequency and quality of contact with the remote monitoring team, and whether they had received any support from family or friends. Data related to experience of relaying data and the clinical relationship were also coded deductively from two open-ended survey questions. Survey responses were compared with patients who had reported they had relayed readings via tech-enabled or analogue modes. We analysed staff survey respondent characteristics. Staff reported on their experience of delivering the service, capacity/resources to deliver the service, the impact of the role on their workload and their views of patient engagement with the service. Data related to processing and responding to symptom data and the clinical relationship were coded deductively from one open-ended survey question. To make comparisons across models, staff were categorised as delivering a tech-enabled and analogue model if sites adopted a mixed approach, or an analogue-only model if a tech-enabled platform was not used.

For patient and staff survey data, we used descriptive statistics including frequencies and percentages, and univariate analyses were performed. Where data were missing for specific questions, available case analysis was performed and the denominator reported. We conducted Pearson's chi-square tests and logistic regression modelling to compare the characteristics of patients using tech-enabled and analogue-only models, and determine the association between patient characteristics and mode of submission. We used non-parametric Mann-Whitney U tests to compare patient-rated experiences of receiving services and staff experiences of delivering services for tech-enabled and analogue-only models.

Results

Participant characteristics

Two hundred and ninety-two surveys were received from NHS staff and 1069 surveys were received from patients and carers. We conducted 58 interviews with staff and 62 interviews with patients/carers (see *Chapter 4* and *Supplementary file 2* for demographic characteristics).
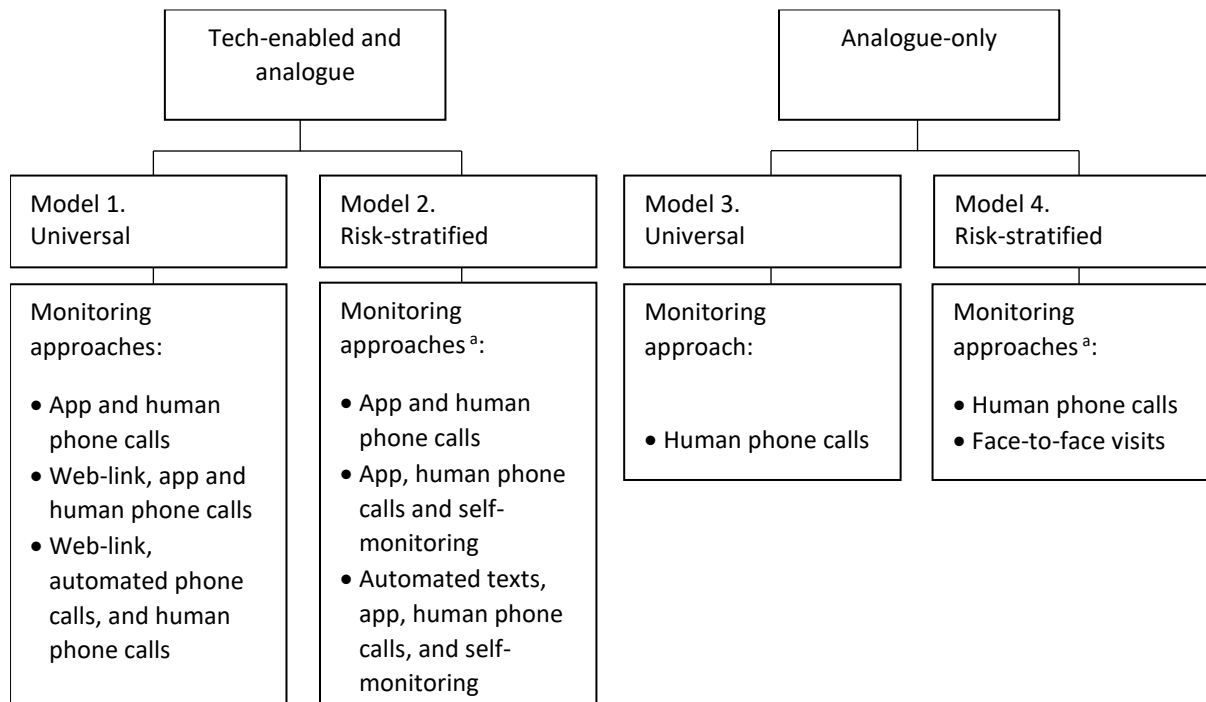
The majority of staff reported delivering tech-enabled and analogue services (81% interview participants, 77% survey participants) compared with analogue-only models (19% interview participants, 23% survey participants).

More patients reported using a tech-enabled mode for data submission (66% of interview participants and 51% of survey participants) than an analogue-only mode (31% of interview participants and 49% of survey participants). Of the patients surveyed: 29% reported providing readings via text, 25% via digital app, and 1% via email.

A comparison of participant characteristics for survey participants who used tech-enabled compared with survey participants who used analogue methods of submission is shown in *Supplementary file 8*. The logistic regression analysis found statistical evidence of differences in patient characteristics between survey participants who used tech-enabled versus analogue-only models, for age (p=0.005), level of education (p=0.011) and ethnicity (p=0.043) (see *Supplementary file 8*).

Models of COVID-19 remote home monitoring adopted

Services were categorised into four models (Figure 26). Services within Model 1 (10/17 services) and Model 2 (4/17 services) offered tech-enabled and analogue services submission modes. Services within Model 3 (1/17 service) and Model 4 (2/17 services) offered analogue-only modes of submission. Models 1 and 3 outline 'universal' services which offered the same submission options and frequency of human contact to all participants, whereas Models 2 and 4 outline 'risk-stratified' services which adapted the submission method and/or frequency of contact depending on patients' needs. For example, two services within Model 2 offered self-monitoring (analogue-only options to low-risk patients) and some services within Model 4 offered more frequent phone calls or face-to-face visits for high-risk patients. See *Supplementary file 4* for further details.

Tech-enabled and analogue		Analogue-only	
Model 1. Universal	**Model 2.** Risk-stratified	**Model 3.** Universal	**Model 4.** Risk-stratified
Monitoring approaches: • App and human phone calls • Web-link, app and human phone calls • Web-link, automated phone calls, and human phone calls	Monitoring approaches [a]: • App and human phone calls • App, human phone calls and self-monitoring • Automated texts, app, human phone calls, and self-monitoring	Monitoring approach: • Human phone calls	Monitoring approaches [a]: • Human phone calls • Face-to-face visits

[a] Frequency of contact dependent on patient risk level.

Figure 26. Models of COVID-19 remote home monitoring.

Patients' experiences of using tech-enabled and analogue methods to relay symptoms

We constructed two key themes related to patients' experiences of relaying symptom data using tech-enabled and analogue, and analogue-only modes: allocation of mode, and ease of relaying readings and the functionality of tech-enabled systems.

Allocation of mode

Most patient interviewees did not recall being given a choice about the mode in which they could submit readings; however, most patients were happy with the mode they were given. Several patients mentioned that it had been unproblematic to switch modes during their time with the service. Staff interviewees across many sites reported that they were aware that older patients in particular might lack digital skills/infrastructure or experience cognitive/physical impairments that might make engaging with tech-enabled systems challenging, and offered phone calls as appropriate. Given the differences between patient groups using tech-enabled and analogue-only modes, staff may have

been attuned to which option might best suit patients *or* may have assumed that certain patients (for example, older patients) would not be able to manage a tech-enabled approach.

Ease of relaying readings and the functionality of tech-enabled systems
Most patient interviewees across sites reported that it was "easy", "simple" or "straightforward" to relay readings whether by tech-enabled or analogue modes. A number of patients thought that the simplicity of the tech-enabled systems was its strength:

> "*I'm really un-techy, but… the text message reminder came through, you clicked on it, you put in… your name and date of birth, it took you straight through it… you could be as thick as you like and you would manage to do that. It was really [laughs]… no technical prowess required.*" **(Site M, Patient 1)**

Similarly, survey analysis found patients rated both tech-enabled and analogue-only modes for submitting data positively. Patients using a tech-enabled mode reported that recording readings (p=0.009) and providing readings (p=0.001) to services was easier than patients using analogue-only methods (see *Supplementary file 8*). However, differences might reflect differing characteristics of patient groups.

The main barriers to submitting readings (for both tech-enabled and analogue, and analogue-only models) reported by patient and staff interviewees were feeling too poorly or tired to engage or forgetting to submit readings. Many patients and staff highlighted that family members or carers had assisted patients in relaying readings, particularly for patients using a tech-enabled modality, who lacked confidence in their technical skills:

> "*In the beginning I found it [entering the information] difficult because I was poorly but then I had a member of my family to help me and then it was just easy to do and I'm not good at things like that. I found it easier to do after a while.*" **(Site C, Patient 6)**

The functionality of the technologies was not discussed in detail by patients, however several patients and staff reported issues particularly related to set-up because they required downloading and remembering log-in details. Two sites offered face-to-face support to patients at onboarding for this.

Staff's experiences of using the models to process symptom data for large numbers of patients
Two themes emerged as key to staff experiences of processing symptom data: the scalability of the models, and the ease-of-use and functionality of tech-enabled systems.

Scalability of the models
Tech-enabled and analogue models were considered by staff to be more scalable than analogue-only models. Service leads from three sites reported in interviews that they had adopted tech-enabled platforms to ensure services could cope with a high volume of patients, and staff from six tech-enabled sites highlighted that there were efficiency gains from data being entered by patients in real time:

> "*At the peak we were on I think hundred and ninety-six on the service… and each of them were submitting three or four points of data, three times a day…. that's well over two thousand bits of data coming in a day. There's just no way manually we would have been able to do that.*" **(Site G, interviewee 1 - Service lead)**

Staff interviewees from two analogue-only sites noted that phone calls were labour intensive and necessitated a larger workforce (relative to patient numbers), and manual data entry, was required

for each patient so that services could keep abreast of patients using the service. Staff survey findings indicated that mixed tech-enabled and analogue models had more positive impact (p=0.034) on workload compared to analogue-only ones: 52% of staff using tech-enabled models reported a positive impact while only 35% of staff using analogue-only reported one (see *Supplementary file 8*). However, service lead/manager perceptions of the capacity/resources needed to deliver services (as reported in the survey) were not statistically significantly different (p=0.554) across models (although the smaller sample size for this question should be noted, see *Supplementary file 8*).

Ease-of-use and functionality of tech-enabled systems
Staff reported monitoring patients as statistically significantly easier (p=0.005) for tech-enabled and analogue service models (77% of staff reported monitoring as easy/very easy) compared to analogue-only models (56% of staff reported monitoring as easy/very easy) (see *Supplementary file 8*). However, staff interviewees reported an extensive number of ways that tech-enabled platforms could be enhanced to support their clinical and operational needs (see *Appendix 5, Table 28*), and staff across several sites reported that they were frustrated by the length of time it took for tech providers to make changes to platforms.

Patients' and staff's experiences of the clinical relationship
Three themes emerged relating to patients' and staff's experiences of the patient-clinician relationship embodied in the remote home monitoring models: staff knowledge of patients' condition, reassurance and providing appropriate care, and concordance in the patient-clinician relationship.

Staff knowledge of patients' condition
Phone calls were an essential element of both models, enabling staff to gain comprehensive knowledge of their patients' condition. Staff using tech-enabled and analogue models used the data they received to get an overview of patients' health status and called patients if there were signs of deterioration to conduct a more thorough assessment (e.g. assessing breathlessness, re-taking readings, measuring oxygen saturation after exertion, and assessing patients' coherence and anxiety). Phone calls were also useful for gaining information about patients' social circumstances and mental health, sometimes prompting referrals to other services:

> "*Many of the patients when we come across… live on their own. So, it's not just their health it's the… wellbeing of the patients as well… There are many times where I have done the referrals… and provided more support for them, for food and other medications and things like that.*" **(Site D, interviewee 4 - Healthcare professional delivering the service)**

Some staff members (across both tech-enabled and analogue and analogue-only models) highlighted that on the phone (or in person) patients were more likely to mention other medical symptoms in passing, which might require attention. Staff from two analogue-only sites reported that the depth of knowledge gained from phone calls was one of the key reasons for not adopting a tech-enabled model of care.

Reassurance and providing appropriate care
Patient and staff interviewees across all sites reported that patients found services very reassuring at a time when they were feeling very unwell, isolated or anxious about the diseasee. There was no evidence of a difference (p=0.559) between models in how patients rated contact with the service team (see *Supplementary file 8*). Staff across all sites reported that the opportunity for patients to discuss symptoms with a clinician reassured them and prevented patients from unnecessarily contacting emergency services or encouraged deteriorating patients to go into hospital when they were afraid to:

"So a lot of [patients], when you speak to them, and you say, 'Actually look, your levels were 92. I've exerted you for a minute they've dropped down to 89, can you hear yourself gasping on the phone?' They say, 'Yes.' And I say, 'Well that's really serious you do need to call an ambulance.' And then they will come around to it." **(Site A, interviewee 4 - Healthcare professional delivering the service)**

Regardless of the mode (p=0.158), patient survey respondents reported that contacting a health professional was relatively easy. However, seeking further help if they had concerns about their health was statistically significantly easier (p=0.006) for patients using tech-enabled modes (see *Supplementary file 8*). Several patients using tech-enabled models reported that despite receiving an automatic prompt to escalate their care when readings were low they preferred to first speak to the service for a more personalised/thorough assessment.

Managing the patient-clinician relationship

Patient interviewees reported that being contacted by staff if they had missed readings gave them a sense of security and reassurance. However, for staff, chasing and managing non-submitters could be time-consuming, frustrating and worrying, consuming valuable resources. Services tried to encourage patients to relay data by setting out service requirements at onboarding, and emphasising the importance of relaying readings:

"What we found initially was that [expectation of submitting twice a day] wasn't explained fully and then we were having to chase them a lot for readings. So that is really explicit at the start now that… almost like as daft as it sounds like a verbal contract. You know, 'We will do all of this however, what we expect of you is you know readings twice a day to be compliant'." **(Site I, interviewee 3 – Staff member involved in data)**

Several staff delivering tech-enabled and analogue models highlighted the importance of patients understanding that whilst readings were reviewed regularly, communication was not synchronous and patients still needed to call emergency services if oxygen saturation levels were low. However, some patients reported preferring to speak to services before escalating their care.

Discussion

Key findings

Tech-enabled care was not a substitute for human contact in COVID-19 remote monitoring services; phone calls and human relationships were a feature of all models of remote monitoring and patients found services reassuring (across models). This indicates that technology cannot completely replace phone calls. Patients using tech-enabled methods tended to be younger, well-educated and more likely to identify as White-British compared to analogue methods and most patients did not recall being given a choice about the mode offered. Staff considered tech-enabled and analogue services to be more scalable and able to deal with larger volumes of data and patients than analogue-only services.

How findings relate to previous research

Consistent with previous studies,[165, 227, 229] staff noted that better functioning systems that fit with their work practices would have greatly improved efficiency, highlighting the need to involve clinicians in the design and development of technical platforms. Patient involvement was also missing from their development; patient participation groups and patient experience work were considered non-essential early on in the pandemic.[234] As a number of different tech-enabled models have now been established, there is an opportunity for service leads to trial different systems and incorporate patient feedback/involvement.

Patients in all models were contacted by telephone if their symptoms deteriorated or they did not submit readings, with the exception of two sites that offered a self-monitoring service. Staff reported that pursuing non-submitting patients could unnecessarily consume resources. Consistent with previous research showing staff concerns about patient safety in chronic conditions, the acute nature of COVID-19 caused staff anxiety about rapid deterioration.[165] There is a question of whether services' resources could have been better optimised for patients' needs, by addressing concerns about risk in staff supervision and training, by offering more lower-risk patients self-monitoring, by adapting tech-enabled platforms to offer varying levels of automated contact, and/or following more stringent protocols for managing non-submitters (for example, discharging patients back to the care of their GP if they miss three data submission points).

Previous studies have shown that both patients and staff have responded positively to remote home monitoring for chronic health conditions,[227, 235] and a small number of studies have been conducted on patients' experiences of COVID-19 remote home monitoring. [222] This is the first study to examine in-depth patient and staff experiences of using tech-enabled and analogue modalities to respectively relay and process COVID-19 symptom data and compare experiences of the patient-clinician relationship. It builds on our work looking more broadly at patients' experiences of COVID-19 remote home monitoring services (see *Chapter 9*).

This study supports prior work that has shown that some patients may need additional support to engage with technology or access to analogue options,[219, 231] and the importance of maintaining human contact.[232, 233] Older patients, less well-educated patients and patients identifying as non-White were more likely to relay symptoms through phone calls with the service, with staff primarily determining the allocation of mode. Co-designing digital health services with patients, improving digital health literacy in the population, training and supporting the workforce to build digital skills and confidence, and gathering data on patients' access to technology and digital skills could widen patient participation in digital healthcare.[204, 226]

Staff engagement has been explored in previous studies,[165, 227] but this study extends previous research by considering the scalability of models, with staff considering tech-enabled and analogue models better equipped for managing large patient numbers without jeopardising clinical relationships. However, future models of remote monitoring should tailor their frequency of contact to patients' level of risk and include systems which create a dialogue between patients and staff as to their preferences.

Strengths and Limitations

There was a high level of variation between different models (see *Chapter 4*). Few sites adopted analogue-only modes of data submission, and no sites used tech-enabled-only modes, making it difficult to assess whether differences in patient and staff experiences between tech-enabled and analogue models were due to the engagement with the technology, or related to other service factors. This also meant it was not possible to use multivariate analyses to look at staff experiences (based on survey responses) across models, due to the limited sample size in analogue-only sites. Therefore the univariate analyses of staff and patient experiences could have been subject to false positives due to the number of comparisons made. However, in-depth data collection from staff on the functionality of tech-enabled models at four sites enabled us to draw out specific tech-related findings.

We had originally planned to use 'think aloud' methodology with patients but in practice, these did not work because patients no longer had access to the tech-enabled platforms they had used and their recall of their use and functionality during ill health was poor.

The language and terminology describing technology was unfamiliar to some staff and patients, for example, understanding the difference between a web-link and a digital app.

Conclusions

Organisations implementing tech-enabled remote home monitoring at scale should consider providing flexible models which can tailor processes and resources to accommodate patients with different needs and requirements. These include: risk levels, abilities to engage with and access technology, support available at home from family or carers, and levels of desire for support versus self-management. Services routinely collecting and monitoring data on patients' access to technological infrastructure and skills could inform digital inclusion strategies for remote home monitoring.

