COVID Oximetry @home evaluation
Interpretation of findings

November 2021

RSET rapid service evaluation team

BRACE Rapid Evaluation Centre

FUNDED BY NIHR | National Institute for Health Research

Imperial College London

INSTITUTE OF GLOBAL HEALTH INNOVATION

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Contents

1. About this report

This reports presents the interpretation of the findings across three independent separate evaluations into the impact of the COVID Oximetry @home (CO@h) programme.

All statements in this report are based on a synthesis of the evidence carried out by the evaluators; further insights may be derived from the more detailed results from each of the evaluations.

Please note that the findings in this report have not yet been peer reviewed. The findings of the independent evaluations will be submitted for peer review publication separately.

The three evaluation teams for the evaluation and synthesis are:

- a collaboration between NIHR RSET (Rapid Service Evaluation Team) and NIHR BRACE (Birmingham, RAND and Cambridge Evaluation)
- Institute of Global Health Innovation, NIHR Imperial Patient Safety Translational Research Centre, Imperial College London
- Improvement Analytics Unit (a partnership between the Health Foundation and NHS England and NHS Improvement).

For more details, see the teams' summary of methods and limitations (A1, A2 and A3) and contact information (A4).

2. Summary

Across England the NHS has implemented COVID Oximetry @home (CO@h) services rapidly and flexibly. The use of pulse oximeters at home allows early detection of low oxygen saturation levels and escalation as necessary. There was large variability in the models implemented in relation to the design and intensity of monitoring, workforce numbers and skill mix, start date, uptake levels and enrolment criteria (e.g. national age criteria were broadened in nearly all areas studied).

It was expected that CO@h may reduce mortality and lead to better use of secondary care services, however this robust national evaluation, delivered by three evaluation teams, did not identify these effects. There was a lower uptake of services than expected, spread across a wider group of patients than envisaged in national guidance. The evaluation process was complicated by low uptake and/or missing data along with the wide range of CO@h services offered and the challenges of developing new data flows alongside rapid service implementation. As a result, it is not possible to determine whether the lack of significant findings represents a lack of impact of the programme on the outcomes examined or an inability to detect an impact.

People accessing CO@h and the workforce supporting it valued CO@h. Patients and carers felt that the service and human contact provided them with reassurance and that it was mostly easy to engage with. However, patients' ability to engage with the service was conditional on a range of factors including support from family/friends and staff, being in relatively good health, and understanding how to engage with the programme.

The workforce generally felt confident in their new roles within CO@h, with 75% of staff reporting increased job satisfaction. Staff needs identified included increased access to competency based training and clinical oversight.

67% of services studied took active measures to be inclusive. All services provided patients with access to a non-digital option to record their oxygen saturation levels, recognising the potential risks of digital exclusion. People with an ethnic minority background or from more deprived areas may be comparatively more likely to access CO@h. However, older patients, those with a health problem/disability and non-White ethnic groups were more likely to report difficulties engaging with services. Older patients found the service less helpful and reported a less positive experience.

CO@h uptake in care homes was lower still, at about half that observed among the wider eligible population. The CO@h programme seems to have been well-received by staff and beneficial to the care home sites in contact with it, but over half of survey respondents were unaware of the programme.

This national evaluation provides a number of lessons for future provision of these services for COVID-19 patients and potentially for remote home monitoring of patients with other conditions.

3. About the evaluators (1/3)

NIHR RSET / NIHR BRACE

Two rapid evaluation teams: NIHR RSET (a collaboration between UCL, Nuffield Trust and Cambridge University) and NIHR BRACE (a collaboration between University of Birmingham, RAND Europe, the University of Cambridge and National Voices).

Project team for the evaluation and care homes extension: Naomi Fulop, Jon Sussex, Cecilia Vindrola, Manbinder Sidhu, Chris Sherlaw-Johnson, Theo Georghiou, Holly Walton, Nadia Crellin, Sonila M Tomini, Jennifer Bousfield, Jo Ellins, Ian Litchfield, Steve Morris, Pei Li Ng, Lauren Herlitz, Lina Massou, Barbara Janta, Giulia Maistrello, Robin Miller, Jamie-Rae Tanner.

This evaluation is independent research funded by the National Institute for Health Research, Health Services & Delivery Research programme (RSET Project no. 16/138/17; BRACE Project no. 16/138/31) and NHSEI.

The views expressed in this publication are those of the authors and not necessarily those of the National Institute for Health Research or the Department of Health and Social Care.

Ethical approval: for main study:

Quantitative analysis, cost analysis and staff survey/interviews 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).

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).

For care homes study: ethical approval received from the University of Birmingham Research Ethics Committee (ERN_13-1085AP40).

RSET rapid service evaluation team

BRACE Rapid Evaluation Centre

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3. About the evaluators (2/3)

Imperial College London

Institute of Global Health Innovation, NIHR Imperial Patient Safety Translational Research Centre, Imperial College London (ICL).

- Core team: Thomas Beaney, Jonathan Clarke, Ana Luisa Neves.
- Wider team: Ahmed Alboksmaty, Hutan Ashrafian, Paul Aylin, Owen Bray, Ara Darzi, Sarah Elkin, Roberto Fernandez Crespo, Kelsey Flott, Gianluca Fontana, Saira Ghafur, Melanie Leis, Mahsa Mazidi.