Chapter 12. Discussions and conclusions

Overview

This study was a mixed-methods evaluation of COVID-19 remote home monitoring services in England.

Phase 1 of the evaluation (rapid systematic review, empirical mixed-methods implementation study) aimed to analyse implementation and impact of COVID-19 remote home monitoring services, develop a conceptual map of these services, explore implementation and staff experiences and understand data use, staffing and resource allocation (see *Chapter 1* and [32, 36]). We also shared findings in a timely way so these could inform the national roll-out of COVID-19 remote home monitoring services implemented throughout England.

Phase 2 aimed to explore effectiveness, cost, implementation, and staff and patient experiences of COVID-19 remote home monitoring services (see *Chapter 1*). It comprised four workstreams. Workstream 1 explored effectiveness of COVID-19 remote home monitoring services (see *Chapters 5* and *6*). Workstream 2 included an analysis of the composition of the workforce involved in providing COVID-19 remote home monitoring services and a cost analysis of these services (see *Chapter 7*). Workstreams 3 and 4 included a national survey and in-depth case studies of implementation, staff and patient experience, including a focus on health disparities and mode of data submission offered by services, whether technology-enabled and analogue or analogue-only (see *Chapters 4* and *8-11*).

Within this chapter, we provide a summary of key findings with a focus on our research questions (see *Chapter 1*). We then discuss the implications and lessons learned, the strengths and limitations of our evaluation, the potential impact of our findings, future research areas and conclusions.

Summary of key findings

Below, we describe key findings from Phases 1 and 2 of our evaluation (see Figure 27 for a summary).
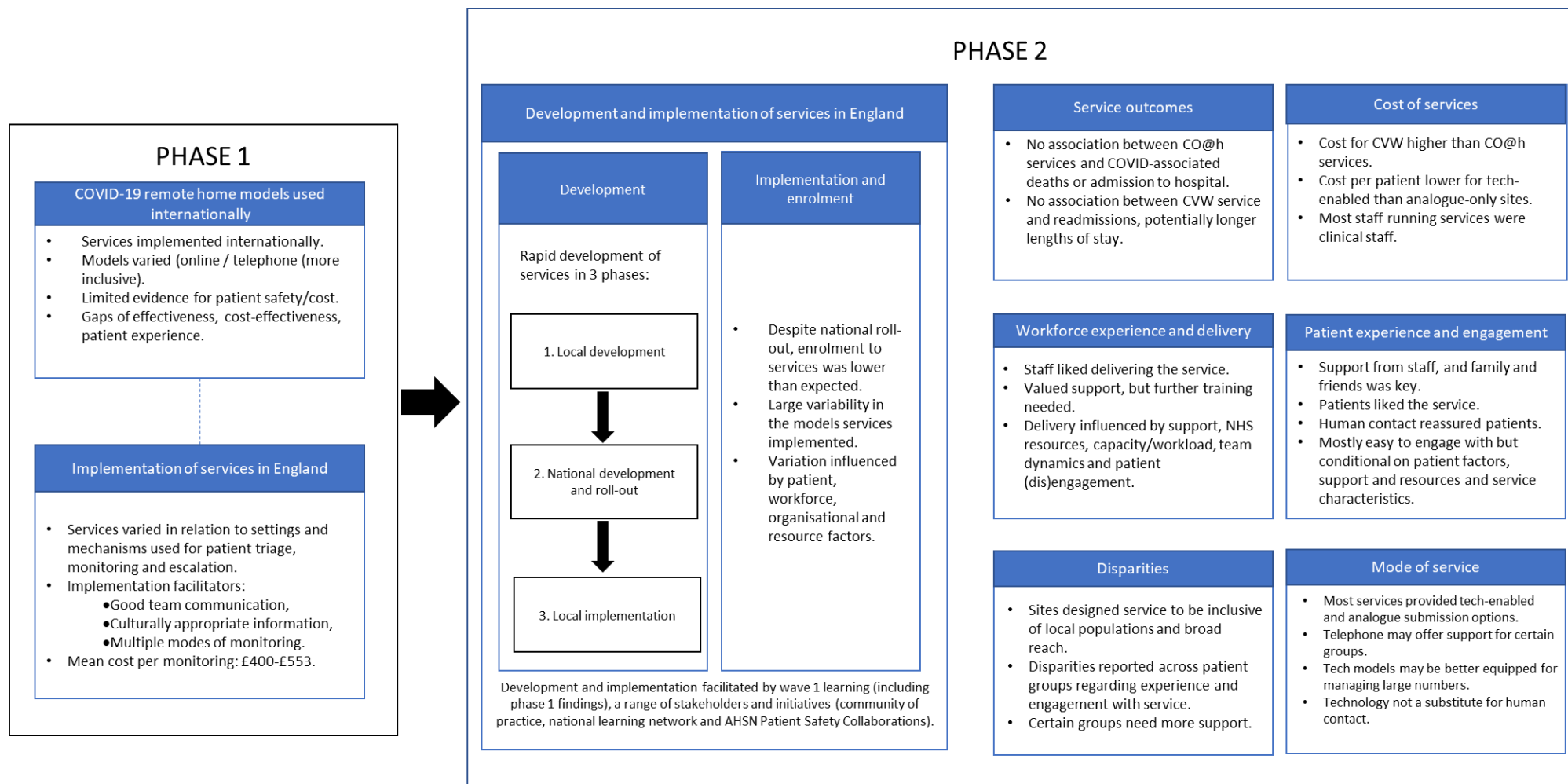
PHASE 1

COVID-19 remote home models used internationally

- Services implemented internationally.
- Models varied (online / telephone (more inclusive).
- Limited evidence for patient safety/cost.
- Gaps of effectiveness, cost-effectiveness, patient experience.

Implementation of services in England

- Services varied in relation to settings and mechanisms used for patient triage, monitoring and escalation.
- Implementation facilitators:
    - Good team communication,
    - Culturally appropriate information,
    - Multiple modes of monitoring.
- Mean cost per monitoring: £400-£553.

PHASE 2

Development and implementation of services in England

Development

Rapid development of services in 3 phases:

1. Local development

2. National development and roll-out

3. Local implementation

Implementation and enrolment

- Despite national roll-out, enrolment to services was lower than expected.
- Large variability in the models services implemented.
- Variation influenced by patient, workforce, organisational and resource factors.

Development and implementation facilitated by wave 1 learning (including phase 1 findings), a range of stakeholders and initiatives (community of practice, national learning network and AHSN Patient Safety Collaborations).

Service outcomes

- No association between CO@h services and COVID-associated deaths or admission to hospital.
- No association between CVW service and readmissions, potentially longer lengths of stay.

Cost of services

- Cost for CVW higher than CO@h services.
- Cost per patient lower for tech-enabled than analogue-only sites.
- Most staff running services were clinical staff.

Workforce experience and delivery

- Staff liked delivering the service.
- Valued support, but further training needed.
- Delivery influenced by support, NHS resources, capacity/workload, team dynamics and patient (dis)engagement.

Patient experience and engagement

- Support from staff, and family and friends was key.
- Patients liked the service.
- Human contact reassured patients.
- Mostly easy to engage with but conditional on patient factors, support and resources and service characteristics.

Disparities

- Sites designed service to be inclusive of local populations and broad reach.
- Disparities reported across patient groups regarding experience and engagement with service.
- Certain groups need more support.

Mode of service

- Most services provided tech-enabled and analogue submission options.
- Telephone may offer support for certain groups.
- Tech models may be better equipped for managing large numbers.
- Technology not a substitute for human contact.

Figure 27. Summary of key findings.

Key findings from Phase 1 (see *Chapter 3*)

Systematic review of COVID-19 remote home monitoring services [32]

- Remote home monitoring services have been implemented internationally for COVID-19, an acute condition, during the pandemic.
- Models of remote home monitoring for COVID-19 varied (online platforms, paper-based systems with telephone calls or wearable sensors), but models using phone calls were considered more inclusive.
- This review was unable to reach substantive conclusions regarding patient safety and cost, due to study design, missing data and the lack of standardised reporting.
- Gaps in evidence for effectiveness, cost-effectiveness and patient experience of COVID-19 remote monitoring services.

Implementation of services during wave 1 [36]

- COVID-19 remote home monitoring services implemented throughout England varied in relation to the healthcare settings and mechanisms used for patient triage, monitoring and escalation.
- Many factors facilitated implementation, including good communication within clinical teams, culturally appropriate information for patients and carers, and the combination of multiple approaches for patient monitoring (app and paper-based).
- The mean cost per monitored patient varied from £400 to £553, depending on the service.

Key findings from Phase 2

Development and implementation of services during wave 2 (see *Chapter 4*)

- The rapid development of national remote home monitoring services took place in three phases: local development, national development and roll-out and local implementation.
- Development and implementation were facilitated by learning from wave 1, a range of national and local stakeholders and organisations, and a range of initiatives (community of practice, national learning network, AHSN Patient Safety Collaborations).
- Despite national roll-out, patient enrolment to COVID-19 remote home monitoring services was lower than expected.
- There was large variability in the models of remote home monitoring services that were implemented.
- Variation was influenced by patient, workforce, organisational and resource factors.

Outcomes (see *Chapters 5* and *6*)

- We found no association between rates of patient enrolment to CO@h services and COVID-associated mortality or admission to hospital. Additionally, for hospital admissions, no relationships were found between enrolment rates and in-hospital mortality or LOS (see *Chapter 5*).
- We found no evidence that the roll-out of CVW services reduced lengths of stay in hospital or rates of readmission for hospitalised COVID-19 patients (see *Chapter 6*).
- Low rates of patient enrolment and incomplete data may have affected the chances of detecting any possible impact.

Cost (see *Chapter 7*)

- We were unable to conduct a cost utility analysis due to the absence of impact of the services on mortality or hospitalisation.
- For CO@h services, the mean cost per patient triaged was £351.8 and per patient monitored was £527.5. For CVW services, the mean cost per patient triaged was £581.8 and per patient monitored was £599.1.

- The mean cost per patient monitored was lower for tech-enabled and analogue sites than analogue-only sites (CO@h and CVW services).
- Most staff involved in running COVID-19 remote home monitoring services were clinical staff. Examples of clinical roles included consultants, emergency department staff, GPs, nurses, advanced nurse practitioners and medical students.

Workforce experience and delivery (see *Chapter 8*)
- Staff generally reported positive experiences of delivery and felt that services were easy to deliver.
- Staff valued support provided nationally and locally. But some staff would have benefitted from further training.
- Support for delivering the service, NHS resources, capacity and staff workload, multidisciplinary team dynamics, and patient (dis)engagement influenced delivery.

Patient experience and engagement (see *Chapter 9*)
- Many patients and carers reported positive experiences and felt that services and human contact received reassured them and were mostly easy to engage with.
- Engagement was conditional on a range of factors including patient factors (e.g. knowledge and health), support and resources, and service characteristics.
- Findings indicate that burden of treatment may be experienced by patients and families when implementing remote monitoring for COVID-19.

Disparities (see *Chapter 10*)
- Many sites designed their service in an attempt to be inclusive of the needs of local populations and to ensure a broad reach.
- Despite local adaptions to services, disparities were reported across patient groups (e.g. with age, health status, ethnicity and level of education) in their experience of, and engagement with services in terms of accessibility, achievability of tasks, and problems experienced.
- Certain groups may therefore require additional support to engage with COVID-19 remote home monitoring services.

Modality of service (see *Chapter 11*)
- Most services offered both analogue and tech-enabled submission options.
- The patient cohort using tech-enabled modes of relaying symptom data differed from patients using analogue methods (i.e. by age, level of education and ethnicity).
- The choice of mode used by patients was primarily made by staff, but most patients reported being satisfied with the mode allocated.
- Staff considered the tech-enabled models better equipped to manage large patient numbers.
- Many improvements were suggested to improve functionality of technology systems to better fit staff and patient needs.
- Tech-enabled engagement was not a substitute for human contact.

How findings relate to previous research
In this section we present findings in relation to previous research.

Implementation

The use of remote home monitoring

In recent years, remote home monitoring services have become a priority for policy makers and the NHS.[18, 159] Previous research demonstrated that remote home monitoring models have been widely implemented for a range of chronic conditions.[19-21] This evaluation extends the evidence base by showing that remote home monitoring models have also been widely used internationally for patients with COVID-19 (see *Chapters 3* and *4*). We provide evidence for the range of services implemented for

COVID-19 and the types and frequencies of remote home monitoring used. Additionally, our review and implementation study provide insights into the components and processes involved in these services.

Major system change

Our evaluation provides nuanced understanding of major system change in a rapid emergency context (i.e. a global pandemic). There are different ways of implementing major system change (top-down and bottom-up approaches), but a combination of approaches may be beneficial.[108] Findings from COVID-19 remote home monitoring services indicate that rapid implementation processes may follow a bottom-up, top-down then bottom-up process (as described in *Chapter 4*). Therefore, rapid implementation may vary from major system change in non-rapid contexts (e.g. [107]).

Previous research outlined five conditions for major system change: involving stakeholders from all levels, establishing feedback loops, attending to history, engaging healthcare providers, and engaging patients and families.[106, 108] Our findings offer support for the involvement of professionals and patients and families in service change as staff and patient engagement was integral in implementing COVID-19 remote home monitoring services. Whilst engagement from staff and patients/carers is critical when implementing services rapidly, it is also potentially more challenging due to time constraints. Additionally, we highlight the importance of national and local clinical leaders and their pivotal roles in developing and shaping services, and the facilitating impact of collaboration between organisations.

Factors influencing implementation and variation

Prior to this evaluation, there was limited evidence regarding how COVID-19 remote home monitoring services have been implemented. This evaluation (see *Chapters 3* and *4*) found that most remote home monitoring services studied had low patient enrolment and that there was considerable variation in which model was implemented and how according to local context. These findings support previous research demonstrating likelihood of variation when implementing national services generally [82-84, 93-96] and in response to the COVID-19 pandemic.[90-92] Previous research has highlighted differences in the models implemented and the ways in which services are implemented must be considered when interpreting effectiveness and cost-effectiveness of services.[57, 82, 84, 85, 89]

The context of rapidly developing COVID-19 remote home monitoring services during a global pandemic may explain some of the variation identified between national guidance and local implementation. Findings demonstrated that service models were initially developed locally, then further developed and rolled out nationally, before being implemented locally (see *Chapter 4*). It is likely that the rapid process of development of services may have culminated in variation (between national guidance and local services, and between different local services), as sites were often running prior to national guidance. Given the low enrolment rates and variation demonstrated in our evaluation, further consideration is needed to identify the 'right' balance between adhering to national SOPs (e.g. [38, 39]) and flexibility needed within local services. This balance may be challenging to achieve for services like COVID-19 remote home monitoring, which have been rapidly developed and implemented during a pandemic, when time is limited. This limits the ability for national and local stakeholders to give, receive and implement feedback and also to understand how different approaches to implementation may relate to effectiveness.

Additionally, our evaluation offers support for previous research which has highlighted the role that local factors have on implementation.[82-88] We demonstrate that local factors (patient, staff, organisational and resource factors) are of importance when implementing national services for COVID-19 (see *Chapter 4*). Our Phase 1 study also demonstrated facilitators (e.g. clear communication channels, positive engagement from patients, dedicated clinical leaders and support from senior management) and barriers (e.g. unclear referral processes, challenges monitoring patients remotely,

lack of administrative support and resources, workforce capacity and lack of data systems) (see *Chapter 3* and [36]).

Evaluating effectiveness and cost of services

Effectiveness of COVID-19 remote home monitoring services

Prior to this evaluation, there was little robust evidence for the effectiveness and cost of COVID-19 remote home monitoring services. Our findings on the national CO@h programme are consistent with other evaluations of the same programme, which found no impact on mortality or health service utilisation.[43] However, our findings (for both CO@h and CVW) contrast with potentially promising effects of remote home monitoring services for COVID-19 patients (e.g. [116, 118, 119, 125-127]) and individuals with other health and care needs.[236, 237] Our findings differ from previous COVID-19 research findings possibly due to differences in study design and limitations associated with these (including with respect to the intervention cohorts, outcomes, and comparator groups). In addition, these other studies typically reported on single-site or single-area implementation (see *Chapters 5* and *6* for discussion of these studies). The low rates of patient enrolment and lack of complete, or linkable data may have affected the ability of our studies to detect any true impact that may have existed. [116, 118, 119, 125-127, 236, 237]

Despite some evidence that remote monitoring of COVID-19 patients can be locally effective we have not been able to replicate such findings at a wider level. Because of the influence of missing data, lower enrolment to the CO@h service than expected and the lack of linkable data for the virtual wards, the more immediate concerns are for better data collection processes and enrolment rather than any judgement as to whether the services are worthwhile. Indeed, the effectiveness of some local programmes could have been lost among the analysis of national data.

Cost of COVID-19 remote home monitoring services

Prior to this evaluation, there was limited evidence of cost analyses for remote home monitoring services (see *Chapter 3* and [32]). Previous studies have stated that similar interventions may be cost saving by reducing downstream costs (in terms of avoiding hospital admissions and bed days).[31] Findings from our cost analysis of COVID-19 remote home monitoring services were consistent with a recent Australian study where staffing costs were the main contributors to the total costs of monitoring.[149]

Staff and patient experiences

Staff-patient relationships

Previous research has highlighted concerns over the staff-patient relationship being jeopardised by remote delivery of healthcare services.[165, 171] However, learning from our staff and patient studies indicated that this was not the case. For example, our analysis of staff experience delivering tech-enabled and analogue modes of remote home monitoring indicated that staff valued remote home monitoring services as they were able to support patients and appropriately identify the right place of care for them, allowing a therapeutic relationship to develop (see *Chapter 11*). Additionally, the patient study indicated that patients felt reassured by the contact provided by staff remotely and that the care provided at a distance was appropriate (see *Chapter 9*). Remote home monitoring services do not necessarily jeopardise staff-patient relationships usually built during face-to-face appointments. That said, our findings indicate that some form of human contact is imperative within these services, supporting previous research.[232, 233]

Staff experiences delivering COVID-19 remote home monitoring services

Previous research indicated that there were several potential benefits and challenges of remote home monitoring services for staff.[154, 156, 158, 159] This evaluation extends previous research by demonstrating that staff generally had positive experiences of delivering remote home monitoring services in this context, but that there are specific barriers that need to be overcome, for example relating to training

and provision of oversight by senior clinicians. However, it must be acknowledged that some staff felt that there was additional burden and workload associated with delivering remote home monitoring services and, more generally, it is clear that delivery relies heavily on staff.

Patient engagement

Previous research has explored patient involvement in healthcare delivery (e.g. self-management, engagement and treatment burden) for many chronic conditions,[50, 51, 180, 187, 188] but little research had been conducted into patient experience and involvement in remote home monitoring services (using tech-enabled and analogue modes) for acute conditions such as COVID-19. Our evaluation offers considerable evidence to indicate that patients were able to engage with remote home monitoring services when managing acute conditions such as COVID-19 (see *Chapters 9* and *11*), but that this engagement was conditional on a range of patient, staff, organisational and resource factors and heavily relied on support from family and friends (see *Chapter 9*).

Staff and patient qualitative and survey findings indicated that there are groups of individuals for whom remote home monitoring services may be less appropriate due to enhanced difficulties engaging with services (see *Chapters 8-11*). This finding is consistent with previous research.[200-203, 219, 226, 238, 239] Additionally, we highlight further challenges that must be considered for COVID-19, including infection transmission for family members providing support, and uncertainty and fear around seeking help in hospital settings.

Co-production

This evaluation extends previous research by outlining the importance of co-production of services with staff involved in delivering these services and patients receiving these services. Previous research has highlighted that it is necessary to involve patients and staff in development and implementation to ensure that services meet their needs [240] and that service components, such as digital solutions, are fit for purpose.[165, 227, 229, 234] Our results indicated that efficiency, utility and value functionality of tech-enabled solutions could be improved by involving staff in co-design and offering them opportunities to observe and test different platforms. Whilst findings indicated services did try to develop and implement strategies to meet the needs of their population (see *Chapter 10*), patient involvement was not necessarily consistently incorporated throughout service development and implementation (see *Chapter 4*). The rapid nature of development and set-up of services appeared to limit scope for involving staff and patients in decision-making. This meant that staff and patient experience was at times hindered by decisions made without involvement (see *Chapter 11*). There remain gaps on if and how conventional methods of engagement can work within rapid timescales; it is possible that engagement approaches for coproduction may need to be reconsidered within rapid contexts.

Implications

In this section we outline overarching implications arising from these findings which relate to implementation, evaluating remote home monitoring services, and staff and patient experience (see Table 23 for implications). These implications apply to COVID-19 but may also apply to remote home monitoring services for patients with other conditions.

Table 23. Summary of implications arising from the findings in this evaluation for remote home monitoring services (for COVID-19 and in some cases for other conditions).

Topic		Implication
Implementation		
The use of remote home monitoring	1.	Details on how remote home monitoring services have been used, and the components of these services, can be used to inform the rapid future development, implementation and local adaptation of remote home monitoring services for COVID-19 but potentially also other acute conditions.
Implementation of COVID-19 remote home monitoring services	2.	Our understanding of how services have been implemented can be used to interpret effectiveness and cost of COVID-19 remote home monitoring services.
Factors influencing implementation and variation	3.	When developing and rapidly implementing national roll-out of remote home monitoring services, considering the context and priorities of local organisations may facilitate implementation. For example, service planners need to acknowledge that the eligible population and local population needs may vary between sites and over time, and that clinician discretion may play an important role in enrolment decisions.

	4.	Services and national programmes need to be developed and evaluated in ways that encourage local variation and flexibility. Key considerations identified in the study of 28 services included:
		    i. Providing strategies to proactively identify cases and onboard eligible patients
		    ii. Providing an indication to local services of the level of clinical oversight and staffing needed
		    iii. Supporting local services to work collaboratively across settings
		    iv. Providing guidance on the resources needed to implement remote monitoring services.

	5.	Learning networks and communities of practice may be helpful in supporting local services to share and receive information on how services have adapted the national model, what is working or not working, and to learn from one another. This may facilitate informal feedback loops into the development and implementation process.
Evaluating remote home monitoring services		
Effectiveness	6.	There is a need for better data collection processes that operate alongside future services in order to evaluate impact and cost, not least to help understand which modes of implementation are most effective. This includes routine linkable patient-level data on onboarding and use of remote monitoring in the community and on the use of virtual wards after hospital discharge.
Service reach	7.	Demographic data for those accessing services should be collected, so that service planners/providers can understand reach and gaps in reach, and develop strategies to address these.
Cost	8.	Information on staff involved (by band, hours worked), the monitoring mode use (tech-enabled vs. analogue) and the other resources used should be consistently and carefully collected.

	9. Due to the ad-hoc nature of the COVID-19 remote home monitoring wards, information on planned and unutilised capacities will help to understand actual costs and support future planning.
	10. Linkage of health outcomes with the economic costs would add significant knowledge for a possible cost-effectiveness analysis of remote home monitoring services.
Staff and patient experiences	
Staff-patient relationships	11. Service planners may be able to consider the use of COVID-19 remote home monitoring services (which include human contact) in lieu of establishing relationships face-to-face. Some patients had a wish for human contact (for health-related and emotional support), especially in the context of safety-netting. Therefore, services that do not offer human contact with staff may not always be appropriate or meet the full range of patient needs. The balance between remote and face-to-face modes needs to be considered for patients with COVID-19 and other conditions as appropriate. However, learnings must be viewed within the unique pandemic context (in which face-to-face contact was minimised and not necessarily desirable). It is not yet known whether public and staff views on the acceptability and appropriateness of remotely delivered care will endure beyond the pandemic.
Staff experiences	12. Service planners and local services must ensure that processes are in place to support staff to deliver services efficiently, e.g. making sure there is sufficient staff capacity to manage demand for the service, availability of senior clinicians to provide oversight and greater training and guidance available to staff.
Patient engagement	13. When designing services, service planners need to take into account and address the impact of treatment burden and the barriers faced by groups of patients who found engagement harder (e.g. older patients, those from ethnic minorities and patients with existing health problems). For example, different patients may require different levels of support, therefore services could develop/adapt their services to ensure they are providing sufficient frequency of contact with patients at different level of risk
	14. As many patients required support to engage with these services, consideration needs to be given to infection transmission, the caring burden and those living alone.
Co-production	15. Service planners (nationally and locally) should ensure that intended service users (patients and carers) and staff are consulted at the design stage of a service, in order to ensure that services are appropriate for use. It is not yet known how best to involve patients and staff in co-production when developing services rapidly.

Strengths and limitations

Strengths

Our evaluation was a large-scale mixed methods evaluation which included analysis of national datasets, and primary data collection from 28 sites which were representative of a range of regions, levels of deprivation, ethnicity, size of population, and a range of urban versus rural sites. However, it is possible that our study may not be representative of all sites. Using mixed methods (consisting of a systematic review, qualitative data collection and analysis, quantitative data collection and analysis and economic data collection and analysis), enabled us to explore a range of topics and triangulate data from multiple perspectives and sources. For example, we were able to explore possible reasons for low patient enrolment demonstrated by the quantitative national datasets within the qualitative case-study findings.

This evaluation was a rapid evaluation completed over two time periods. Our Phase 1 study was completed within two months, and our Phase 2 mixed-methods study was completed within one year, with data collection taking less than six months. Our rapid approach to this evaluation meant that learnings from the evaluation were able to be used in real time to inform future service development and evaluation (see *Project website documentation - Dissemination*). Additionally, conducting our evaluation over two time periods (coinciding with wave 1 and wave 2 of the pandemic) enabled us to capture learnings and constants/changes over time.

Throughout our evaluation, a number of actions were taken to ensure robustness of qualitative findings (see Chapter 2).

Our evaluation team (a multi-disciplinary research team) worked collaboratively with, yet independently from two other evaluation teams and key stakeholders from NHSEI and other organisations. This meant that evaluation teams were able to share findings in order to evaluate services from multiple perspectives, thus providing findings with more credibility. Additionally, our evaluation team worked closely with our PPI group and the 70@70 cohort throughout the study.

Limitations

Data completeness was a limitation of the quantitative and cost elements of this study. The evaluation of effectiveness for CO@h could only be carried out for CCGs where the onboarding data was believed to be complete, which was only one quarter of all CCGs. For CVWs, we were able to undertake a national analysis, but we had no knowledge about which patients were referred to a virtual ward, or even how many. Additionally, cost and resource use data provided by some sites were incomplete.

Our CO@h effectiveness study (see *Chapter 5*) and the cost study (See *Chapter 7*) used aggregated data rather than individual patient-level data for key analyses. This meant that patient-level variation in outcomes and programme costs could not be examined. However, patient-level data on outcomes were examined by the other evaluation teams.[42-45]

It was not possible to conduct all aspects of the evaluation as planned in the protocol. For example, a cost-utility analysis was not undertaken, given there was no evidence found of an effect of COVID-19 remote home monitoring services on mortality or downstream hospital utilisation. Additionally, for the qualitative study, we were unable to fully embed 'think aloud' interviews within our tech-enabled four case study sites as this was not feasible in practice.

Compared to patient onboarding data,[115] the sample in the patient experience study was under-representative of some groups (e.g. older patients, ethnic minorities and most deprived) and over-representative of other groups. Additionally, the response rate for the patient and carer survey was fairly low (17.5%). For patient experience surveys and interviews, participants who had declined services could not be recruited. Additionally, our study would not have included the views of staff or

patients who were unable or did not want to take part in surveys and interviews. Therefore, our study may not be representative of all patient and staff groups and experiences.

These services were rapidly developed to respond to the global pandemic. Additionally, our evaluation was rapidly conducted within a pandemic. Therefore, our conclusions may lack generalisability to other acute conditions, as staff and patient expectations and attitudes may be different during a pandemic (e.g. perhaps staff and patients may be more appreciative of the service, given the wider context).

Future research

Whilst this evaluation has contributed to growing evidence on COVID-19 remote home monitoring services, there are still some further avenues of future research which would benefit from being explored.

Firstly, further research, including longitudinal evidence, is needed to explore further the effectiveness and cost-effectiveness of COVID-19 remote home monitoring services. However, for this to happen, high quality complete data need to be collected for the uptake and use of these services that can be linked to routine datasets.

Secondly, further research is needed on the most appropriate type of model for remote home monitoring for different groups of patients. For example, further research could compare the effectiveness, cost-effectiveness, implementation and staff/patient experiences of remote home monitoring services which are supported by staff, versus those which are purely self-monitoring models (patients monitor and escalate their own care). Additionally, research could explore whether there is an optimum frequency of contact for patients with varying needs and risks; which models of remote home monitoring services are most appropriate for which groups of patients; how 'standard' models can be adapted to be more accessible and appropriate for diverse groups; and whether different models impact on number of patients onboarded to these services.

Finally, further research is needed to explore other experiences which may not have been captured within this evaluation. For example, sites who were less research active, groups of staff whose views may not have been included or were limited in this evaluation (i.e. ambulance staff and volunteers) and patients who we were unable to reach in this evaluation (e.g. those who declined or disengaged from the service). Additionally, future research needs to explore carers' perspectives in more detail and any treatment burden associated with informal care provided as part of these services.

Equality, Diversity and Inclusion

Participant representation

Within this evaluation, we aimed to ensure that participants were representative of different locations within England and different backgrounds.

Site characteristics

We recruited 28 sites to our national staff and patient surveys and 17 sites for staff and patient interviews. The 28 sites included services from all regions across England, represented CCGs and trusts, varied in urban/rural characteristics, deprivation scores, ethnicity and size (see *Chapter 4* and *Supplementary file 2*).

Strategies to improve representation

Within the study we undertook a range of strategies to try and ensure that our study was inclusive. For example, we offered a choice of paper or electronic surveys for patients, and attempted to make it easy for participants to return surveys by providing free post envelopes. We also provided patient and carer study materials (information sheets, surveys) in English, Polish, Bengali, Urdu, Punjabi,

French and Portuguese and offered translation services for interviews if needed. Whilst sites offered potential participants translated materials, uptake of these was low and the research team received no completed translated surveys. We also aimed to purposively sample using a range of criteria (e.g. age, gender, ethnicity, onboarding mechanism, type of monitoring and outcome), to ensure that our sample was as inclusive and representative as possible. We offered different modes of interview (telephone, Microsoft teams, or zoom) and different times depending on participants' preferences and to ensure accessibility for as many people as possible. We offered the option for a family member to answer on behalf of patients for both the survey and interview if appropriate.

Further efforts are needed to ensure that studies are as representative as they can be in future, e.g. raising awareness of translated materials and opportunities for interpretation services. There were limited opportunities in our study to reach out further due to services being gatekeepers to potential participants and the rapid pragmatic timescales of our study.

Participant characteristics
Our patient and carer surveys and interviews included a range of participants of different ages, living circumstances, educational qualifications, work situations, disability, and deprivation score. However, our patient and carer survey and interview participants were mostly white, straight and had English as a first language (see *Chapter 4* and *Supplementary file 2*). We also compared our participant demographics with service patient onboarding data,[115] and found that our survey and interview sample was under-representative of some groups (e.g. older patients and ethnic minorities) and over-representative of other groups (e.g. participants from white ethnic groups and patients in the least deprived deciles of the IMD). Additionally, patient and carer response rates for the survey was only 18%. We were unable to interview or survey anyone who had declined the service or disengaged.

Staff included in our surveys and interviews varied in their role, whether they were redeployed, length of time in position, and the location they were based (see *Chapter 4* and *Supplementary file 2*). Additionally, staff response rates for the survey was only 39%. We did not collect data relating to staff personal demographics e.g., ethnicity as we focused on professional characteristics.

Research topics relating to equality, diversity and inclusion
Our study had a clear focus on inequalities of COVID-19 remote home monitoring services, including an analysis of disparities relating to service reach and patient engagement with these services (see *Chapter 10*) and an analysis of patient and staff experiences of different modes of submission (see *Chapter 11*).

Reflections on research team and wider involvement

Research team
The research team consisted of researchers from two rapid evaluation teams: RSET and BRACE. Overall, our team included researchers from academic university settings and also think tanks. The research team was a large, mixed-methods multi-disciplinary team from many different disciplines (statistics, sociology, applied health research, health psychology, health economics and project management) and team members differed in seniority from professors to postdoctoral researchers and research fellows. The research team comprised a mix of backgrounds in relation to gender and ethnicity. Team members who took maternity/paternity leave during the course of the study were supported to remain engaged with the study and to ensure their contributions were recognised.

The team held weekly project meetings and weekly data collection and analysis meetings throughout the project to ensure that all members of the team were well supported. All members of the team have been involved in all aspects of the project, from conception, to data collection and analysis and

dissemination of findings – both written (papers for publication and chapters) and oral (see *Contributions of Authors*). All researchers were supported by the principal investigator and senior members of the team.

Wider involvement

In addition to the research team, our evaluation also included input from our Clinical Advisory Group and RSET and BRACE PPI groups, who were actively involved throughout the project (including project planning, analysis and dissemination). Our PPI panel, involved throughout the project, included six members (representing a range of ages, gender and ethnicity). All of our PPI panel members have experience with engaging with PPI activity across research and evaluation prior to their involvement in this study. Our PPI panel members have experience with a range of long-term conditions and all have experience of navigating and/or working within the healthcare system. Through online meetings, workshops and email, PPI members were involved throughout all stages of the research, including: shaping the research questions, focus and methods, developing data collection tools for staff and patients, interpreting findings, and dissemination (e.g. all PPI members had the opportunity to comment on all chapters/papers if they wanted to and based on their interests, prior to their submission.

We attempted to work with services to seek specific PPI input from patients who had received COVID-19 remote home monitoring services, in relation to survey development and topic guide development; though this proved difficult to achieve due to rapid timescales. We also could have developed a specific study PPI group, but again this would have been difficult within the urgent rapid timeframe.

Conclusions

To conclude, our evaluation was unable to provide evidence regarding the effectiveness of COVID-19 remote home monitoring services, but this may have been influenced by incomplete data and lower patient enrolment to services than expected. However, this evaluation offers insight into the cost, implementation, staff and patient experience of these services, and lessons learned. There was large variability in the models implemented in relation to the design and intensity of monitoring, workforce, uptake levels and enrolment criteria. Implementation was influenced locally by a range of patient, staff, organisational and resource factors. Tech-enabled monitoring was widely used and all sites offered an analogue monitoring option. Services proactively used a range of strategies to ensure that their services were inclusive. Staff and patients generally viewed COVID-19 remote home monitoring services positively, and felt that they provided reassurance for patients. However, these services were not without limitations, with staff and patients identifying some challenges to delivery and engagement. Findings indicate that for some patients and carers, remote home monitoring services may be burdensome, particularly for some groups. Future remote home monitoring services for COVID-19 and other conditions should operate alongside effective data collection processes, ensure that staff are well supported and have capacity to deliver these services and that patients have appropriate support, ability, and understanding to engage with them.

Acknowledgements

Data sharing statement

Individual patient-level data and data supplied under specific data sharing agreements cannot be made available by the study team. Sources for data that are already publicly available are supplied either in the text or the references. Aggregate survey data collected by the study team are presented within this final report.

The anonymised qualitative data that support the findings of this study are available on request from the corresponding authors. To protect anonymity of interviewees, the data are not publicly available. Further information can be obtained from the corresponding authors.

Ethical Approval

Phase 1 received ethical approval from the University of Birmingham Humanities and Social Sciences ethics committee (ERNE_13-1085AP37) and was categorised as a service evaluation by the Health Research Authority (HRA) decision tool and University College London/University College London Hospitals (UCL/UCLH) Joint Research Office.

The study protocol was divided into two separate protocols:

> (1) Covered workstreams 1 and 2 and the staff elements of workstreams 3 and 4, received ethical approval from the University of Birmingham Humanities and Social Sciences ethics

committee (ERN_13-1085AP39) and was categorised as a service evaluation by the HRA decision tool and UCL/UCLH Joint Research Office (Jan 2021).

(2) The patient experience study (survey and case study interviews – workstreams 3 and 4) was reviewed and given favourable opinion by the London-Bloomsbury Research Ethics Committee (REC reference: 21/HRA/0155 (Feb 2021).