This evaluation was funded by NHS England and Improvement and NHSX

Imperial College London

INSTITUTE OF GLOBAL HEALTH INNOVATION

NIHR | Imperial Patient Safety Translational Research Centre

3. About the evaluators (3/3)

Improvement Analytics Unit

The Improvement Analytics Unit (IAU) is a unique partnership between NHS England and NHS Improvement and the Health Foundation that evaluates complex initiatives in health care in order to support learning and improvement.

Project team for the evaluation: Richard Brine, Stefano Conti, Liz Crellin, Therese Lloyd, Paris Pariza, Will Parry, Arne Wolters.

4. Description of CO@h service based on the national standard operating procedure

The national COVID Oximetry @home (CO@h) programme was launched in November 2020, providing pulse oximeters to patients diagnosed with COVID-19 and at risk of health deterioration due to silent hypoxia. These devices were intended to support self-management, by enabling patients to take oxygen saturation readings three times a day and, where appropriate, report these to the service (either analogue* or tech-enabled* depending on the service and patient preference). Local CO@h services were already up and running in parts of the country, and pulse oximeter devices were made available to these sites by NHSEI from May 2020.

The national standard operating procedure sets out the original criteria for eligibility for the service as those patients diagnosed with COVID-19 who are symptomatic and either: (i) 65 years of age or over; or (ii) clinically extremely vulnerable (CEV) to COVID-19; or (iii) identified by a clinician as likely to benefit from the programme. If patients do not show signs of health deterioration within 14 days of onset of symptoms, they are discharged from the programme. Local standard operating procedures may vary.

CO@h is also available to care home residents.

In February 2021, the NHSEI encouraged local areas to consider extending the age criteria for CO@h to people aged 50 and over as vaccination progressed, and placed more emphasis on clinical judgement to determine enrolment.

* For full definitions, see appendix A5.

5. Logic model as agreed October 2020

Rationale

COVID-19 has led to many individuals suffering severe complications and deaths. One issue is people presenting to hospital with low oxygen saturation levels, often without accompanying breathlessness (so-called silent hypoxia). Delayed presentation can lead to invasive treatment in ICUs being required, longer hospital stay and increased risk of death.

The use of pulse oximeters at home would allow for early detection of low oxygen saturation levels, followed by early intervention and timely hospital admission, resulting in better outcomes for patients.

Input

CCGs advised in November to set up COVID Oximetry @home services as rapidly as possible.

Default assumption is model primarily implemented in general practice as one of seven priority goals for the additional £150m funding in the General Practice COVID Capacity Expansion Fund.

Timely referral of patients who may meet the entry criteria from all relevant providers operating within the area.

Supply of pulse oximeters available to CCGs based on national modelling assumptions of case demand using agreed entry criteria.

Activities

[National CO@h programme]
National roll-out of pulse oximeters to eligible population, following the **standard operating procedures**. [ref]

Eligible population:
People who are clinically suspected of having, or test positive for, COVID-19 and are:

- aged 65 or over, or
- aged 18 and over and considered clinically vulnerable.

[Local CO@h]
Local level roll-out of pulse oximeters to patients who have been identified as likely to benefit from the intervention, based on **local eligibility criteria**.

Output

Three-times daily oximeter readings, which are proactively monitored and may lead to **referral to hospital for early intervention**.

Data completion might vary for patients, depending on compliance with the CO@h protocol. Non-compliance might be caused by difficulty operating the equipment, digital exclusion, issues with access to carers or clinical condition.

The accuracy of the oximetry readings may be compromised by patients not adhering to guidelines (eg hands too cold, not waiting for a minute).

Data completion will also likely be different for patients in care homes, as they would be less likely to take their own readings, but instead be supported by care home staff.

Similarly, patients with learning disabilities are also more likely to be supported by a carer, possibly resulting in better compliance with the protocol.

Outcomes

Knowledge of healthy oxygen saturation levels may ease worry of patients who would otherwise present at A&E, resulting in a **reduction in A&E attendances**.

Early detection of deterioration of oxygen saturation levels will lead to early intervention, resulting in an **increase in the number of emergency admissions.**

Erroneous detection of deterioration of oxygen saturation levels ('false positives') may **increase the number of A&E attendances.**

Early intervention might lead to less invasive and shorter treatment, resulting in **reduction of length of stay** following emergency admissions.
Similarly, treatment may be provided in a less intensive setting, or require fewer days in ICU resulting in **reduction of hospital bed days in ICU.**

Early treatment might lead to better outcomes for patients and result in a **reduction in COVID-19 related mortality**.

Long-term outcome

Early detection of deterioration of oxygen saturation levels, leading to early and less invasive treatment, may have a long-term benefit for COVID-19 patients, **reducing the negative impacts of long COVID and long-term complications of prolonged hospital admission**.

Any impact on hospital utilisation by patients enrolled on the CO@h pathway may have a knock-on effect on the outcomes of non-COVID-19 patients.

Activities outside CO@h

[Virtual Wards]
National roll-out of pulse oximeters **following discharge from hospital**.

[PRINCIPLE Trial, Oxford]
Trial into alternative treatment for COVID-19 on the over-50 population.

Output outside CO@h

Patients who recover from COVID-19 in hospital, who require no further hospital care, may be monitored from home, allowing **early discharge from hospital**.

Patients recruited on the trial may experience **better health outcomes** across all metrics.

Impact on CO@h outcomes

Any effect on **length of stay** may be confounded by the Virtual Wards programme, and need to be interpreted with care.

Depending on the level of recruitment onto the PRINCIPLE Trial, and effectiveness of alternative treatment, **all health outcomes** may be impacted, and need to be interpreted with care.