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Contributions of authors

- **Professor Naomi J. Fulop** (Professor of Health Care Organisation and Management) was the principal investigator and led the overall evaluation. She led on, and contributed to conception, design, analysis and write-up of all aspects of the study, and is lead author of this report.

- **Dr Holly Walton** (Research Fellow) contributed to design and data collection of workstreams 3 and 4 (Phase 2), co-led the analysis for the implementation and patient experience chapters, and supported analysis of the workforce chapter. She contributed to the design and interpretation of all other aspects of the study (Phase 2). She was involved in contributing to the drafting of the final report (including drafting Chapters 1,2 and 12, leading/co-leading Chapters 4 and 9, and supporting Chapter 8).

- **Dr Nadia Crellin** (Fellow) contributed to design and data collection of workstreams 3 and 4 (Phase 2), co-led the analysis for the implementation and disparities chapters, and supported analysis of the workforce and modality chapter. She contributed to the design and interpretation of all other aspects of the study (Phase 2). She was involved in contributing to the drafting of the final report (including leading/co-leading Chapters 4 and 10 and supporting Chapters 2, 8 and 11).

- **Theo Georghiou** (Senior Fellow) contributed to design and data collection of the Phase 1 study and workstream 1 (Phase 2), led on the effectiveness of virtual wards chapter and supported on the effectiveness of CO@h chapter. He contributed to the design and interpretation of all other aspects of the study. He was involved in contributing to the drafting of the final report (including leading Chapter 6 and supporting on Chapters 2 and 5).

- **Dr Lauren Herlitz** (Research Fellow) contributed to design and data collection of workstreams 3 and 4 (Phase 2), led the analysis for the modality chapter, and supported analysis of the disparities chapter. She contributed to the design and interpretation of all other aspects of the study (Phase 2). She was involved in contributing to the drafting of the final report (including leading Chapter 11 and supporting Chapters 2 and 10).

- **Dr Ian Litchfield** (Research Fellow) contributed to design and data collection of workstreams 3 and 4 (Phase 2) and lead/co-lead the analysis for the implementation chapter. He contributed to the design and interpretation of all other aspects of the study (Phase 2). He was involved in contributing to the drafting of the final report (including co-leading Chapter 4 and supporting Chapter 2).

- **Dr Efthalia Massou** (Research Associate) contributed to design and data collection of workstream 2 (Phase 2), and co-lead on the cost analysis chapter. She contributed to the design and interpretation of all other aspects of the study (Phase 2). She was involved in contributing to the drafting of the final report (including co-leading Chapter 7 and supporting Chapter 2).

- **Chris Sherlaw-Johnson** (Senior fellow) contributed to design and data collection of the Phase 1 study and workstream 1 (Phase 2). He led on the effectiveness of CO@h chapter and supported on the effectiveness of virtual wards chapter. He contributed to the design and interpretation of all other aspects of the study (Phases 1 and 2). He was involved in contributing to the drafting of the final report (including leading Chapter 5 and supporting on Chapters 2 and 6).

- **Dr Manbinder Sidhu** (Research Fellow) contributed to design and data collection of the Phase 1 study and workstreams 3 and 4 (Phase 2). He led the analysis for the workforce chapter, and supported analysis of the disparities chapter. He contributed to the design and interpretation

of all other aspects of the study (Phases 1 and 2). He was involved in contributing to the drafting of the final report (including leading Chapter 8 and supporting Chapters 2 and 11).

- **Dr Sonila M. Tomini** (Research Fellow) contributed to design and data collection of the Phase 1 study and workstream 2 (Phase 2), and co-lead on the cost analysis chapter. She contributed to the design and interpretation of all other aspects of the study (Phases 1 and 2). She was involved in contributing to the drafting of the final report (including co-leading Chapter 7 and supporting Chapter 2).

- **Dr Cecilia Vindrola-Padros** (Senior Research Fellow) contributed to design and data collection of the Phase 1 study, and workstreams 3 and 4 (Phase 2). Cecilia led the analysis for Phase 1, and supported analysis of the patient experience and modality chapters. She contributed to the design and interpretation of all other aspects of the study (Phases 1 and 2). She was involved in contributing to the drafting of the final report (including leading Chapter 3 and supporting Chapters 2 and 9).

- **Dr Jo Ellins** (Senior Fellow) contributed to the design and analysis of all aspects of the evaluation, in particular supporting with analysis and interpretation of findings relating to workstreams 3 and 4, and supported with drafting of the final report.

- **Professor Stephen Morris** (Professor of Health Services Research) contributed to the design and analysis of all aspects of the evaluation, led and oversaw workstream 2, and supported with drafting the final report.

- **Pei Li Ng** (Project manager) led on the project management of the evaluation and supported with drafting of the final report.

All authors contributed to integrating the findings of the study. All authors made critical revisions to the report content and approved the final manuscript. All authors agree to be accountable for all aspects of this work in ensuring that questions related to the accuracy or integrity of any part of the final report are appropriately investigated and resolved.

Publications

Published

Greenhalgh T, Knight M, Inda-Kim M, Fulop NJ, Leach J, Vindrola-Padros C. Remote management of covid-19 using home pulse oximetry and virtual ward support. BMJ. 2021;372. doi: https://doi.org/10.1136/bmj.n677

Vindrola-Padros C, Sidhu MS, Georghiou T, Sherlaw-Johnson C, Singh KE, Tomini SM, et al. The implementation of remote home monitoring models during the COVID-19 pandemic in England. EClinicalMedicine. 2021;34:100799. doi: 10.1016/j.eclinm.2021.100799

Vindrola-Padros C, Singh KE, Sidhu MS, Georghiou T, Sherlaw-Johnson C, Tomini SM, et al. Remote home monitoring (virtual wards) for confirmed or suspected COVID-19 patients: a rapid systematic review. EClinicalMedicine. 2021;37:100965. doi: 10.1016/j.eclinm.2021.100965

Vindrola, C., Fulop, N., Greenhalgh T. Virtual wards: caring for COVID-19 patients at home could save lives. The Conversation. 2020. Link: https://theconversation.com/virtual-wards-caring-for-covid-19-patients-at-home-could-save-lives-149292

Sherlaw-Johnson C, Georghiou T, Morris S, Crellin N, Litchfield I, Massou E, et al. The impact of remote home monitoring of people with COVID-19 using pulse oximetry: a national population and observational study. EClinicalMedicine. 2022. doi: https://doi.org/10.1016/j.eclinm.2022.101318

Georghiou T, Sherlaw-Johnson C, Massou E, Morris S, Crellin NE, Herlitz L, et al. The impact of post-hospital remote monitoring of COVID-19 patients using pulse oximetry: a national observational study using hospital activity data. eClinicalMedicine. 2022. doi: https://doi.org/10.1016/j.eclinm.2022.101441

Walton H, Vindrola-Padros C, Crellin N, Sidhu MS, Herlitz L, Litchfield I, et al. Patients' and carers' experiences of, and engagement with remote home monitoring services for COVID-19 patients: a rapid mixed-methods study. Health Expectations (accepted, forthcoming). 2021. doi: https://doi.org/10.1101/2021.12.17.21267968 (preprint)

Pre-prints/submitted for review

Sidhu M, Walton H, Crellin N, Ellins J, Herlitz L, Litchfield I, Massou E, Tomini S, Vindrola-Padros C, Fulop N. Staff experiences of training and delivery of remote home monitoring services for patients diagnosed with COVID-19: a mixed methods study. Submitted for consideration (January 2022).

Crellin N, Herlitz L, Sidhu MS., Ellins J., Georghiou T., Litchfield I., Massou E., Ng PL., Sherlaw-Johnson C., Tomini SM., Vindrola-Padros C., Walton H., Fulop N. Examining disparities relating to service reach and patient engagement with COVID-19 remote home monitoring services in England: a mixed methods rapid evaluation. medRxiv. 2021. doi: https://www.medrxiv.org/content/10.1101/2022.02.21.22270793v1

Herlitz L, Crellin N., Vindrola-Padros C, Ellins J, Georghiou T, Litchfield I, Massou E, Ng PL, Sherlaw-Johnson C, Sidhu MS, Tomini SM, Walton H, Fulop NJ. Technology-enabled and analogue models of remote home monitoring care for COVID-19: a rapid mixed-method evaluation of patient and staff experiences. medRxiv.

References

1.   Freedman L. Strategy for a Pandemic: The UK and COVID-19. Survival. 2020;62(3):25-76. doi: 10.1080/00396338.2020.1763610

2.   World Health Organisation. Coronavirus disease (COVID-19). 2021. Retrieved 10/11/2021 from https://www.who.int/health-topics/coronavirus#tab=tab_1

3.   World Health Organisation. Timeline: WHO's COVID-19 Response. 2021. Retrieved 10/11/2021 from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline/

4.   Al-Tawfiq JA, Leonardi R, Fasoli G, Rigamonti D. Prevalence and fatality rates of COVID-19: What are the reasons for the wide variations worldwide? Travel Med Infec Dis. 2020;35:101711. doi: 10.1016/j.tmaid.2020.101711

5.   World Health Organisation. WHO Coronavirus (COVID-19) Dashboard. 2021. Retrieved 23/11/2021 from https://covid19.who.int/

6.   Scobie S. What has been the impact of COVID-19 across the UK countries? 2021. Retrieved 10/11/2021 from https://www.nuffieldtrust.org.uk/news-item/what-has-been-the-impact-of-covid-19-across-the-uk-countries?gclid=EAIaIQobChMImoncj-ON9AIVFIBQBh2mLwq-EAAYAiAAEgIyL_D_BwE

7.   Cabinet Office. Guidance: Staying at home and away from others (social distancing). n.d. Retrieved 10/11/2021 from https://www.gov.uk/government/publications/full-guidance-on-staying-at-home-and-away-from-others/full-guidance-on-staying-at-home-and-away-from-others

8.   Oxtoby K. Covid-19:"Life on hold" for NHS patients needing musculoskeletal care. BMJ. 2021;373. doi: https://doi.org/10.1136/bmj.n1616

9.   Leite H, Lindsay C, Kumar M. COVID-19 outbreak: Implications on healthcare operations. The TQM Journal. 2020. doi: https://doi.org/10.1108/TQM-05-2020-0111

10.   National Health Service. Clinical guide for the management of remote consultations and remote working in secondary care during the coronavirus pandemic. 2020. Retrieved 10/11/2021 from https://www.nice.org.uk/Media/Default/About/COVID-19/Specialty-guides/specialty-Guide-Virtual-Working-and-Coronavirus.pdf

11.   Hutchings R. The impact of Covid-19 on the use of digital technology in the NHS 2020. Retrieved 07/06/2022 from https://www.nuffieldtrust.org.uk/research/the-impact-of-covid-19-on-the-use-of-digital-technology-in-the-nhs

12.   Public Health England. Disparities in the risk and outcomes of COVID-19. 2020. Retrieved 23/11/2021 from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/908434/Disparities_in_the_risk_and_outcomes_of_COVID_August_2020_update.pdf

13.   Greenhalgh T, Knight M, Inda-Kim M, Fulop NJ, Leach J, Vindrola-Padros C. Remote management of covid-19 using home pulse oximetry and virtual ward support. BMJ. 2021;372. doi: https://doi.org/10.1136/bmj.n677

14.   Levitan RM. Pulse Oximetry As a Biomarker for Early Identification and Hospitalization of Covid Pneumonia. Acad Emerg Med. 2020. doi: 10.1111/acem.14052

15.   Alaa A, Qian Z, Rashbass J, Benger J, van der Schaar M. Retrospective cohort study of admission timing and mortality following COVID-19 infection in England. BMJ Open. 2020;10(11):e042712. doi: 10.1136/bmjopen-2020-042712

16.   Mansab F, Donnelly H, Albrecht Kussner JN, Bhatti S, Goyal DK. Oxygen and mortality in COVID-19 pneumonia: a comparative analysis of supplemental oxygen policies and health outcomes across 26 countries. Front Public Health. 2021;9. doi: 10.3389/fpubh.2021.580585

17.   National Health Service. NHS at home n.d. Retrieved 07/12/2021 from https://www.england.nhs.uk/nhs-at-home/

18.   National Health Service. The NHS long term plan 2019. Retrieved 07/12/2021 from https://www.longtermplan.nhs.uk/

19.   Peretz D, Arnaert A, Ponzoni NN. Determining the cost of implementing and operating a remote patient monitoring programme for the elderly with chronic conditions: A systematic review of economic evaluations. JTelemed Telecare. 2018;24(1):13-21. doi: 10.1177/1357633X16669239

20.   Castelyn G, Laranjo L, Schreier G, Gallego B. Predictive performance and impact of algorithms in remote monitoring of chronic conditions: A systematic review and meta-analysis. IntJMed Inform. 2021;156:104620. doi: 10.1016/j.ijmedinf.2021.104620

21.   Jonker LT, Plas M, de Bock GH, Buskens E, van Leeuwen BL, Lahr MM. Remote home monitoring of older surgical cancer patients: Perspective on study implementation and feasibility. AnnSurg Oncol. 2021;28(1):67-78. doi: 10.1245/s10434-020-08705-1

22.   Peek N, Sujan M, Scott P. Digital health and care in pandemic times: impact of COVID-19. BMJ Health Care Inform. 2020;27(1). doi: 10.1136/bmjhci-2020-100166

23.   Margolius D, Hennekes M, Yao J, Einstadter D, Gunzler D, Chehade N, et al. On the front (phone) lines: results of a COVID-19 hotline. J Am Board. 2021;34(Supplement):S95-S102. doi: 10.3122/jabfm.2021.S1.200237

24.   Karampela I, Nikoloupoulous, M., Tzortzis, E., Stratigou, T., Antonakos, G., Diomidous, M., Dalamaga, M. Remote monitoring of patients in quarantine in the era of SARS-CoV-2 pandemic. The Importance of Health Informatics in Public Health during a Pandemic. Stud Health Tecnol Inform. 2020;272:33. doi: 10.3233/SHTI200486

25.   Thornton J. The "virtual wards" supporting patients with covid-19 in the community. BMJ. 2020;369. doi: 10.1136/bmj.m2119

26.   Hutchings OR, Dearing C, Jagers D, Shaw MJ, Raffan F, Jones A, et al. Virtual health care for community management of patients with COVID-19 in Australia: observational cohort study. JMed Internet Res. 2021;23(3):e21064. doi: 10.2196/21064

27.   Kricke G, Roemer, PE., Barnard, C., Peipert, JD., Henschen, BL., Bierman, J.A., Blahnik, D., Grant, M., Linder, JA., . Rapid implementation of an outpatient Covid-19 monitoring program. NEJM Catalyst Innovations in Care Delivery. 2020. doi: 10.1056/CAT.20.0214.

28.   Annis T, Pleasants S, Hultman G, Lindemann E, Thompson JA, Billecke S, et al. Rapid implementation of a COVID-19 remote patient monitoring program. J Am Med Inform Assoc. 2020;27(8):1326-30. doi: 10.1093/jamia/ocaa097

29.   O'Keefe JB, Tong EJ, Taylor TH, O'Keefe GDD, Tong DC. Initial experience in predicting the risk of hospitalization of 496 outpatients with COVID-19 using a telemedicine risk assessment tool. medRxiv. 2020. doi: 10.1101/2020.07.21.20159384

30.   Ford D, Harvey JB, McElligott J, King K, Simpson KN, Valenta S, et al. Leveraging health system telehealth and informatics infrastructure to create a continuum of services for COVID-19 screening, testing, and treatment. J Am Med Inform Assoc. 2020;27(12):1871-7. doi: 10.1093/jamia/ocaa157

31.   Nunan J, Clarke D, Malakouti A, Tannetta D, Calthrop A, Xu XH, et al. Triage into the community for COVID-19 (TICC-19) patients pathway-service evaluation of the virtual monitoring of patients with COVID pneumonia. Acute Med. 2020;19(4):183-91. Retrieved 07/06/2022. https://acutemedjournal.co.uk/wp-content/uploads/2020/11/p183-191-1.pdf

32.   Vindrola-Padros C, Singh KE, Sidhu MS, Georghiou T, Sherlaw-Johnson C, Tomini SM, et al. Remote home monitoring (virtual wards) for confirmed or suspected COVID-19 patients: a rapid systematic review. EClinicalMedicine. 2021;37:100965. doi: 10.1016/j.eclinm.2021.100965

33.   World Health Organisation. Living guidance for clinical management of COVID-19 2021. Retrieved 14/01/2022 from https://www.who.int/publications/i/item/WHO-2019-nCoV-clinical-2021-2

34.   Steimer M, Leabo J, Wang H, Heyer D, Addison N, Bowles N, et al. Remote home monitoring of patients with cancer during the COVID pandemic: A pilot study. JCO Oncol Pract. 2021:OP. 20.00995. doi: 10.1200/OP.20.00995

35.   Inada-Kim M, Chmiel FP, Boniface MJ, Pocock H, Black JJ, Deakin CD. Validation of home oxygen saturations as a marker of clinical deterioration in patients with suspected COVID-19. medRxiv. 2020. doi: https://doi.org/10.1101/2020.11.06.20225938

36.   Vindrola-Padros C, Sidhu MS, Georghiou T, Sherlaw-Johnson C, Singh KE, Tomini SM, et al. The implementation of remote home monitoring models during the COVID-19 pandemic in England. EClinicalMedicine. 2021;34:100799. doi: 10.1016/j.eclinm.2021.100799

37.   Medicines and healthcare products Regulatory Agency. The use and regulation of pulse oximeters (information for healthcare professionals 2021. Retrieved 11/01/2022 from https://www.gov.uk/guidance/the-use-and-regulation-of-pulse-oximeters-information-for-healthcare-professionals

38.   National Health Service. Novel coronavirus (COVID-19) standard operating procedure: COVID Oximetry @home. v1.2. Retrieved 10/11/2021 from https://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/11/C1396-sop-covid-oximetry-@home-v2-september-21.pdf

39.   National Health Service. Novel coronavirus (COVID-19) standard operating procedure: COVID Virtual Ward. V1.0. . Retrieved 10/11/2021 from https://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2021/01/C1042-sop-discharge-covid-virtual-ward-13-jan-21.pdf

40.   NHS England and Improvement. Supporting general practice – additional £150 million of funding from NHS England (official letter). 2020. Retrieved 11/01/2022 from https://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/03/C0828_GP-funding-letter-_second-wave_9novreb.pdf

41.   NHS Digital. Helping providers identify potential oximetry @home patients. 2021. Retrieved 11/01/2022 from https://digital.nhs.uk/coronavirus/covid-oximetry-at-home-digital-and-data-services/helping-providers-identify-potential-oximetry--at-home-patients

42.   Beaney T, Clarke J, Alboksmaty A, Flott K, Fowler A, Benger JR, et al. Evaluating the impact of a pulse oximetry remote monitoring programme on mortality and healthcare utilisation in patients with covid-19 assessed in Accident and Emergency departments in England: a retrospective matched cohort study. medRxiv. 2021. doi: Retrieved 07/06/2022 from https://www.medrxiv.org/content/10.1101/2021.11.25.21266848v1

43.   Beaney T, Clarke J, Alboksmaty A, Flott K, Fowler A, Benger JR, et al. Population-level impact of a pulse oximetry remote monitoring programme on mortality and healthcare utilisation in the people with covid-19 in England: a national analysis using a stepped wedge design. Emerg Med J 2022. doi: 10.1136/emermed-2022-212378

44.   Beaney T, Neves AL, Alboksmaty A, Ashrafian H, Flott K, Fowler A, et al. Trends and associated factors for Covid-19 hospitalisation and fatality risk in 2.3 million adults in England. Nature Communications. 2022;13(2356). doi: https://doi.org/10.1038/s41467-022-29880-7

45.   Pariza P, Conti S. Statistical analysis protocol for an evaluation of COVID Oximetry@ home using a Generalised Synthetic Control approach 2021. Retrieved 23/11/2021 from https://www.health.org.uk/sites/default/files/2021-03/SAP_Oximetry_Generalised_Synthetic_Control.pdf

46.   PSTRC IGHI. COVID Oximetry@home (CO@h) Service Evaluation protocol. n.d. Retrieved 23/11/2021 from https://www.imperial.ac.uk/media/imperial-college/institute-of-global-health-innovation/PROTOCOL_FINAL_IGHI.pdf

47.   Sidhu M, Litchfield, I., Miller R., Fulop NJ., Janta B., Tanner JR., Maistrello G., Bousfield, J., Vindrola-Padros C., Sussex, J A mixed methods rapid evaluation investigating the use of pulse oximetry in care homes across England to manage residents with COVID-19 and long-term health conditions. NIHR; forthcoming.

48.   Tricco AC, Langlois E, Straus SE, Organization WH. Rapid reviews to strengthen health policy and systems: a practical guide: World Health Organization; 2017.

49.   Lehoux P, Blume S. Technology assessment and the sociopolitics of health technologies. JHealth Polit Policy Law. 2000;25(6):1083-120. doi: 10.1215/03616878-25-6-1083

50.   Greenhalgh T, Procter R, Wherton J, Sugarhood P, Hinder S, Rouncefield M. What is quality in assisted living technology? The ARCHIE framework for effective telehealth and telecare services. BMC Med. 2015;13(1):1-15. doi: 10.1186/s12916-015-0279-6

51.   Greenhalgh T, Shaw S. Understanding heart failure; explaining telehealth–a hermeneutic systematic review. BMC Cardiovasc Disord. 2017;17(1):1-16. doi: 10.1186/s12872-017-0594-2

52.	Powell J, Gunn L, Lowe P, Sheehan B, Griffiths F, Clarke A. New networked technologies and carers of people with dementia: An interview study. Ageing Soc. 2010;30(6):1073-88. doi: 10.1017/S0144686x1000019x

53.	Greenhalgh T, Wherton J, Papoutsi C, Lynch J, Hughes G, Hinder S, et al. Beyond adoption: a new framework for theorizing and evaluating nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. JMed Internet Res. 2017;19(11):e367. doi: 10.2196/jmir.8775

54.	Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. Journal of chronic diseases. 1987;40(5):373-83. doi: 10.1016/0021-9681(87)90171-8

55.	Fulop NJ et al. A mixed methods evaluation of remote home monitoring models during the COVID-19 pandemic in England (Phase Two evaluation) - Protocol. 2021. Retrieved 15/11/2021 from https://fundingawards.nihr.ac.uk/award/NIHR135016

56.	Michie S, Van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 2011;6(1):1-12. doi: 10.1186/1748-5908-6-42

57.	Borrelli B. The assessment, monitoring, and enhancement of treatment fidelity in public health clinical trials. JPublic Health Dent. 2011;71:S52-S63. doi: 10.1111/j.1752-7325.2011.00233.x

58.	Walton H, Spector A, Tombor I, Michie S. Measures of fidelity of delivery of, and engagement with, complex, face-to-face health behaviour change interventions: A systematic review of measure quality. BrJHealth Psychol. 2017;22(4):872-903. doi: 10.1111/bjhp.12260

59.	Lyratzopoulos G, Elliott M, Barbiere J, Henderson A, Staetsky L, Paddison C, et al. Understanding ethnic and other socio-demographic differences in patient experience of primary care: evidence from the English General Practice Patient Survey. BMJ QualSaf. 2012;21(1):21-9. doi: 10.1136/bmjqs-2011-000088

60.	Pianori D, Maietti E, Lenzi J, Quargnolo M, Guicciardi S, Adja KYC, et al. Sociodemographic and health service organizational factors associated with the choice of the private versus public sector for specialty visits: Evidence from a national survey in Italy. PloS one. 2020;15(5):e0232827. doi: 10.1371/journal.pone.0232827

61.	English Longitudinal Study of Ageing. The data we collect 2019. Retrieved 15/11/2021 from https://www.elsa-project.ac.uk/the-data-we-collect

62.	Wenz A, Al Baghal T, Gaia A. Language proficiency among respondents: Implications for data quality in a longitudinal face-to-face survey. JSurvStatMethodol. 2021;9(1):73-93. doi: 10.1093/jssam/smz045

63.	Office for National Statistics. Ethnic group, national identity and religion. n.d. Retrieved 15/11/2021 from https://www.ons.gov.uk/methodology/classificationsandstandards/measuringequality/ethnicgroupnationalidentityandreligion

64.	UK government. Age groups 2018. Retrieved 15/11/2021 from https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity/demographics/age-groups/latest

65.   Office for National Statistics. Lower layer Super Output Area population estimates (supporting information). Mid-2019 2020. Retrieved 12/04/2022 from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationesti mates/datasets/lowersuperoutputareamidyearpopulationestimates

66.   Office for National Statistics. Rural Urban Classification (2011) of Lower Layer Super Output Areas in England and Wales 2019. Retrieved 12/04/2022 from https://geoportal.statistics.gov.uk/datasets/rural-urban-classification-2011-of-lower-layer-super-output-areas-in-england-and-wales/explore

67.   Ministry of Housing communities & Local Government. English indices of deprivation 2019, File 1: index of multiple deprivation 2019. Retrieved 12/04/2022 from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file /833970/File_1_-_IMD2019_Index_of_Multiple_Deprivation.xlsx

68.   Office for National Statistics. Ethnic group by sex by age, Census 2011, Table LC2101EW 2013. Retrieved 12/04/2022 from https://www.nomisweb.co.uk/census/2011/lc2101ew

69.   Office for National STatistics. Lower Layer Super Output Area (2011) to Clinical Commissioning Group to Local Authority District (April 2020) Lookup in England 2020. Retrieved 12/04/2022 from https://geoportal.statistics.gov.uk/datasets/lower-layer-super-output-area-2011-to-clinical-commissioning-group-to-local-authority-district-april-2020-lookup-in-england/explore

70.   Vindrola-Padros C, Chisnall G, Cooper S, Dowrick A, Djellouli N, Symmons SM, et al. Carrying out rapid qualitative research during a pandemic: emerging lessons from COVID-19. QualHealth Res. 2020;30(14):2192-204. doi: 10.1177/1049732320951526

71.   Patton MQ. Enhancing the quality and credibility of qualitative analysis. Health Serv Res. 1999;34(5 Pt 2):1189. doi: Retrieved 07/06/2022 from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1089059/

72.   Flick U. Triangulation in data collection. London: SAGE Publications Ltd; 2018. 527-44 p.

73.   Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. International journal for quality in health care. 2007;19(6):349-57. doi: https://doi.org/10.1093/intqhc/mzm042

74.   Bradshaw C, Atkinson S, Doody O. Employing a qualitative description approach in health care research. Global qualitative nursing research. 2017;4:2333393617742282. doi: https://doi.org/10.1177/2333393617742282

75.   Moher D, Liberati A, Tetzlaff J, Altman DG, Group* P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine. 2009;151(4):264-9. doi: https://doi.org/10.7326/0003-4819-151-4-200908180-00135

76.   Gale NK, Heath G, Cameron E, Rashid S, Redwood S. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. BMC medical research methodology. 2013;13(1):1-8. doi: 10.1186/1471-2288-13-117

77.   Vindrola C, Fulop, N, Greenhalgh T. . Virtual wards: caring for COVID-19 patients at home could save lives. The Conversation. 2020.

78.   Yahoo! finance. Virtual wards: caring for COVID-19 patients at home could save lives 2020. Retrieved 14/01/2022 from https://uk.finance.yahoo.com/news/virtual-wards-caring-covid-19-114742193.html?guccounter=1

79.   Vindrola C, Fulop, N., Greenhalgh, T. Could doctors care for Covid patients on 'virtual wards'? Independent. 2020 16th November

80.   Fulop N, Vindrola, C, Sidhu M, Sherlaw-Johnson C, Georghou T, Tomini SM, Singh, K, Ellins, J, Morris S, Ng PL. Rapid evaluation of remote home monitoring models during COVID-19 pandemic in england: Nuffield Trust; 2020. Retrieved 14/01/2022 from https://www.nuffieldtrust.org.uk/files/vw-evaluation-final-slideset-for-dissemination-12th-oct-2020.pdf

81.   Nuffield Trust. Full session video from the Rapid evaluation in health care conference 2021 2021. Retrieved 07/06/2022 from https://www.nuffieldtrust.org.uk/summit/rapid-evaluation-in-health-care-2021/recordings

82.   Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implement Sci. 2009;4(1):1-15. doi: 10.1186/1748-5908-4-50

83.   Glasziou P, Chalmers I, Altman DG, Bastian H, Boutron I, Brice A, et al. Taking healthcare interventions from trial to practice. BMJ. 2010;341. doi: 10.1136/bmj.c3852

84.   Øvretveit J. Understanding the conditions for improvement: research to discover which context influences affect improvement success. BMJ QualSaf. 2011;20(Suppl 1):i18-i23. doi: http://dx.doi.org/10.1136/bmjqs.2010.045955

85.   Bellg AJ, Borrelli B, Resnick B, Hecht J, Minicucci DS, Ory M, et al. Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH Behavior Change Consortium. Health Psychol. 2004;23(5):443. doi: 10.1037/0278-6133.23.5.443

86.   McGee D, Lorencatto F, Matvienko-Sikar K, Toomey E. Surveying knowledge, practice and attitudes towards intervention fidelity within trials of complex healthcare interventions. Trials. 2018;19(1):1-14. doi: 10.1186/s13063-018-2838-6

87.   Michie S, Fixsen D, Grimshaw JM, Eccles MP. Specifying and reporting complex behaviour change interventions: the need for a scientific method. Implement Sci. 2009;4(1):1-6. doi: https://doi.org/10.1186/1748-5908-4-40

88.   Hawkes R, Cameron E, Bower P, French DP. Does the design of the NHS diabetes prevention Programme intervention have fidelity to the programme specification? A document analysis. Diabet Med. 2020;37(8):1357-66. doi: https://doi.org/10.1111/dme.14201

89.   Cook DA, Pencille LJ, Dupras DM, Linderbaum JA, Pankratz VS, Wilkinson JM. Practice variation and practice guidelines: Attitudes of generalist and specialist physicians, nurse practitioners, and physician assistants. PloS one. 2018;13(1):e0191943. doi: 10.1371/journal.pone.0191943

90.   Capano G, Howlett M, Jarvis DS, Ramesh M, Goyal N. Mobilizing policy (in) capacity to fight COVID-19: Understanding variations in state responses. Pol Soc. 2020;39(3):285-308. doi: 10.1080/14494035.2020.1787628

91.   Capano G, Lippi A. Decentralization, policy capacities, and varieties of first health response to the COVID-19 outbreak: evidence from three regions in Italy. J Eur Public Policy. 2021:1-22. doi: 10.1080/13501763.2021.1942156

92.   Hale T, Petherick, A., Phillips, T., Webster, S., Kira, K., & Angrist, N. Coronavirus Government response tracker: Blavatnik School of Government 2020.

93.   Dopson S, Fitzgerald L, Ferlie E. Understanding change and innovation in healthcare settings: reconceptualizing the active role of context. JChange Manag. 2008;8(3-4):213-31. doi: https://doi.org/10.1080/14697010802133577

94.   Gilson L, Schneider H, Orgill M. Practice and power: a review and interpretive synthesis focused on the exercise of discretionary power in policy implementation by front-line providers and managers. Health Policy Plan. 2014;29(suppl_3):iii51-iii69. doi: 10.1093/heapol/czu098

95.   Kaplan HC, Brady PW, Dritz MC, Hooper DK, Linam WM, Froehle CM, et al. The influence of context on quality improvement success in health care: a systematic review of the literature. Milbank Q. 2010;88(4):500-59. doi: 10.1111/j.1468-0009.2010.00611.x

96.   Purtle J, Brownson RC, Proctor EK. Infusing science into politics and policy: The importance of legislators as an audience in mental health policy dissemination research. Adm Policy Ment Health. 2017;44(2):160-3. doi: 10.1007/s10488-016-0752-3

97.   Campbell NC, Murray E, Darbyshire J, Emery J, Farmer A, Griffiths F, et al. Designing and evaluating complex interventions to improve health care. BMJ. 2007;334(7591):455-9. doi: 10.1136/bmj.39108.379965.BE

98.   Seboka BT, Yilma TM, Birhanu AY. Factors influencing healthcare providers' attitude and willingness to use information technology in diabetes management. BMC Med Inform Decis Mak. 2021;21(1):1-10. doi: 10.1186/s12911-021-01398-w

99.   Slev VN, Mistiaen P, Pasman HRW, Verdonck-de Leeuw IM, van Uden-Kraan CF, Francke AL. Effects of eHealth for patients and informal caregivers confronted with cancer: a meta-review. IntJMed Inform. 2016;87:54-67. doi: 10.1016/j.ijmedinf.2015.12.013

100.   Warrington L, Absolom K, Conner M, Kellar I, Clayton B, Ayres M, et al. Electronic systems for patients to report and manage side effects of cancer treatment: systematic review. J Med Internet Res. 2019;21(1):e10875. doi: 10.2196/10875

101.   Academic Health Science Network. COVID Oximetry and virtual wards 2020. Retrieved 07/06/2022 from https://www.ahsnnetwork.com/covid-oximetry

102.   National Health Service. Future NHS 2020. Retrieved 07/06/2022 from https://future.nhs.uk.

103.   NHS Digital. COVID Oximetry @home - digital and data services 2020. Retrieved 07/01/2022 from https://digital.nhs.uk/coronavirus/covid-oximetry-at-home-digital-and-data-services

104.   Clarke N. Workplace learning environment and its relationship with learning outcomes in healthcare organizations. Hum Resour DevInt. 2005;8(2):185-205. doi: https://doi.org/10.1080/13678860500100228

105.   Rogers L, De Brún A, Birken SA, Davies C, McAuliffe E. The micropolitics of implementation; a qualitative study exploring the impact of power, authority, and influence when implementing change in healthcare teams. BMC Health Serv Res. 2020;20(1):1-13. doi: 10.1186/s12913-020-05905-z

106.   Best A, Greenhalgh T, Lewis S, Saul JE, Carroll S, Bitz J. Large-system transformation in health care: a realist review. Milbank Q. 2012;90(3):421-56. doi: 10.1111/j.1468-0009.2012.00670.x

107.   Fulop NJ, Ramsay AI, Perry C, Boaden RJ, McKevitt C, Rudd AG, et al. Explaining outcomes in major system change: a qualitative study of implementing centralised acute stroke services in two large metropolitan regions in England. Implement Sci. 2015;11(1):1-13. doi: https://doi.org/10.1186/s13012-016-0445-z

108.   Turner S, Ramsay A, Perry C, Boaden R, McKevitt C, Morris S, et al. Lessons for major system change: centralization of stroke services in two metropolitan areas of England. JHealth Serv ResPolicy. 2016;21(3):156-65. doi: 10.1177/1355819615626189

109.   Ogunlayi F, Britton P. Achieving a 'top-down'change agenda by driving and supporting a collaborative 'bottom-up'process: case study of a large-scale enhanced recovery programme. BMJ Open Qual. 2017;6(2):e000008. doi: http://dx.doi.org/10.1136/bmjoq-2017-000008

110.   Sherlaw-Johnson C, Georghiou T, Morris S, Crellin N, Litchfield I, Massou E, et al. The impact of remote home monitoring of people with COVID-19 using pulse oximetry: a national population and observational study. EClinicalMedicine. 2022. doi: https://doi.org/10.1016/j.eclinm.2022.101318

111.   Clarke J, Flott K, Crespo RF, Ashrafian H, Fontana G, Benger J, et al. Assessing the safety of home oximetry for COVID-19: a multisite retrospective observational study. BMJ Open. 2021;11(9):e049235. doi: 10.1136/bmjopen-2021-049235

112.   Freedman DA. Ecological inference and the ecological fallacy. International Encyclopedia of the social & Behavioral sciences. 1999;6(4027-4030):1-7. Retrieved 07/06/2022 from http://michaeljohnsonphilosophy.com/wp-content/uploads/2012/10/ecological-fallacy.pdf

113.   NHS England and Improvement. COVID-19 Vaccinations 2021. Retrieved 01/09/2021 from https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-vaccinations/covid-19-vaccinations-archive/

114.   Jabłońska K, Aballéa S, Toumi M. The real-life impact of vaccination on COVID-19 mortality in Europe and Israel. medRxiv. 2021. doi: 10.1016/j.puhe.2021.07.037

115.   NIHR Rapid Service Evaluation Team; NIHR Birmingham RAND and Cambridge Evaluation Centre;   Imperial College London; Improvement Analytics Unit. COVID Oximetry @home evaluation interpretation of findings: Nuffield Trust; 2021. Retrieved 07/01/2022 from https://www.nuffieldtrust.org.uk/files/2021-11/co-h-interpretation-of-evaluation-findings-final-slide-deck-nov-2021.pdf