6. Evaluation overview and approach

The evaluation was undertaken using a mixed methods approach, with three independent evaluation partners adopting a range of methodologies. Three separate quantitative studies of the impact of the CO@h programme on mortality and secondary care utilisation were conducted by the IAU, RSET/BRACE and ICL.

ICL examined inequalities in the odds of being enrolled onto a CO@h programme among eligible patients.

Further quantitative evaluations of the differences between technology-enabled and analogue pathways were conducted by ICL and RSET/BRACE.

RSET/BRACE conducted a study of implementation and patient/carer and workforce experience using a survey of 292 staff in 28 services, a survey of 1,069 patients/carers in 25 services, interviews with 62 patients/carers and 58 staff in 17 services, and interviews with 5 national leads.

RSET/BRACE conducted a cost analysis of setting up and running the CO@h programme at 22 sites, based on aggregate data over the period October 2020–April 2021; data were collected on the number of patients monitored, the staffing models and the allocation of resources.

RSET/BRACE conducted a cost analysis to compare the costs of using tech-enabled (digital) and analogue models.

RSET/BRACE conducted a study of the use of oximetry in care homes through a national survey of care home managers and interviews with staff in six care homes.

Further details on methods can be found on slides A1, A2 and A3

7. Summary findings (1/3)

Overall service use

- Use of the service was low (2.1%) in those aged 65 or over or CEV, with onboarding data received for 8,914 patients. This is likely an underestimate of the true use of the service.
- Only 44.8% of onboarded patients were aged 65 or over or CEV.

Impact on mortality and health care resource use

- No statistically significant impact on mortality was observed at a population level across all three quantitative evaluations.
- Two evaluations showed no statistically significant change, and one showed an increase, in A&E presentations and hospital admissions at a population level.
- At the Clinical Commissioning Group (CCG) level there was no evidence of a relationship between uptake and length of hospital stay for patients admitted with COVID-19 or suspected COVID-19.
- In a matched cohort study of patients presenting to A&E with a positive COVID-19 test, those onboarded had lower mortality and higher A&E presentations and hospital admissions within 28 days.
- Lower than expected uptake of the service and/or incomplete data limited the sample size available for all studies.
- As a result of this limitation, it is not possible to determine whether the lack of significant findings represents a lack of impact of the programme on the outcomes examined or an inability to detect a significant impact.

Inclusion

- Efforts have been made to onboard people who may be at greater risk of health inequalities. Strategies include widening the eligibility criteria, prioritising vulnerable groups, translating materials into seven languages, creating referral pathways from other services, and educating and supporting GPs to encourage referrals.
- However, older patients, patients with a health problem/disability, and non-White ethnic groups were more likely to report difficulties engaging with services. Older patients found the service less helpful and reported a less positive experience.

7. Summary findings (2/3)

Range of services implemented

- There was large variability in the type of models implemented. Variability related to: type of model, sector leading the service, type of monitoring, admission criteria, workforce numbers and type, start date and uptake.
- No services solely used patient self-monitoring.

Impact on patients, carers and workforce

- Staff members valued the service and generally felt confident in delivering the service. However, there were some challenges to delivering the service, eg ensuring that there is sufficient capacity within the workforce and that there is capacity to manage demands of the service.
- Patients and carers felt that the service and human contact provided them with reassurance and that it was mostly easy to engage with. However, patients' ability to engage with the service was conditional on a range of factors including having support from family/friends and staff, being in good health and knowing what they needed to do and how to do it.

Technology-enabled pathways

- Tech-enabled monitoring was widely used (in 55.5% of onboarded patients) and was less likely to be offered to care home residents or those with a learning disability, chronic neurological disease or severe mental illness, suggesting underlying barriers to use.
- Where tech-enabled models were used, they were successfully adopted; however, tech platforms could be improved through co-design with staff to improve their efficiency, utility and value.

CO@h in care homes

- CO@h uptake in care homes was lower than expected (1.1%), also when compared to the wider eligible population (2.1%).
- The CO@h programme seems to have been well-received and beneficial at the care home sites in contact with it, but over half of survey respondents were unaware of the programme.

7. Summary findings (3/3)

Staffing models and cost

- The mean number of staff per site was 7.4 full time equivalent (FTE). For technology-enabled with analogue sites it was 6.4 FTE per site; for analogue-only sites it was 10.0 FTE per site.
- Across all sites, 68.4% of staff involved in delivering services were clinical staff. The proportion of staff who were clinical was lower in technology-enabled with analogue sites (61.2%), compared to analogue-only sites (80.7%).
- Across all sites, just over 50% of staff (clinical and non-clinical staff combined) were Band 5 and below, and just under 50% were Band 6 and above. These percentages were similar for technology-enabled with analogue sites and analogue-only sites.

8. Who has accessed CO@h? (1/2)

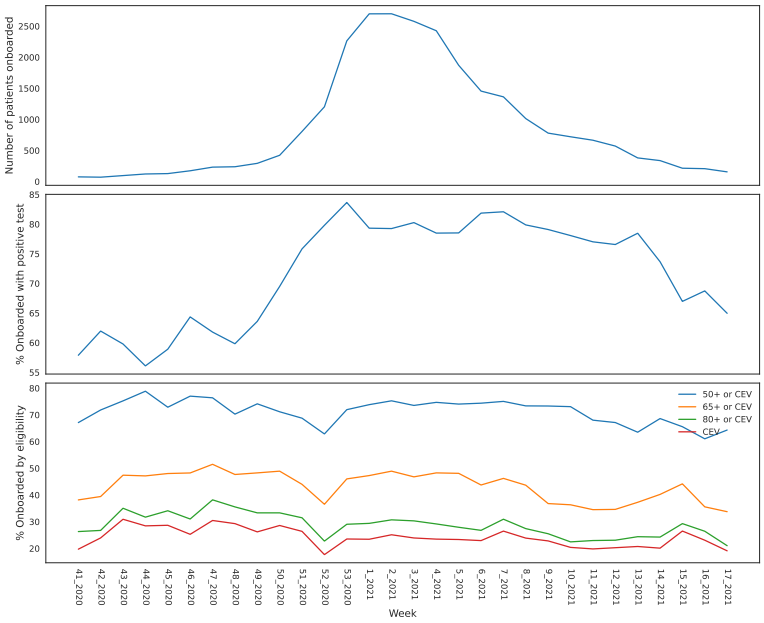
Data were received for 26,361 patients onboarded onto a CO@h programme across 91 CCGs in England between 1 October 2020 and 30 April 2021.

20,557 (78%) were onboarded within 7 days before and 28 days after presenting a positive COVID-19 test.

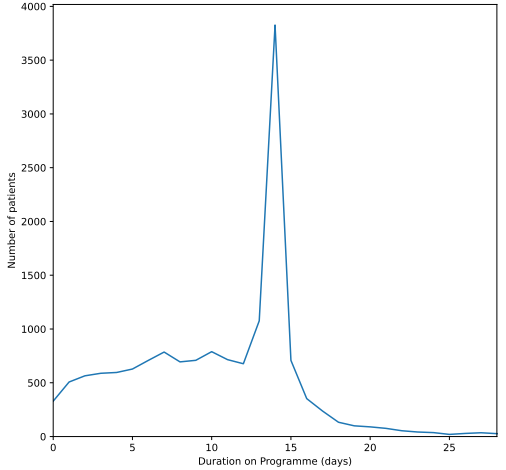
Of those onboarded, 44.8% were aged 65 or over or CEV.

Of the 2,125,737 patients with a positive COVID-19 test in 87 CCGs in England, 20,649 (0.97%) were onboarded onto a CO@h programme.

8,914 (2.1%) of the 417,225 patients aged 65 or over or identified as CEV with a positive COVID-19 test were onboarded onto a CO@h programme.



Number of patients onboarded onto CO@h programmes over each week of the study period (top). Percentage of onboarded patients with a recent positive COVID-19 test (middle). Percentage of all onboarded patients according to eligibility criteria (bottom).



Number of patients onboarded onto the CO@h programme for 0 days or more, alongside time spent on the programme

8. Who has accessed CO@h? (2/2)

Variable	N	%
Age (years)		
18-39	4,637	17.6
40-49	4,016	15.2
50-59	6,336	24.0
60-69	5,182	19.7
70-79	3,489	13.2
80+	2,689	10.2
Sex		
Female	14,716	55.8
Male	11,600	44.0
Missing	45	0.2
Ethnicity		
White	19,984	75.8
Asian / Asian British	2,969	11.3
Black / African / Caribbean / Black British	1,086	4.1
Mixed / Multiple ethnic groups	394	1.5
Other ethnic group	645	2.4
Missing	1,283	4.9
Care home resident		
Yes	1,032	3.9
No	24,370	92.4
Missing	959	3.6

Variable	N	%
IMD decile		
1 (most deprived)	3,882	14.7
2	3,396	12.9
3	3,041	11.5
4	3,044	11.5
5	2,567	9.7
6	2,396	9.1
7	2,261	8.6
8	2,256	8.6
9	1,861	7.1
10 (least deprived)	1,627	6.2
Body mass index		
Underweight	441	1.7
Healthy weight	5,381	20.4
Overweight	7,920	30.0
Obese	10,185	38.6
Missing	2,434	9.2
Smoking status		
Never smoker	13,845	52.5
Ex-smoker	7,421	28.2
Current smoker	4,127	15.7
Missing	968	3.7

Variable	N	%
Clinically extremely vulnerable		
No	19,187	72.8
Yes	6,215	23.6
Missing	959	3.6
Comorbidities*		
Hypertension	8,237	31.2
Chronic cardiac disease	3,691	14.0
Chronic kidney disease	379	1.4
Chronic respiratory disease	9,278	35.2
Dementia	666	2.5
Diabetes	4,986	18.9
Chronic neurological disease (incl. epilepsy)	1,349	5.1
Learning disability	354	1.3
Malignancy or immunosuppression	3,683	14.0
Severe mental illness	992	3.8
Peripheral vascular disease	451	1.7
Stroke or transient ischaemic attack (TIA)	1,305	5.0

Characteristics of the 26,361 patients with submitted CO@h onboarding data.

*Comorbidity data were absent for 968 onboarded patients.

9. What CO@h services have been implemented?

The study of 28 services found large variability in the type of models implemented. Variability related to: type of model, sector leading the service, type of monitoring, admission criteria, workforce numbers and type, start date and uptake.

Most of the services were either CO@h (46%) or integrated CO@h/COVID-19 Virtual Ward models (39%), started before November 2020 (39%) or in November 2020 (46%), and were led by primary/community sectors (57%). Some services were led by secondary care (18%) or both sectors (18%).

75% of the 28 services used both tech-enabled and analogue models. 25% of services were analogue only. No services solely used patient self-monitoring.

82% of the services used age criteria of 18 years or over, or 50 years or over. Only 4% of sites used 65+ age criteria. The remaining 14% did not report using age as a criterion.

84% of services (21/25) reported onboarding patients with risk factors. The remaining sites did not report using risk factors (n=4).