116.   Casariego-Vales E, Blanco-López R, Rosón-Calvo B, Suárez-Gil R, Santos-Guerra F, Dobao-Feijoo MJ, et al. Efficacy of telemedicine and telemonitoring in at-home monitoring of patients with covid-19. J Clin Med. 2021;10(13):2893. doi: 10.3390/jcm10132893

117.   Nematswerani N, Collie S, Chen T, Cohen M, Champion J, Feldman C, et al. The Impact of Routine Pulse Oximetry Use on Outcomes in COVID-19-Infected Patients at Increased Risk of Severe Disease: A Retrospective Cohort Analysis. Available at SSRN 3804758. 2021. doi: 10.7196/SAMJ.2021.v111i10.15880

118.   Boniface M, Burns D, Duckworth C, Duruiheoma F, Armitage H, Ratcliffe N, et al. COVID Oximetry@ home: evaluation of patient outcomes. medRxiv. 2021. doi: https://doi.org/10.1101/2021.05.29.21257899

119.   Bell LC, Norris-Grey C, Luintel A, Bidwell G, Lanham D, Marks M, et al. Implementation and evaluation of a COVID-19 rapid follow-up service for patients discharged from the emergency department. Clin Med. 2021;21(1):e57. doi: 10.7861/clinmed.2020-0816

120.   Agarwal P, Mukerji G, Laur C, Chandra S, Pimlott N, Heisey R, et al. Adoption, feasibility and safety of a family medicine–led remote monitoring program for patients with COVID-19: a descriptive study. CMAJ Open. 2021;9(2):E324. doi: 10.9778/cmajo.20200174

121.   Francis NA, Stuart B, Knight M, Vancheeswaran R, Oliver C, Willcox M, et al. Predictors of clinical deterioration in patients with suspected COVID-19 managed in a 'virtual hospital'setting: a cohort study. BMJ Open. 2021;11(3):e045356. doi: 10.1136/bmjopen-2020-045356

122.   Medina M, Babiuch C, Card M, Gavrilescu R, Zafirau W, Boose E, et al. Home monitoring for COVID-19. Cleve Clin JMed. 2020. doi: 10.3949/ccjm.87a.ccc028

123.   Georghiou T, Sherlaw-Johnson C, Massou E, Morris S, Crellin NE, Herlitz L, et al. The impact of post-hospital remote monitoring of COVID-19 patients using pulse oximetry: a national observational study using hospital activity data. eClinicalMedicine. 2022. doi: https://doi.org/10.1016/j.eclinm.2022.101441

124.   Uminski K, Komenda P, Whitlock R, Ferguson T, Nadurak S, Hochheim L, et al. Effect of post-discharge virtual wards on improving outcomes in heart failure and non-heart failure populations: A systematic review and meta-analysis. PloS one. 2018;13(4):e0196114. doi: 10.1371/journal.pone.0196114

125.   Gordon WJ, Henderson D, DeSharone A, Fisher HN, Judge J, Levine DM, et al. Remote patient monitoring program for hospital discharged COVID-19 patients. ApplClin Inform. 2020;11(05):792-801. doi: 10.1055/s-0040-1721039

126.   Grutters L, Majoor K, Mattern E, Hardeman J, van Swol C, Vorselaars A. Home telemonitoring makes early hospital discharge of COVID-19 patients possible. JAm Med Inform Assoc. 2020;27(11):1825. doi: 10.1093/jamia/ocaa168

127.   Salford Royal NHS Foundation Trust. Case study. Rapid development of a COVID-19 Virtual Ward (Oximetry at home) to improve patient experience, flow and the interface to Same Day Emergency Care 2020. Retrieved 19/11/2021 from https://www.ahsnnetwork.com/app/uploads/2020/11/salford-SDEC-Oximetry.pdf

128.   Maghrabi F, Bazaz R, Wilson E, O'Reilly S, Calisti G, Richardson R, et al. S57 The development and implementation of a virtual discharge ward for patients with COVID-19 pneumonia: data on the first 300 patients. Thorax. 2021;76(A35-A36). doi: 10.1136/thorax-2020-BTSabstracts.62

129.   Kyriakides J, Khani A, Coleman R, Kelly C. Analysis of an Ambulatory Care Pathway for Patients With COVID-19 Utilising Remote Pulse Oximetry at a London District General Hospital. Cureus. 2021;13(1). doi: 10.7759/cureus.12979

130.   Kodama R, Arora S, Anand S, Choudhary A, Weingarten J, Francesco N, et al. Reengineering the discharge transition process of COVID-19 patients using telemedicine, remote patient monitoring, and Around-the-Clock remote patient monitoring from the emergency department and inpatient units. TelemedJ E Health. 2021;27(10):1188-93. doi: https://doi.org/10.1089/tmj.2020.0459

131.   Bambra C, Riordan R, Ford J, Matthews F. The COVID-19 pandemic and health inequalities. J Epidemiol Community Health. 2020;74(11):964-8. doi: 10.1136/jech-2020-214401

132.   Ayoubkhani D, Khunti K, Nafilyan V, Maddox T, Humberstone B, Diamond I, et al. Post-covid syndrome in individuals admitted to hospital with covid-19: retrospective cohort study. BMJ. 2021;372. doi: 10.1136/bmj.n693

133.   Raman B, Cassar MP, Tunnicliffe EM, Filippini N, Griffanti L, Alfaro-Almagro F, et al. Medium-term effects of SARS-CoV-2 infection on multiple vital organs, exercise capacity, cognition, quality of life and mental health, post-hospital discharge. EClinicalMedicine. 2021;31:100683. doi: 10.1016/j.eclinm.2020.100683

134.   Ramos-Casals M, Brito-Zerón P, Mariette X. Systemic and organ-specific immune-related manifestations of COVID-19. Nat Rev Rheumatol. 2021;17(6):315-32. doi: 10.1038/s41584-021-00608-z

135.   Office for National Statistics. Deaths registered in private homes, England and Wales: 2020 final and January to June 2021, provisional. 2020. Retrieved 23/11/2021 from https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/deathsinprivatehomesenglandandwales/2020finalandjanuarytojune2021provisional.

136.   Ramos-Martínez A, Parra-Ramírez LM, Morrás I, Carnevali M, Jiménez-Ibañez L, Rubio-Rivas M, et al. Frequency, risk factors, and outcomes of hospital readmissions of COVID-19 patients. SciRp. 2021;11(1):1-10. doi: 10.1038/s41598-021-93076-0

137.   Thiruvengadam G, Lakshmi M, Ramanujam R. A Study of Factors Affecting the Length of Hospital Stay of COVID-19 Patients by Cox-Proportional Hazard Model in a South Indian Tertiary Care Hospital. J Prim Care Community Health. 2021;12:21501327211000231. doi: 10.1177/21501327211000231

138.   Richardson S, Hirsch JS, Narasimhan M, Crawford JM, McGinn T, Davidson KW, et al. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City area. JAMA. 2020;323(20):2052-9. doi: 10.1001/jama.2020.6775

139.   Thorpe KE, Joski PJ. SARS-CoV-2 Outcomes: The Role of Patient Characteristics and Chronic Disease Comorbidities. Popul Health Manag. 2021. doi: 10.1089/pop.2021.0116

140.   Nematshahi M, Soroosh D, Neamatshahi M, Attarian F, Rahimi F. Factors predicting readmission in patients with COVID-19. BMC ResNotes. 2021;14(1):1-6. doi: 10.1186/s13104-021-05782-7

141.   Michaud TL, Zhou J, McCarthy MA, Siahpush M, Su D. Costs of home-based telemedicine programs: a systematic review. IntJ Technol Assess Health Care. 2018;34(4):410-8. doi: 10.1017/S0266462318000454

142.   Curtis LA BA. Unit costs of health and social care: Personal Social Services Research Unit, University of Kent, Canterbury; 2020.

143.   Newbould J, Abel G, Ball S, Corbett J, Elliott M, Exley J, et al. Evaluation of telephone first approach to demand management in English general practice: observational study. BMJ. 2017;358. doi: 10.1136/bmj.j4197

144.   Salisbury C, Murphy M, Duncan P. The impact of digital-first consultations on workload in general practice: modeling study. JMed Internet Res. 2020;22(6):e18203. doi: 10.2196/18203

145.   Bowles KH, Hanlon AL, Glick HA, Naylor MD, O'Connor M, Riegel B, et al. Clinical effectiveness, access to, and satisfaction with care using a telehomecare substitution intervention: a randomized controlled trial. IntJTelemedAppl. 2011;2011. doi: https://doi.org/10.1155/2011/540138

146.   Hæsum LKE, Ehlers L, Hejlesen OK. Telehomecare Technologies Enhance Self-management and Empowerment among Pa-tients with Chronic Obstructive Pulmonary Disease (COPD)–Where does Health Literacy Fit into this Equation? Stud Health Technol Inform. 2013:1182-. doi: 10.3233/978-1-61499-289-9-1182

147.   Mierdel S, Owen K. Telehomecare reduces ER use and hospitalizations at William Osler health system. Stud Health Technol Inform. 2015;209:102-8. doi: 10.3233/978-1-61499-505-0-102

148.   Mistry H. Systematic review of studies of the cost-effectiveness of telemedicine and telecare. Changes in the economic evidence over twenty years. JTelemedTelecare. 2012;18(1):1-6. doi: 10.1258/jtt.2011.110505

149.   Schultz K, Vickery H, Campbell K, Wheeldon M, Barrett-Beck L, Rushbrook E. Implementation of a virtual ward as a response to the COVID-19 pandemic. Aust Health Rev. 2021. doi: 10.1071/Ah20240

150.   Caffery LJ, Bradford NK, Wickramasinghe SI, Hayman N, Smith AC. Outcomes of using telehealth for the provision of healthcare to Aboriginal and Torres Strait Islander people: a systematic review. Aust N Z JPublic Health. 2017;41(1):48-53. doi: 10.1111/1753-6405.12600

151.   Sidhu M, Walton, H., Crellin N., Ellins J., Herlitz L., Litchfield I., Massou E., Tomini S., Vindrola-Padros C., Fulop N., . Staff experiences of training and delivery of remote home monitoring services for patients diagnosed with COVID-19: a mixed methods study. Submitted for consideration (Jan 2022).

152.   Asthana S, Jones R, Sheaff R. Why does the NHS struggle to adopt eHealth innovations? A review of macro, meso and micro factors. BMC Health ServRes. 2019;19(1):1-7. doi: https://doi.org/10.1186/s12913-019-4790-x

153. Rodgers M, Raine GA, Thomas S, Harden M, Eastwood AJ. Informing NHS policy in'digital-first primary care': a rapid evidence synthesis. Health Services and Delivery Research. 2019:1-154. doi: https://doi.org/10.3310/hsdr07410

154. Topol EJ. The Topol Review: Preparing the healthcare workforce to deliver the digital future 2019. Retrieved 15/11/2021 from https://topol.hee.nhs.uk/wp-content/uploads/HEE-Topol-Review-2019.pdf

155. The King's fund. NHS workforce: our position 2021. Retrieved 17/11/2021 from https://www.kingsfund.org.uk/projects/positions/nhs-workforce

156. Heath C, Hindmarsh J. Analyzing interaction: video, ethnography and situated conduct In: T M, editor. Qualitative research in action. London: Sage; 2002. p. 99-122.

157. Suchman L. Making work visible. Communications of the ACM. 1995;38(9):56-64. doi: 10.1145/223248.223263

158. Royal College of General Practitioners. General practice in the post Covid world: Challenges and opportunities for general practice 2020. Retrieved 11/01/2022 from https://www.rcgp.org.uk/policy/general-practice-post-covid.aspx

159. National Health Service. Remote-monitoring service for people living with heart and long diseases reduces A&E admissions in Norfolk n.d. Retrieved 17/11/2021 from https://www.longtermplan.nhs.uk/case-studies/remote-monitoring/

160. Manacorda T, Bandiera P, Terzuoli F, Ponzio M, Brichetto G, Zaratin P, et al. Impact of the COVID-19 pandemic on persons with multiple sclerosis: Early findings from a survey on disruptions in care and self-reported outcomes. J Health Serv Res Policy. 2020:1355819620975069. doi: 10.1177/1355819620975069

161. Shaw SE, Cameron D, Wherton J, Seuren LM, Vijayaraghavan S, Bhattacharya S, et al. Technology-Enhanced consultations in diabetes, cancer, and heart failure: protocol for the qualitative analysis of remote consultations (QuARC) project. JMIR Res Protoc. 2018;7(7):e10913. doi: 10.2196/10913

162. Liberati E, Richards N, Parker J, Willars J, Scott D, Boydell N, et al. Remote care for mental health: qualitative study with service users, carers and staff during the COVID-19 pandemic. BMJ Open. 2021;11(4):e049210. doi: 10.1136/bmjopen-2021-049210

163. Houlding E, Mate KK, Engler K, Ortiz-Paredes D, Pomey M-P, Cox J, et al. Barriers to use of remote monitoring technologies used to support patients with COVID-19: Rapid review. JMIR mHealth and uHealth. 2021;9(4):e24743. doi: 10.2196/24743

164. Cane J, O'Connor D, Michie S. Validation of the theoretical domains framework for use in behaviour change and implementation research. Implement Sci. 2012;7(1):1-17. doi: 10.1186/1748-5908-7-37

165. Brewster L, Mountain G, Wessels B, Kelly C, Hawley M. Factors affecting front line staff acceptance of telehealth technologies: A mixed-method systematic review. J Adv Nurs. 2014;70(1):21-33. doi: 10.1111/jan.12196

166.   Walton H, Vindrola-Padros C, Crellin N, Sidhu MS, Herlitz L, Litchfield I, et al. Patients' and carers' experiences of, and engagement with remote home monitoring services for COVID-19 patients: a rapid mixed-methods study. Health Expectations (forthcoming). 2021. doi: https://doi.org/10.1101/2021.12.17.21267968 (preprint)

167.   Colbert GB, Venegas-Vera AV, Lerma EV. Utility of telemedicine in the COVID-19 era. RevCardiovasc Med. 2020;21(4). doi: 10.31083/j.rcm.2020.04.188

168.   Barr N, Vania D, Randall G, Mulvale G. Impact of information and communication technology on interprofessional collaboration for chronic disease management: a systematic review. JHealth Serv Res Policy. 2017;22(4):250-7. doi: 10.1177/1355819617714292

169.   Albert NM, Dinesen B, Spindler H, Southard J, Bena JF, Catz S, et al. Factors associated with telemonitoring use among patients with chronic heart failure. JTelemed Telecare. 2017;23(2):283-91. doi: 10.1177/1357633x16630444

170.   Braithwaite J, Vincent C, Garcia-Elorrio E, Imanaka Y, Nicklin W, Sodzi-Tettey S, et al. Transformational improvement in quality care and health systems: the next decade. BMC Med. 2020;18(1):1-17. doi: 10.1186/s12916-020-01739-y

171.   Pols J. Care at a distance: on the closeness of technology. Amsterdam: Amsterdam University Press; 2012.

172.   May CR, Eton DT, Boehmer K, Gallacher K, Hunt K, MacDonald S, et al. Rethinking the patient: using Burden of Treatment Theory to understand the changing dynamics of illness. BMC Health Serv Res. 2014;14(1):1-11. doi: 10.1186/1472-6963-14-281

173.   Vallo Hult H, Hansson A, Svensson L, Gellerstedt M. Flipped healthcare for better or worse. Health Informatics J. 2019;25(3):587-97. doi: 10.1177/1460458219833099

174.   Greene J, Hibbard JH. Why does patient activation matter? An examination of the relationships between patient activation and health-related outcomes. JGen Intern Med. 2012;27(5):520-6. doi: 10.1007/s11606-011-1931-2

175.   Barlow J, Wright C, Sheasby J, Turner A, Hainsworth J. Self-management approaches for people with chronic conditions: a review. Patient EducCouns. 2002;48(2):177-87. doi: 10.1016/s0738-3991(02)00032-0

176.   Lorig KR, Sobel DS, Stewart AL, Brown Jr BW, Bandura A, Ritter P, et al. Evidence suggesting that a chronic disease self-management program can improve health status while reducing hospitalization: a randomized trial. Med Care. 1999:5-14. doi: 10.1097/00005650-199901000-00003

177.   Donaldson L. Expert patients usher in a new era of opportunity for the NHS: The expert patient programme will improve the length and quality of lives. BMJ. 2003;326(7402):1279-80. doi: https://doi.org/10.1136/bmj.326.7402.1279

178.   Ruckenstein M, Schüll ND. The datafication of health. Annu Rev Anthropol. 2017;46:261-78. doi: 10.1146/annurev-anthro-102116-041244

179.   Ong BN, Rogers A, Kennedy A, Bower P, Sanders T, Morden A, et al. Behaviour change and social blinkers? The role of sociology in trials of self-management behaviour in chronic conditions. Sociol Health Illn. 2014;36(2):226-38. doi: 10.1111/1467-9566.12113

180.   Tran V-T, Barnes C, Montori VM, Falissard B, Ravaud P. Taxonomy of the burden of treatment: a multi-country web-based qualitative study of patients with chronic conditions. BMC Med. 2015;13(1):1-15. doi: 10.1186/s12916-015-0356-x

181.   Sadler E, Wolfe CD, McKevitt C. Lay and health care professional understandings of self-management: a systematic review and narrative synthesis. SAGE Open Med. 2014;2:2050312114544493. doi: 10.1177/2050312114544493

182.   Mair FS, Montori VM, May CR. Digital transformation could increase the burden of treatment on patients. BMJ. 2021;375. doi: https://doi.org/10.1136/bmj.n2909

183.   Mair FS, May CR. Thinking about the burden of treatment. BMJ. 2014;349. doi: https://doi.org/10.1136/bmj.g6680

184.   Coulter A, Locock L, Ziebland S, Calabrese J. Collecting data on patient experience is not enough: they must be used to improve care. BMJ. 2014;348. doi: https://doi.org/10.1136/bmj.g2225

185.   Mira JJ, Tomás O, Virtudes-Pérez M, Nebot C, Rodríguez-Marín J. Predictors of patient satisfaction in surgery. Surgery. 2009;145(5):536-41. doi: 10.1016/j.surg.2009.01.012