Numbers of staff involved in setting up the service ranged from two to over 20, while those delivering the service ranged from two to over 70. A range of clinical and administrative staff were involved in delivering the services.

Examples of variation between the 28 local services included differences in the method and frequency of monitoring. Examples of variation between the national standard operating procedure and local implementation included discharge processes, whereby only 76% of sites (19/25) reported having discharge processes, and pulse oximeter practicalities, whereby only 69% of patients were asked to return the oximeter.

10. Data completeness

To support the evaluation a bespoke data collection was set up with most providers of CO@h, either through the CCG or directly from software providers.

87 CCGs submitted weekly data to the programme, out of a total of 135* CCGs. However, submission of data was inconsistent and not considered complete for all CCGs.

Based on a desk assessment by data liaison officers at NHS Digital, data are considered complete for 28 CCGs and nearly complete for 12 CCGs.

Absence of data for a particular CCG/week may indicate either that data have not been submitted, or that there was no CO@h activity; however it is not possible to distinguish between the two.

Quantitative analyses presented in this document have been adjusted to account for missing data where possible.

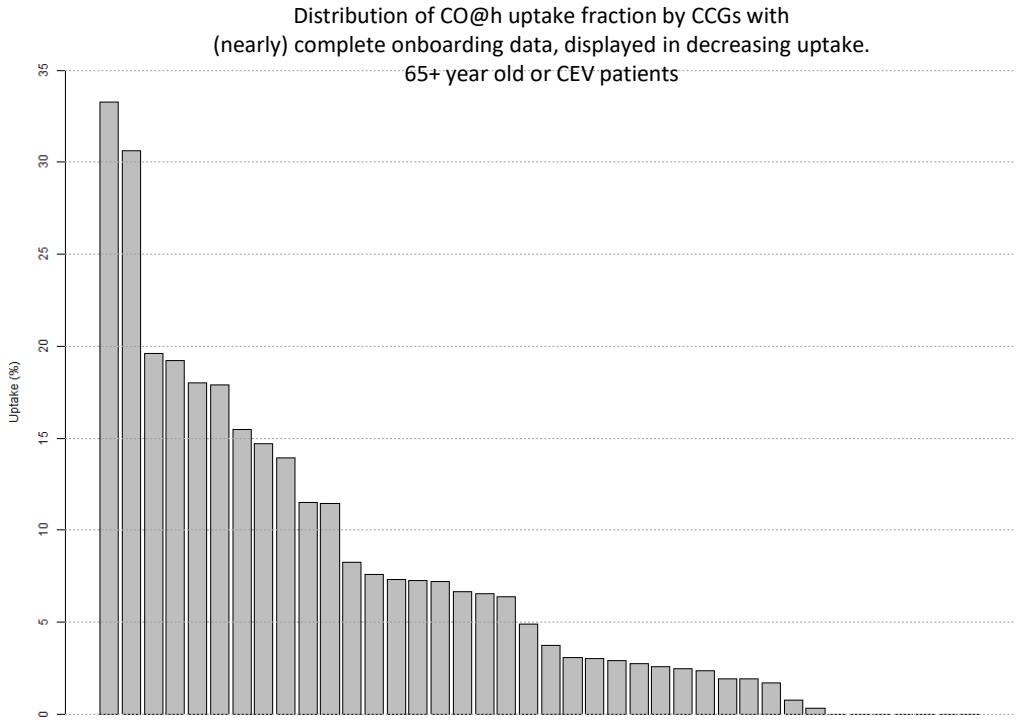
* Due to CCG mergers from April 2021, there are 106 CCGs in England.

11. Uptake

Uptake of the CO@h programme was lower than expected. Based on the data received from 87 CCGs, only 2.1% of patients aged 65 years or over or identified as CEV, who tested positive for COVID-19, were onboarded onto the programme. This uptake drops to 0.97% when looking at the entire adult population.

Uptake increases from January 2021 onwards, but varies greatly between CCGs as well as within CCGs over time, as depicted in the median uptake in the first 18 weeks of 2021 for CCGs providing (nearly) complete data. Across these CCGs, the average median uptake was 5.25%.

Findings from the qualitative study indicate that possible influences on uptake include: whether sites used active case finding, whether sites had collaborations and well-established partnership working with other sectors and external providers, and the number of staff involved.



12. What is the impact of CO@h on mortality?

At a population level there was no evidence of an impact of the programme on mortality across the three quantitative evaluations:

1. ICL: Comparing before and after site implementation using a stepped wedge design, there was no significant difference in the odds of 28-day mortality after implementation (OR = 1.06, 95% CI = 0.93 – 1.21, p=0.405)
2. IAU: No evidence of a difference in mortality rates during the first 18 weeks of 2021 between high- and low-uptake CCGs with (nearly) complete data (ATT = -0.29; 95% CI = -2.93, 8.66; p=0.672). There was a decrease in mortality from January, but this was similar for high- and low-uptake CCGs.
3. RSET/BRACE: Multi-variate modelling at the CCG level, for 37 CCGs where the data was assumed to be complete, found no significant relationship between uptake of CO@h and mortality (relative risk per 10% increase in uptake = 0.98, 95% CI = 0.96 – 1.01, p=0.170).

Several factors may explain this:

- There is no significant effect of the programme on mortality.
- Low uptake of the programme and incomplete data. Data were received for 2.5%* of the eligible population, which may dilute the effect at the population level.
- The COVID-19 mortality rate was rising as sites were becoming operational.

At a patient level there was some evidence of lower mortality. In a matched cohort study from the ICL evaluation of patients attending A&E departments soon before/soon after a positive COVID-19 test (15,621 patients, of whom 639 were enrolled), odds of 28-day mortality was 52% lower in those onboarded (OR 95%, CI = 0.25 – 0.93, p=0.030).† However, these findings apply only to the small subset of those onboarded following A&E attendance and may not be generalisable.

* This number is different from the 2.1% reported in previous slides as the eligible population for the stepped wedge study used only symptomatic, PCR-positive COVID-19 tests.
† Findings from the matched cohort study may be confounded by bias in those selected for onboarding. However, A&E attendances and admissions were higher in those onboarded, but mortality lower, suggesting no systematic differences in disease severity between the two groups.

13. What is the impact of CO@h on NHS service use?

At a population level, there was mixed evidence for impact on utilisation across the three evaluations:

1. ICL: This evaluation found evidence of a 12% increase in A&E utilisation (OR 95% CI = 1.06 – 1.18, p<0.001) and 12% increase in hospital admissions (OR 95% CI = 1.05 – 1.20, p<0.001) following implementation of the CO@h programme. There was some evidence of a 24% increase in critical care admissions of those admitted (OR 95% CI = 1.05 – 1.47, p=0.012). There was no significant impact on length of stay of those admitted.
2. RSET/BRACE: The evaluation was carried out for 37 CCGs where the data was assumed to be complete. This found no evidence of a change in hospital admission (relative risk per 10% increase in uptake = 1.02, 95% CI = 0.98 – 1.05, p=0.374) or length of stay (change per 10% increase in uptake = 1.3%, 95% CI = -1.6% – 4.2%, p=0.384).
3. IAU: No evidence was found of a difference in hospital activity during the first 18 weeks of 2021 between high- and low-uptake CCGs with (nearly) complete data – ie rate of A&E attendance (ATT = 0.52, 95% CI = -7.82, 7.95; p=0.916), rate of emergency admission (ATT = -2.36, 95% CI = -14.54, 9.72; p = 0.528) and rate of admission into critical care (ATT = 0.91, 95% CI = -4.12, 3.67; p=0.830), all within 28 days of a positive COVID-19 test.

At a patient level, in a matched cohort study from the ICL evaluation of patients attending A&E departments soon before/soon after a positive COVID-19 test (15,621 patients, of whom 639 were enrolled) patients onboarded following A&E attendance had a 37% higher odds of a subsequent A&E attendance (OR 95% CI = 1.16 – 1.63, p<0.001) and 59% higher odds of emergency admission (OR 95% CI = 1.32 – 1.91, p<0.001), but 53% lower odds of requiring critical care of those admitted (OR 95% CI = 0.24 – 0.93, p=0.03), compared to patients not onboarded.

14. Site-reported impact on outcomes and NHS service use

Throughput and outcome	Total number of patients		Tech enabled** (16 sites)		Analogue only*** (6 sites)	
	No. of patients	% of monitored patients	No. of patients	% of monitored patients	No. of patients	% of monitored patients
Patients triaged*	26,126	149.94%	18,906	141.31%	7,219	178.46%
Patients monitored	17,424	100%	13,379	100.%	4,045	100%
Patients deteriorated and escalated	2,898	16.63%	2,352	17.58%	547	13.51%
Deaths	160	0.92%	117	0.87%	43	1.07%
Patients deteriorated and escalated	**No. of patients**	**% of deteriorated & escalated patients**	**No. of patients**	**% of deteriorated & escalated patients**	**No. of patients**	**% of deteriorated & escalated patients**
Emergency department	2,240	77.29%	1,295	55.05%	946	172.98%
Admitted to the hospital	1,257	43.37%	855	36.37%	402	73.45%
ICU	403	13.92%	389	16.53%	15	2.71%
Primary care	1,806	62.32%	1,546	65.75%	260	47.56%

Note: Data in the table are self-reported data provided by 22 sites during Wave 2 of the COVID-19 pandemic (October 2020 – April 2021). 16 sites used the tech-enabled (digital) platform for monitoring the patients; 6 sites used analogue-only ways for monitoring the patients.
* The % of patients triaged is calculated as the number of patients triaged over the number of patients monitored. The number of the patients triaged is larger or equal to the number of patients monitored.
** Tech enabled is defined as sites with a mixture of tech-enabled and analogue-monitored patients.
*** Analogue only is defined as sites with exclusively analogue-monitored patients.

In comparison with data from similar services running during Wave 1 of the COVID-19 pandemic (March–August 2020):

- Proportion of patients deteriorated and escalated:
  - Increase in proportion of patients escalated and deteriorated from Wave 1 to Wave 2 (from 10.0% to 16.6%).

- Mortality:
  - Slight decrease in mortality from Wave 1 to Wave 2 (from 1.1% to 0.9%).

15. What is the impact on inclusion?

Quantitative analysis based on the national dataset described in section 8 shows that efforts have been made to onboard people who may be at greater risk of health inequalities.

Of those patients aged 65 years or over or identified as CEV:

- patients of Black or Asian ethnicity, those living in the most deprived areas, those with chronic respiratory disease or learning disability and those who are overweight or obese were significantly more likely to be enrolled into a CO@h programme, after accounting for other risk factors (all p-values<0.05).
- care home residents, patients with a history of chronic heart disease, dementia, stroke or transient ischaemic attack and those who were underweight were significantly less likely to be enrolled into a CO@h programme, after accounting for other risk factors (all p-values<0.05).