186.   Vassilev I, Rogers A, Sanders C, Kennedy A, Blickem C, Protheroe J, et al. Social networks, social capital and chronic illness self-management: a realist review. Chronic Illn. 2011;7(1):60-86. doi: 10.1177/1742395310383338

187.   Russell S, Ogunbayo OJ, Newham JJ, Heslop-Marshall K, Netts P, Hanratty B, et al. Qualitative systematic review of barriers and facilitators to self-management of chronic obstructive pulmonary disease: views of patients and healthcare professionals. NPJ Prim Care Respir Med. 2018;28(1):1-13. doi: 10.1038/s41533-017-0069-z

188.   Walton H, Spector A, Roberts A, Williamson M, Bhatt J, Tombor I, et al. Developing strategies to improve fidelity of delivery of, and engagement with, a complex intervention to improve independence in dementia: a mixed methods study. BMC Medical Res Methodol. 2020;20(1):1-19. doi: 10.1186/s12874-020-01006-x

189.   Boulton ER, Horne M, Todd C. Multiple influences on participating in physical activity in older age: Developing a social ecological approach. Health Expect. 2018;21(1):239-48. doi: 10.1111/hex.12608

190.   Roberts SH, Bailey JE. Incentives and barriers to lifestyle interventions for people with severe mental illness: a narrative synthesis of quantitative, qualitative and mixed methods studies. J Adv Nurs. 2011;67(4):690-708. doi: 10.1111/j.1365-2648.2010.05546.x

191.   Crellin N, Herlitz, L., Sidhu MS., Ellins J., Georghiou T., Litchfield I., Massou E., Ng PL., Sherlaw-Johnson C., Tomini SM., Vindrola-Padros C., Walton H., Fulop N. Examining disparities relating to service reach and patient engagement with COVID-19 remote home monitoring services in England: a mixed methods rapid evaluation. medRxiv. 2021. doi: Retrieved 07/06/2022 from https://www.medrxiv.org/content/10.1101/2022.02.21.22270793v1

192.   Blundell R, Costa Dias M, Joyce R, Xu X. COVID-19 and Inequalities. Fisc Stud. 2020;41(2):291-319. doi: 10.1111/1475-5890.12232

193.   Leung MST, Lin SG, Chow J, Harky A. COVID-19 and Oncology: Service transformation during pandemic. Cancer Med. 2020;9(19):7161-71. doi: 10.1002/cam4.3384

194.   Wosik J, Fudim M, Cameron B, Gellad ZF, Cho A, Phinney D, et al. Telehealth transformation: COVID-19 and the rise of virtual care. J Am Med Inform Assoc. 2020;27(6):957-62. doi: 10.1093/jamia/ocaa067

195.   Gentles SJ, Lokker C, McKibbon KA. Health information technology to facilitate communication involving health care providers, caregivers, and pediatric patients: a scoping review. J Med Internet Res. 2010;12(2):e22. doi: 10.2196/jmir.1390

196.   Eruchalu CN, Pichardo MS, Bharadwaj M, Rodriguez CB, Rodriguez JA, Bergmark RW, et al. The expanding digital divide: digital health access inequities during the COVID-19 pandemic in New York City. J Urban Health. 2021;98(2):183-6. doi: 10.1007/s11524-020-00508-9

197.   Honeyman M, Maguire D, Evans H, Davies A. Digital technology and health inequalities: a scoping review. Public Health Wales NHS Trust. 2020. Retrieved 07/06/2022 from https://phw.nhs.wales/publications/publications1/digital-technology-and-health-inequalities-a-scoping-review/

198.   Litchfield I, Shukla D, Greenfield S. Impact of COVID-19 on the digital divide: a rapid review. BMJ Open. 2021;11(10):e053440. doi: 10.1136/bmjopen-2021-053440

199.   White M, Adams J, Heywood P. How and why do interventions that increase health overall widen inequalities within populations. In: S B, editor. Social Inequality and Public Health. Bristol: Policy Press; 2009. p. 65-82.

200.   Davies AR, Honeyman M, Gann B. Addressing the Digital Inverse Care Law in the Time of COVID-19: Potential for Digital Technology to Exacerbate or Mitigate Health Inequalities. J Med Internet Res. 2021;23(4):e21726. doi: 10.2196/21726

201.   McAuley A. Digital health interventions: widening access or widening inequalities? Public Health. 2014;12(128):1118-20. doi: 10.1016/j.puhe.2014.10.008

202.   Reiners F, Sturm J, Bouw LJ, Wouters EJ. Sociodemographic factors influencing the use of eHealth in people with chronic diseases. Int J Environ Res Public Health. 2019;16(4):645. doi: 10.3390/ijerph16040645

203.   Durand M-A, Carpenter L, Dolan H, Bravo P, Mann M, Bunn F, et al. Do interventions designed to support shared decision-making reduce health inequalities? A systematic review and meta-analysis. PloS one. 2014;9(4):e94670. doi: https://doi.org/10.1371/journal.pone.0094670

204.   Ortega G, Rodriguez JA, Maurer LR, Witt EE, Perez N, Reich A, et al. Telemedicine, COVID-19, and disparities: policy implications. Health Policy Technol. 2020;9(3):368-71. doi: 10.1016/j.hlpt.2020.08.001

205.   Iacobelli F, Adler RF, Buitrago D, Buscemi J, Corden ME, Perez-Tamayo A, et al. Designing an mHealth application to bridge health disparities in Latina breast cancer survivors: a community-supported design approach. Design Health. 2018;2(1):58-76. doi: 10.1080/24735132.2018.1452871

206.   Phelan JC, Link BG, Tehranifar P. Social conditions as fundamental causes of health inequalities: theory, evidence, and policy implications. JHealth Soc Behav. 2010;51(1_suppl):S28-S40. doi: 10.1177/0022146510383498

207.   Crespí-Lloréns N, Hernández-Aguado I, Chilet-Rosell E. Have policies tackled gender inequalities in health? A scoping review. Int J Environ res Public Health. 2021;18(1):327. doi: https://doi.org/10.3390/ijerph18010327

208.   MacGuire FA. Reducing Health Inequalities in Aging Through Policy Frameworks and Interventions. Front Public Health. 2020;8. doi: 10.3389/fpubh.2020.00315

209.   Peek ME, Simons RA, Parker WF, Ansell DA, Rogers SO, Edmonds BT. COVID-19 among African Americans: an action plan for mitigating disparities. Am J Public Health. 2021;111(2):286-92. doi: 10.2105/Ajph.2020.305990

210.   King RK, Green AR, TAN-McGRORY A, Donahue EJ, KIMBROUGH-SUGICK J, Betancourt JR. A plan for action: key perspectives from the racial/ethnic disparities strategy forum. Milbank Q. 2008;86(2):241-72. doi: 10.1111/j.1468-0009.2008.00521.x

211.   Bambra C, Gibson M, Sowden A, Wright K, Whitehead M, Petticrew M. Tackling the wider social determinants of health and health inequalities: evidence from systematic reviews. JEpidemiol Community Health. 2010;64(4):284-91. doi: 10.1136/jech.2008.082743

212.   Welch V, Tugwell P, Petticrew M, de Montigny J, Ueffing E, Kristjansson B, et al. How effects on health equity are assessed in systematic reviews of interventions. Cochrane Database Syst Rev. 2010(12). doi: 10.1002/14651858.MR000028.pub2

213.   Braun V, Clarke V. Using thematic analysis in psychology. QualRes Psychol. 2006;3(2):77-101. doi: 10.1191/1478088706qp063oa

214.   Miles MB, Huberman AM. Qualitative data analysis: An expanded sourcebook. London: Sage Publications; 1994.

215.   Mead N, Roland M. Understanding why some ethnic minority patients evaluate medical care more negatively than white patients: a cross sectional analysis of a routine patient survey in English general practices. BMJ. 2009;339. doi: 10.1136/bmj.b3450

216.   Scobie S. MJ. Quality and inequality: digging deeper: Nuffield Trust and the Health Foundation (Quality Watch Briefing); 2020. Retrieved 07/06/2022 from https://www.nuffieldtrust.org.uk/resource/quality-and-inequality-digging-deeper

217.   Ali PA, Watson R. Language barriers and their impact on provision of care to patients with limited English proficiency: Nurses' perspectives. J Clin Nurs. 2018;27(5-6):e1152-e60. doi: 10.1111/jocn.14204

218.   MacLeod S, Musich S, Gulyas S, Cheng Y, Tkatch R, Cempellin D, et al. The impact of inadequate health literacy on patient satisfaction, healthcare utilization, and expenditures among older adults. Geriatr Nurs. 2017;38(4):334-41. doi: 10.1016/j.gerinurse.2016.12.003

219.   Greenhalgh T, Rosen R, Shaw SE, Byng R, Faulkner S, Finlay T, et al. Planning and evaluating remote consultation services: a new conceptual framework incorporating complexity and practical ethics. Front in Digit Health. 2021:103. doi: 10.3389/fdgth.2021.726095

220.   Cooper LA, Hill MN, Powe NR. Designing and evaluating interventions to eliminate racial and ethnic disparities in health care. JGen Intern Med. 2002;17(6):477-86. doi: 10.1046/j.1525-1497.2002.10633.x

221.   Centre for Ageing Better. COVID-19 and the digital divide: supporting digital inclusion and skills during the pandemic and beyond 2021. Retrieved 8/10/2021 from https://ageing-better.org.uk/sites/default/files/2021-07/COVID-19-and-the-digital-divide.pdf

222.   Coffey JD, Christopherson LA, Glasgow AE, Pearson KK, Brown JK, Gathje SR, et al. Implementation of a multisite, interdisciplinary remote patient monitoring program for ambulatory management of patients with COVID-19. NPJ Digit Med. 2021;4(1):1-11. doi: 10.1038/s41746-021-00490-9

223.   Hill CV, Pérez-Stable EJ, Anderson NA, Bernard MA. The National Institute on Aging health disparities research framework. EthnDis. 2015;25(3):245. doi: 10.18865/ed.25.3.245

224.   Thomas EE, Taylor ML, Banbury A, Snoswell CL, Haydon HM, Rejas VMG, et al. Factors influencing the effectiveness of remote patient monitoring interventions: a realist review. BMJ Open. 2021;11(8):e051844. doi: 10.1136/bmjopen-2021-051844

225.   Herlitz L, Crellin, N., Vindrola-Padros C., Ellins J., Georghiou T., Litchfield I., Massou E., Ng PL., Sherlaw-Johnson C., Sidhu MS., Tomini SM., Walton H., Fulop NJ. Technology-enabled and analogue models of remote home monitoring care for COVID-19: a rapid mixed-method evaluation of patient and staff experiences. medRxiv.

226.   Stone E. NP, Shapiro R. Digital inclusion in health and care: Lessons learned from the NHS Widening Digital Participation Programme: Good Things Foundation; 2020. Retrieved 6/12/2021 from https://www.goodthingsfoundation.org/insights/digital-participation-lessons-learned/

227.   Davis MM, Freeman M, Kaye J, Vuckovic N, Buckley DI. A systematic review of clinician and staff views on the acceptability of incorporating remote monitoring technology into primary care. TelemedJ E Health. 2014;20(5):428-38. doi: 10.1089/tmj.2013.0166

228.   Taylor J, Coates E, Brewster L, Mountain G, Wessels B, Hawley MS. Examining the use of telehealth in community nursing: identifying the factors affecting frontline staff acceptance and telehealth adoption. JAdv Nurs. 2015;71(2):326-37. doi: 10.1111/jan.12480

229.   Papoutsi C, Wherton J, Shaw S, Morrison C, Greenhalgh T. Putting the social back into sociotechnical: Case studies of co-design in digital health. J Ame Med Inform Assoc. 2021;28(2):284-93. doi: 10.1093/jamia/ocaa197

230.   Greenhalgh T, Wherton J, Shaw S, Papoutsi C, Vijayaraghavan S, Stones R. Infrastructure revisited: an ethnographic case study of how health information infrastructure shapes and constrains technological innovation. J Med Internet Res. 2019;21(12):e16093. doi: 10.2196/16093

231.   Lundell S, Modig M, Holmner Å, Wadell K. Perceptions of home telemonitoring use among patients with chronic obstructive pulmonary disease: qualitative study. JMIR mHealth uHealth. 2020;8(6):e16343. doi: 10.2196/16343

232.   Mair FS, Hiscock J, Beaton SC. Understanding factors that inhibit or promote the utilization of telecare in chronic lung disease. Chronic Illn. 2008;4(2):110-7. doi: https://doi.org/10.1177/1742395308092482

233.   Shany T, Hession M, Pryce D, Galang R, Roberts M, Lovell N, et al. Home telecare study for patients with chronic lung disease in the Sydney West Area Health Service. Stud Health Technol Inform. 2010;161:139-48. doi: 10.3233/978-1-60750-659-1-139

234.   Khan N, Jones D, Grice A, Alderson S, Bradley S, Carder P, et al. A brave new world: the new normal for general practice after the COVID-19 pandemic. BJGP Open. 2020;4(3). doi: 10.3399/bjgpopen20X101103

235.   Leonardsen A-CL, Hardeland C, Helgesen AK, Grøndahl VA. Patient experiences with technology enabled care across healthcare settings-a systematic review. BMC Health Serv Res. 2020;20(1):1-17. doi: 10.1186/s12913-020-05633-4

236.   Lewis C, Moore Z, Doyle F, Martin A, Patton D, Nugent LE. A community virtual ward model to support older persons with complex health care and social care needs. Clin Interv Aging. 2017;12:985. doi: 10.2147/CIA.S130876

237.   Jones J, Carroll A. Hospital admission avoidance through the introduction of a virtual ward. BrJ Community Nurs. 2014;19(7):330-4. doi: https://doi.org/10.12968/bjcn.2014.19.7.330

238.   Davidson S. Digital Inclusion Evidence Review London: Age UK; 2018. Retrieved 17/01/2022 from https://www.ageuk.org.uk/globalassets/age-uk/documents/reports-and-publications/age_uk_digital_inclusion_evidence_review_2018.pdf

239.   Office for National Statistics. Internet users 2019. Retrieved 07/06/2022 from https://www.ons.gov.uk/businessindustryandtrade/itandinternetindustry/datasets/internetusers

240.   Boivin A, Lehoux P, Lacombe R, Burgers J, Grol R. Involving patients in setting priorities for healthcare improvement: a cluster randomized trial. Implement Sci. 2014;9(1):1-10. doi: 10.1186/1748-5908-9-24

241.   Steenland K, Deddens JA. A practical guide to dose-response analyses and risk assessment in occupational epidemiology. Epidemiology. 2004:63-70. doi: 10.1097/01.ede.0000100287.45004.e7

242.   Griffin S. Covid-19: England comes into line with rest of UK on recording deaths. BMJ. 2020. doi: https://doi.org/10.1136/bmj.m3220

243.   UK Health Security Agency. UK Coronavirus Dashboard: About the data 2021. Retrieved March 2021 from https://coronavirus.data.gov.uk/details/about-data

244.   NHS England and Improvement. COVID-19 Hospital Activity 2021. Retrieved March 2021 from https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-hospital-activity/

245.   Smith T SB. PROC GENMOD with GEE to analyze correlated outcomes data using SAS San Diego (CA): Department of Defense Center for Deployment HEalth Research, Naval Health Research Center; 2006. Retrieved March 2021 from https://www.lexjansen.com/wuss/2006/tutorials/TUT-Smith.pdf.

246.   Austin PC, Rothwell DM, Tu JV. A comparison of statistical modeling strategies for analyzing length of stay after CABG surgery. Health Serv Outcomes Res Methodol. 2002;3(2):107-33. doi: https://doi.org/10.1023/A:1024260023851

247.   SAS Institute Inc. SAS/STAT® 9.4. f Medicine SAS Institute Inc. ; 2020.

248. Herbert A, Wijlaars L, Zylbersztejn A, Cromwell D, Hardelid P. Data resource profile: hospital episode statistics admitted patient care (HES APC). Int J Epidemiol. 2017;46(4):1093-i. doi: 10.1093/ije/dyx015

249. Ministry of Housing Communities & Local Government. English indices of deprivation 2019. Retrieved 19th November 2021 from https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019

250. NHS England and Improvement. Weekly publication of COVID-19 admissions and bed occupancy data 2021. Retrieved 19th November 2021 from https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-hospital-activity/.

251. Office for National Statistics. Coronavirus (COVID-19) Infection Survey technical article: waves and lags of COVID-19 in England 2021. Retrieved 19th November 2021 from https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/articles/coronaviruscovid19infectionsurveytechnicalarticle/wavesandlagsofcovid19inenglandjune2021

252. Jeon W-H, Seon JY, Park S-Y, Oh I-H. Analysis of risk factors on readmission cases of COVID-19 in the Republic of Korea: using nationwide health claims data. Int J Environ res Public Health. 2020;17(16):5844. doi: 10.3390/ijerph17165844

253. Guo A, Lu J, Tan H, Kuang Z, Luo Y, Yang T, et al. Risk factors on admission associated with hospital length of stay in patients with COVID-19: a retrospective cohort study. Sci Rep. 2021;11(1):1-7. doi: 10.1038/s41598-021-86853-4

254. Scobie S KE. Chart of the week: How long do COVID-19 patients spend in hospital? 2021. Retrieved 19th November 2021 from https://www.nuffieldtrust.org.uk/resource/chart-of-the-week-how-long-do-covid-19-patients-spend-in-hospital

255. Eccles DW, Arsal G. The think aloud method: what is it and how do I use it? Qualitative Research in Sport, Exercise and Health. 2017;9(4):514-31. doi: 10.1080/2159676X.2017.1331501

256. Rogers L, De Brún A, Birken SA, Davies C, McAuliffe E. The micropolitics of implementation; a qualitative study exploring the impact of power, authority, and influence when implementing change in healthcare teams. BMC Health Serv Res. 2020;20(1):1059. doi: 10.1186/s12913-020-05905-z

257. NHS England. COVID Oximetry @home n.d. Retrieved 7th March 2022 from https://www.england.nhs.uk/nhs-at-home/covid-oximetry-at-home/

Appendix

Appendix 1. A summary of the standard operating procedures for COVID Oximetry@home [38] and COVID virtual wards [39]

Table 24. A summary of standard operating procedures for COVID Oximetry@home and COVID virtual wards

	Characteristics of service		Patient journey				
	Entry criteria	Staffing and oversight	Referral (stage 1)	Triage (stage 2)	Onboarding (stage 3)	Monitoring (stage 4)	Recovery and discharge (stage 5)

Standard operating procedure COVID Oximetry@home[38]	1) Diagnosed with COVID-19 (clinically or positive test result) AND 2) symptomatic and either 65 years or older or under 65 years and clinically extremely vulnerable to COVID.[1]	• Models primarily implemented in general practice (including hot hubs, community teams).
		