Qualitative study of 28 services found that CO@h was designed and implemented with the goal of reducing health inequalities, but additional work is needed to ensure that these benefits are fully realised.

Local sites designed their service to be more inclusive. Strategies included; widening the eligibility criteria, prioritising vulnerable groups, creating referral pathways from other services, and supporting GPs to encourage referrals.

Services encouraged patient uptake and engagement by providing information in different languages, more accessible formats or offering translation services, offering non-digital options, face-to-face assessments, and allowing flexibility of monitoring. 67% (16/24) of service leads reported tailoring the service to accommodate specific user needs.

Despite adaptions to services, patient survey showed differences among patient groups in their experience of, and engagement with, the service. Older patients (p=0.005), patients with a health problem/disability (p=0.001), and non-White ethnic groups (p=0.005) were more likely to report difficulties. Older patients found the service less helpful (p=0.001) and reported a less positive experience (p=0.001).

16. What was the experience of patients and carers?

Patients/carers who took part in the survey and interviews had positive views of the service; 93% rated the service as good. Most patients/carers (91% of survey respondents) felt that the monitoring and support provided them with reassurance. However, interview and open text survey findings indicated some areas for improvement, such as improving awareness of the service and including the discussion of wider symptoms/issues.

Patients/carers generally reported that it was easy to engage with the service. 97% said that the oximeter was easy/very easy to use and 97% said that providing readings was easy/very easy. However, interview participants and 25% of survey participants did identify some problems with engagement, such as not receiving enough information (eg about when to seek help while on the service or upon discharge), not wanting to go to hospital when advised, and problems obtaining and/or returning oximeters.

Interview and survey findings indicated that patients'/carers' ability to engage with the service was influenced by many factors, including patient factors, support and resources, and service factors. For example:

- some patients in poorer health found it harder to engage with the service (patient interview/open text survey).
- patients/carers who felt they had sufficient knowledge about what they needed to do found it easier to engage (55% of survey respondents)
- support from staff members (46% of survey respondents) and family/friends (25% of survey respondents) was crucial in helping many patients to use the service.

17. What was the experience of the workforce?

Staff survey and interviews found that those involved in the delivery of CO@h recognise its value, welcomed working as part of multi-disciplinary teams, and said the service had a positive impact on their job satisfaction (75%).

Most staff felt confident in carrying out responsibilities and 73% found monitoring patients easy/very easy. Training received by staff across different sites was not universal but predominantly delivered in-house by senior clinicians.

Staff indicated a lack of awareness of the COVID-19 home competency framework*; only 9.5% completed the framework while 35.5% were unsure whether they had adhered to the framework or not.

Staff continue to face a range of challenges, including (but not limited to): workforce availability, availability of senior clinicians to provide oversight, and some patients desiring greater human contact.

In general, staff reported high levels of patient engagement. Despite efforts to make the service more inclusive, some patient groups are less likely to engage (eg those with lower digital literacy, those who are frail, older, younger and employed).

*Competencies for staff working in COVID virtual ward setting (as part of the COVID Oximetry@home- Quick Start Guide), October 2020, Wessex Academic Health Science Network, Available on NHS Futures Platform.

18. Factors influencing implementation

Implementation of CO@h services may have varied due to different factors, including patient factors, staff factors, organisational factors and material resources required or available.

Patient needs and provider engagement with these needs varied between sites. 27 out of 28 sites studied broadened the eligibility criteria relating to age from that stated in national guidance to meet the needs of their local population.

There were variations in the qualifications and capacity of staff delivering the service (eg number and type of staff). Training needs and training received also varied across sites.

Organisational capacity to support rapid change influenced implementation – such as having existing, or developing new, collaborations across settings.

Many sites were up and running prior to the introduction of the national CO@h and Virtual Ward standard operating procedures, which may account for variation from the national guidance.

The availability of appropriate software and technology was another factor influencing sites' ability to implement the service.

There were also problems identifying COVID-19 positive patients early enough, eg via test results from Test and Trace.

19. Economic evaluation: implementation cost

RSET/BRACE had intended to undertake a cost-utility analysis of the CO@h programme, but in the absence of any impacts on mortality or hospitalisation being demonstrated by the primary quantitative analysis, the focus shifted to the costs of the intervention only.

Costs were based on self-reported data provided by 22 sites during Wave 2 of the COVID-19 pandemic (October 2020 – April 2021).

Findings were compared to data from similar services running during Wave 1 of the COVID-19 pandemic (March–August 2020).

Mean running costs per patient under the CO@h model*:

- The mean cost per patient triaged was £351 (10th perc.: £68; 90th perc.: £512).
- The mean cost per patient monitored was £527 (10th perc.: £101; 90th perc.: £768).
- The differences in the mean cost per patient between 10th and 90th percentiles are due to the differences in numbers of staff involved in implementing the CO@h programme.
- The mean cost per patient monitored has remained fairly constant from Wave 1 to Wave 2 (£553 vs £527).
- The mean cost per patient monitored was lower at sites using tech-enabled (digital)† monitoring compared to the sites where patients were using only analogue monitoring (Wave 2 only): £515 vs £559.

* All financial values are rounded.

† Tech-enabled refers to sites where patients could be monitored using either tech-enabled or analogue platforms. For sites where the platform was also used for other purposes (i.e., remote home monitoring for conditions other than covid), the entire cost has been assigned to CO@h programme.

The **mean cost per site for setting up a tech-enabled (digital) platform** was £89,072. ‡

‡ The sites with £0 setting up cost are excluded; only sites where the digital platform was introduced for the CO@h programme (N=14) are included.