		• Responsibility lies with CCGs.
			• Timely referral that meets entry requirements from all relevant providers (111, COVID Clinical Assessment Service, Test and Trace and hospital EDs).	• Patients should receive standard assessment (with potential for face-to-face clinical assessment if necessary).
				• Same day as referral.
				• Hot sites – face-to-face assessment.
				• Phone/video – virtual assessment using standard questionnaire & baseline oximetry reading either
					• Patients should be given pulse oximeter and supporting information (including paper diary in variety of languages, app/regular call mechanism), contact details to report readings/symptoms and safety netting instructions:
					  o Immediately if patient seen face-to-face.
					  o Within 12 hours if assessment remotely.
					• Instruct patients to record oximetry readings daily (usually 3x a day). Also give option of prompts at days 2,5,7,10,12 (text message,
						• Patients should be texted or emailed or called as agreed.
						• Check in calls should check patient is using oximeter and diary correctly and that readings are 95% or above.
						• Frequency of calls can be reviewed
							• Discharge patients and give leaving information, safety netting and safe advice on how to return oximeter (hot site, NHS volunteers) within 14 days.
							• Patients can be discharged earlier if negative result or if determined at clinical review.
							• Patients still symptomatic at 14 days = further assessments.

				at hot site or home visit.	email, or non.clinician phone call).	as appropriate.	
					• Instruct patients on how to access help if needed & provide 24/7 access to support.		
					• Agree how patients will return oximeter.		
	Entry criteria	**Staffing and oversight**	**Hospital discharge assessment (stage 1)**		**• Onboarding (stage 2)**	**Monitoring (stage 3)**	**Recovery and discharge (stage 4)**

Standard Operating Procedure CVW [39]	1) Adults in hospital with diagnosis of COVID-19 who have an improving clinical trajectory & no fever for 48 hours.
	
	 2) Patients seen in secondary care or by ambulance clinicians who do not require emergency admission but do
		• Models implemented by one or more acute trust.
		 • Responsibility lies with hospitals.
		 • Clinical, governance and administrative responsibilities provided by appropriately trained staff (including shielding staff). Staff should be supervised by clinically-registered professional.
			• Completion of satisfactory exercise test:
			   o Saturations 95-100% and low NEWS2 and improving clinical trajectories can be discharged to CVW.
			   o Saturations 93-94% with improving clinical trajectories can be considered for CVW (if clinically appropriate).
			   o Saturations 92% or lower or experiencing moderate/severe shortness of breath are unsuitable for early supported discharge unless patient is stable.
			 Clinical judgement necessary.
					• Agree a discharge/escalation plan which includes monitoring arrangements.
					 • Patients given a patient information leaflet, oximeter, instructions and diary.
					 • Patients given hospital number to call for advice or support between 8am and 8pm, 7 days a week.
					 • Onboarding should include provision of a patient held escalation plan.
						• Patient takes 3 readings each day and enters into a diary.
						 • Patient asked to call hospital immediately if reading less than 92%. If not possible attend ED within an hour or call 999.
						 • Service contact the patient by phone every day.
							• Discharged at 14 days (or before if appropriate).
							 • GP should be informed.
							 • If still symptomatic, receive a further clinical assessment.
							 • Friend/family or NHS volunteer collects and returns oximeter for decontamination and reuse.

	require oximetry follow-up.	• CVW led by a named consultant or ST3+ doctor with relevant COVID experience. • Requires staffing for at least 12 hours a day (8am-8pm) 7 days a week + out of hours cover.				
Notes: 1 This changed later as patients below 65 were also eligible. 2 National roll-out November 2020. 3 National roll-out January 2021.						

Appendix 2. Summary of monitoring approach and frequency of monitoring calls (based on staff interviews and clinical lead surveys)

Table 25. Summary of monitoring approach and frequency of monitoring calls

Summary of monitoring approach (based on information reported in staff interviews and clinical lead surveys)	Frequency of calls (for submission of readings)	Number of sites	Example
Self-monitoring only	No scheduled telephone calls from members of staff for all patients (tech-enabled or calls patient-initiated).	0	N/A
Tech-enabled and analogue self-monitoring option if tech-enabled not possible	Regular contact from member of staff regardless of whether using tech-enabled or analogue mode of submitting readings (welcome call, courtesy call mid-way and discharge call). Patients on analogue option asked to ring if any problems with monitoring (self-monitoring).	1	At site D, three options of monitoring are offered: • Analogue option: Patients record using paper diaries and are advised to record readings three times a day and ring the service if they need help (self-monitoring). • Tech-enabled option: Text message readings once a day (encouraged to take readings more than once a day). • Tech-enabled option for those with chronic conditions: submit readings once a day via an app.
Tech-enabled and analogue if tech-enabled not possible (non-automated telephone calls to submit readings)	Once a day or less (with some exceptions*).	10	At site B, three options of monitoring are offered: • Tech-enabled option: Patients submit readings by text 3x a day. • Tech-enabled option: Patients submit readings by automated calls 3x a day. Analogue option: Patients record readings using paper diary and patients are called by service once a day to give their readings.
Tech-enabled and analogue if tech-enabled not possible (non-automated telephone calls to submit readings)	More than once a day.	9	At Site Q, two options of monitoring are offered: • Analogue option: Patients telephoned three times a day to provide readings (or less if stable or less contact preferred). • Tech-enabled option: Patients submit readings via app three times a day.
Tech-enabled monitoring and analogue (non-automated telephone calls to submit readings) if tech-enabled not possible	Regular contact from member of staff regardless of whether using tech-enabled or analogue mode of submitting readings (days 2,5,6,12,14). Telephone calls to submit readings (for analogue patients): More than once a day	1	At Site N, three options of monitoring are offered: • Tech-enabled option: patients are texted to submit readings two or three times day. • Tech enabled option: Patients receive automated calls to submit readings. • Analogue option: Patients are phoned three times a day to submit readings.

Analogue-only. Regular telephone calls from member of staff to submit readings	Varying frequencies (once a day or less to more than once a day depending on needs**).	5	At Site R, one option of monitoring is offered: • Analogue option: Patients telephoned once a day to provide readings (or more frequently if concerns). At Site V, three analogue options are offered: • Analogue option: Patients telephoned daily to provide readings (red category). • Analogue option: Patients telephoned every other day (amber category). • Analogue option: Patients are telephoned weekly to provide readings (green category).
Analogue-only. Regular telephone calls from member of staff to submit readings & face-to-face option (for monitoring) if needed.	Varying frequencies (Once a day or less to more than once a day depending on needs)	2	At Site F, two analogue options are offered: • Analogue option: Patients receive daily, twice daily or on alterative days depending on patient preferences and ability. • Analogue option: If patients are struggling with oximeters and readings, are older or have certain conditions, or are too poorly, patients receive face-to-face appointments every day.

Note

*e.g. One site (E) called patients on oxygen more than once a day, and one site (J) called patients more than once a day if they were identified as 'priority' patients, site L and O varied depending on severity (once a day for those requiring close care to every other day to every seven days), Site O offered a self-monitoring pathway as part of the different levels of monitoring. Frequency not known for site Y.

**One site phones patients every two days, two once a day unless concerns (then more frequently), and one daily/every other day/weekly depending on need, one not specified.

Appendix 3. Patient/carer recommendations to improve the service

Table 26. Patient/carer recommendations to improve the service

Category	Recommendation
Patient awareness	- Need more publicity about the service. - Need to know about the service sooner or earlier referral. - Need to improve link to NHS Track and Trace. - Need national standardised approach or automatic referral.
Patient enablement	- Need more information provision about the service at referral, about escalation and about discharge. - Need a dedicated contact number for patients to contact service if needed. - Some patients require some face-to-face visits. - Need reminders to submit readings.
Workforce	- More continuity of staff and continuity of information. - More contact with doctors desired by some patients.
Individual differences	- More personalised approach. - Flexibility of methods and patient choice.
Equipment	- Provision of thermometers. - Support with using technology (oximeter and digital platforms).
Logistics of service	- Consider timing of monitoring calls and having a specific time slot. - Need to receive calls when promised. - Need to ensure practical and efficient arrangement of oximeter delivery and return.
Signposting	- Following patients up after discharge. - A point of contact after discharge to ask questions to. - Signposting to places that can support them whilst on the service. - Community drives to ease concerns over hospitals.

Appendix 4. Local service adaptations to increase reach and facilitate patient engagement

Table 27. Local service adaptations to increase reach and facilitate patient engagement

Adaptations to service		Patient group (to benefit from adaptation)
Adaptations to increase inclusivity/reach		
Broadening the service entry criteria	- Using broader entry criteria than that specified in the national guidance to meet the needs of local population, for example, including ethnic minority groups, pregnant women, and people with learning disabilities. - In particular, many services used an age criterion lower than 65 years (some adopting a 50+ cut-off, while others using 18+). - This broadening of criteria was also reflected in the national SOP – amendments were made to allow for clinical judgement regarding assessment of entry criteria and under 65s were permitted if clinically vulnerable.	At-risk or vulnerable groups prioritised by services, for example, patients with a learning disability, severe mental illness, ethnic minority groups, and pregnant women.
Active case finding	- Proactively identifying and contacting patients with a positive COVID test (rather than relying on referrals). - Some services were able to do this from set-up, other services introduced this later on (e.g. due to delays between Test and Trace linking positive cases to CCGs), while some services did not have the capacity to do this. - Proactively targeting certain groups, for example, establishing a priority list to for those patients considered to be hard to reach, can address inequalities in those able to ask for or access services.	Hard-to-reach patients (i.e. those less likely to seek help from their GP), could include those with limited digital, numerical or written literacy, frail or elderly patients, or patients with high levels of anxiety.
Design of referral pathways	- Working with primary and/or secondary services to encourage appropriate referrals and improve flow of referrals. - Setting up additional referral pathways, for example, from EDs, 111, the ambulance service, out of hours services, and care homes to increase referrals. - Other, less frequent referral pathways were established including maternity wards, those for young carers, secure units, and sheltered and supported accommodation. - CO@h services supporting, engaging and training health professionals based in primary care services to increase referrals.	Referral pathways can target specific patient groups, e.g. carers, people living in sheltered or supported accommodation, people residing in secure units.

Monitoring service uptake by different at-risk groups	• Regularly reviewing data on service uptake to check the representation of different at-risk groups compared to local population data.	• At-risk or vulnerable groups prioritised by services.
Adaptations to increase patient engagement		
Providing additional support for patients beyond monitoring protocol or national guidance	• Connecting patients with other social support (and related services) in the local area. • Providing more contact time to anxious, lonely or vulnerable patients or those living alone. • Offering additional digital/technology-related training or support to patients less confident or able using technology. • Locally providing additional support to help engagement with the service (e.g. to help with activities such as using the oximeter, recording and submitting readings). • Providing wellbeing calls or welfare checks for vulnerable patients (i.e. telephone or face-to-face).	• Vulnerable or particularly unwell patients may need more assistance, for example, patients living alone/socially isolated, patients who are carers, patients that are very anxious or patients at risk of being digitally excluded.
Collaborating with other teams or specialist services	• Working with other clinical teams or specialist services, e.g. learning disability teams or mental health services, respiratory or cardiac specialists and physiotherapists. • Creating special/integrated pathways to better support patients with particular needs (includes liaising with primary care services). • Local variation in collaboration between the remote home monitoring service and other clinical services – patients in some areas had more seamless access to services, for example, to support existing health conditions or post-COVID recovery.	• Patients requiring additional support such as those with a learning disability or severe mental illness, or patients with long COVID or specific health needs (e.g. pre-existing or associated with their COVID diagnosis).
Delivery of oximeters	• Making arrangements for oximeters to be delivered to patients, where collection by a family member, friend or carer was not possible, for example, using volunteers or the fire service. • Providing the option for oximeters to be collected by patient (or friend/relative/carer) to ensure fastest possible access to equipment. • If patients are advised to use their own oximeter, safety netting information on how to use it still required.	• Particular value for patients living alone, without a support network, or where several family members isolating at the same time.
Adapting patient information	• Providing information in different formats such as braille or large print, easy-read documents, audio descriptions for patients. • Some amendments were made locally, however at a national level NHSE provided an easy read version of how to use the oximeter, a range of other resources and formats.	• Patients with a visual impairment, learning disability, cognitive or hearing impairment or

		difficulty communicating, and patients without digital access.
	• Providing a link to online video demonstrating how to use the oximeter. • Providing information by post if no digital access. • Liaising with family, friends or carers to support patients in understanding the information, or, if patients did not have support available to them, offering home visits. • Recognising the importance of when patient information is given and to whom (i.e. patient and carers). To help patients and carers understand (as best as possible) what the service entails and what is expected of them.	
Translation services	• Locally amending patient information and supporting guidance for patients whom English was not their first language, such as translating documents into other languages. • Nationally, NHSE supported the provision of information in accessible formats and translated supporting information such as paper diaries into different languages. • Providing translation services to translate information and support communication with patients. • Liaising with family members, carers or friends to support non-English speaking patients. • Some digital platforms were able to support non-English speaking patients.	• Patients for whom English was not their first language.
Amending the monitoring processes/ protocols	• Changing the mode of monitoring, such as offering text options rather than telephone calls (e.g. if hearing impairment) or face-to-face appointments for those needing support with the equipment or where communication difficult. • Changing the timing of monitoring according to patient needs or preferences (e.g. around working hours or sleeping patterns). • Changing the frequency of monitoring depending on preference or needs (e.g. less often if requested). • Extending the monitoring period by allowing patients to remain in the service for longer (e.g. if still feeling unwell). • For care homes, providing one phone call for all patients and calling at a routine time.	• To better suit the needs of specific patient groups, such as those with a visual or hearing impairment, cognitive impairment, patients living alone, anxious or working patients, those with low digital literacy or patients who were particularly unwell.
Mode of monitoring	• Offering an analogue (rather than tech-enabled) option for patients to record and submit their readings. • All services offered an analogue mode of monitoring option regardless of whether they had a tech-enabled option or not.	• Patients may desire or need a comprehensive assessment by phone or in person, particularly if they have co-morbidities, mental health concerns, or less-often reported COVID-19 symptoms. • Analogue option can mitigate against digital exclusion.

Providing additional equipment	• Offering patients without access to the technology, a tablet or similar to use to provide the readings throughout the duration of the service. • Variation between services in whether they offered digital equipment and support.	• Patients without access to appropriate technology.
Face-to-face assessments or home visits and/or video consultations	• Offering patients face-to-face or home visits for those considered vulnerable or 'at-risk' or those in which providing readings via phone or text not possible (e.g. where communication difficult via phone/text). • The national SOP specified that during triage face-to-face clinical assessment should take place if deemed necessary and discussions around support requirements should take place.	• Patients who were very unwell or anxious, at higher risk of deterioration, or unable to submit readings. • Patients who are housebound, or patients with a cognitive, hearing or visual impairment may also benefit from being seen face-to-face.
Liaising with family, friends or carer	• Liaising with family members, friends or carers to provide readings for those who were too unwell to use the oximeter/provide readings, not confident with using the equipment or with a hearing or cognitive impairment.	• If patients live alone or do not feel supported by their household, services need to be mindful that they may require additional support to engage with the service.

Note. The themes presented are derived from service lead interviews and staff survey data (i.e. open text responses).

Appendix 5. Functions of COVID-19 remote home monitoring platforms that staff valued or felt needed improvements

Table 28. Functions of COVID-19 remote home monitoring platforms that staff valued or felt needed improvements

Valuable functions	Staff views
Interoperability with other data systems	Staff valued tech-enabled platforms that integrated with existing patient health systems, enabling them to view patients GP records, automate referrals from GP practices, update GP practices on patients' care.
Plasticity	Staff liked features that enabled them to change what they viewed according to their needs and add or change patient readings or notes. For example, being able to: • Organise their main screen according to their needs, such as to view patients receiving oxygen (see also filtering, ordering and sorting). • Open more than one patient record at the same time. • Switch between a patient's readings and their notes. • Easily return to different screens. • Change the parameters for alerts in oxygen level saturations for individual patients (e.g. COPD patients who have lower overall levels of saturation). • Add adhoc readings for patients that have mis-entered their measurements. • Add patient notes for additional information, for example, noting any mental health concerns. • Set different levels of permission for what different staff can view or edit.
Filtering, ordering and sorting information	Staff valued platforms that enabled them to filter, order and sort patients according to their clinical needs or the service's operational needs, for example, by Red Amber Green rating, oxygen saturation levels, by staff allocation, by patients yet to be reviewed.
Task management	Task management functions – that is, automated messages from the system relating to allocated tasks – were valued if they fit the service's needs. In some sites, automated tasks to call patients could facilitate work allocation. In others, inappropriately automated tasks became an additional message to remove because oversensitive alerts were raised for patients.
Exact readings	Staff wanted exact readings for patients' measurements (rather than ranges), for example, oxygen saturation levels (essential when patients were weaned off oxygen) and temperature. In one site, inexact readings for patients using oxygen led to staff calling patients for readings they had already provided through the app. In one site, temperature readings were provided in Fahrenheit rather than Celsius and had to be continually converted by staff.
Automated discharge report	One platform produced automated discharge reports that could be shared with patients' GPs, which was valued by staff. A staff member from another site highlighted the potential efficiency gains from automating the discharge process through the platform so that the tech provider and GP could both be notified of a patients' discharge from the service (and the need for equipment to be collected).

Reporting	For most tech-enabled platforms, reports on patients using the service were provided on a daily or weekly basis by the tech provider. However, built-in reporting function would enable staff to view and interrogate the data themselves.
Data dashboard	Staff reported the utility of a data dashboard to have an overview of all patient records, including referral, onboarding, review and discharge dates.
Visibility of information	Staff valued being able to see patients' readings visually, for example, in tables or charts that could be viewed clearly on one page. Including data points for missing data from non-submission was also useful.