Mean cost per patient for maintenance of the tech-enabled (digital) platform was £37 (range £30 to £44) for an average of 14 days monitoring. (N=2, zeros are excluded)

Under the CO@h model, based on detailed information from four sites:

- When using **tech-enabled** (digital) monitoring there were on average **10** [min: 7 – max:14] **contacts per patient**; the total mean time spent monitoring was **102 minutes per patient**.
- When using the **analogue option** there were **16 contacts per patient**, while the total mean time spent monitoring was **140 minutes per patient**.

20. Staffing models

Type of site (by number of patients)	Number of sites	Mean number of staff	Non-clinical staff (FTE)			Clinical staff (FTE)			
			Proportion of total non-clinical staff	Proportion Band 6+ (over the total)	Proportion Band 5 & below (over the total)	Proportion of total clinical staff	Proportion Band 8+ (over the total)	Proportion Band 6–7 (over the total)	Proportion Band 5 & below (over the total)
The total sample									
Very small sites (0–200 patients)	3	3.7	28.7%	16.6%	12.0%	71.3%	2.5%	24.9%	43.9%
Small sites (201–600 patients)	6	4.2	31.6%	4.3%	27.3%	68.4%	6.4%	26.3%	10.2%
Medium sites (601–1,000 patients)	5	9.7	39.1%	5.7%	33.4%	60.9%	5.9%	29.3%	25.7%
Large sites (1,001+ patients)	8	9.8	27.4%	2.2%	25.2%	72.6%	22.7%	33.3%	28.6%
Total sample	**22**	**7.4**	**31.6%**	**4.5%**	**27.1%**	**68.4%**	**11.3%**	**30.5%**	**25.9%**
Technology-enabled with analogue									
Very small sites (0–200 patients)	3	3.7	28.7%	16.6%	12.0%	71.3%	2.5%	24.9%	43.9%
Small sites (201–600 patients)	2	4.0	69.3%	2.2%	67.1%	30.7%	6.4%	24.3%	0.0%
Medium sites (601–1,000 patients)	5	9.7	39.1%	5.7%	33.4%	60.9%	5.9%	29.3%	25.7%
Large sites (1,001+ patients)	6	5.9	34.7%	3.2%	31.5%	65.3%	22.7%	37.4%	5.3%
Total technology-enabled with analogue	**16**	**6.4**	**38.8%**	**5.7%**	**33.1%**	**61.2%**	**11.3%**	**31.2%**	**18.6%**
Analogue only									
Small sites (201–600 patients)	4	4.2	13.8%	5.3%	8.5%	86.2%	43.9%	27.2%	15.1%
Large sites (1,001+ patients)	2	21.6	21.4%	1.4%	20.1%	78.6%	1.0%	30.0%	47.7%
Total analogue only	**6**	**10.0**	**19.3%**	**2.5%**	**16.8%**	**80.7%**	**13.1%**	**29.2%**	**38.5%**

Note: Data in the table are self-reported data provided by 22 sites during Wave 2 of the COVID-19 pandemic (October 2020 – April 2021). 16 sites used the technology-enabled with analogue mode for monitoring the patients; 6 sites used analogue-only modes for monitoring the patients. There were not any analogue-only sites of very small or medium size.

Summary:

- The mean number of staff per site was 7.4 FTE. For technology-enabled with analogue sites it was 6.4 FTE per site; for analogue-only sites it was 10.0 FTE per site.
- Across all sites, 68.4% of staff involved in delivering services were clinical staff. The proportion of staff who were clinical was lower in technology-enabled with analogue sites (61.2%) compared to analogue-only sites (80.7%).
- Across all sites, just over 50% of staff (clinical and non-clinical staff combined) were Band 5 and below, and just under 50% were Band 6 and above. These percentages were similar for technology-enabled with analogue sites and analogue-only sites.

Mean number of patients monitored	Very small sites (0–200 patients)	Small sites (201–600 patients)	Medium sites (601–1,000 patients)	Large sites (1,001+ patients)	Total
Mean number of patients monitored by FTE staff per week	1.9	3.0	3.0	5.0	4.6
Mean number of patients monitored by FTE staff per week for technology-enabled with analogue services	1.9	3.4	3.0	7.9	4.6
Mean number of patients monitored by FTE staff per week for analogue-only services	–	2.8	–	2.7	2.7

21. Tech enablement

21 out of 28 services adopted a tech-enabled (tech-e) model of patient monitoring alongside an analogue option (phone calls) for patients without technical skills, devices or home broadband. Tech-e methods included an app (14 out of 21 sites), weblink by text/email and automated phone calls/texts. 7 out of 28 sites offered an analogue-only model of monitoring. Tech enablement was widely used in CO@h, accounting for 55.5% of all records received nationally.

There was no evidence of differences in patient outcomes between tech-e and analogue, and analogue-only models of care, based on national data, although inconsistent reporting among sites may have affected these results.

Where tech-e models were used, they were successfully adopted. However, tech platforms could be improved through co-design with staff to increase their efficiency, utility and value – for instance, by enabling staff to filter and sort patients by priority and medical needs, improving interoperability with other data systems. Staff using tech-e and analogue models reported in the survey that monitoring patients was easier compared to analogue-only (77% tech-e and analogue vs 60% analogue-only found monitoring easy/very easy). However, chasing non-submitting patients took time.

Patient survey respondents who used tech-e monitoring were more likely to be younger ($p<0.001$), have a higher level of education ($p < 0.001$), be working full time ($p = 0.001$) and less likely to have a disability/health problem ($p = 0.001$). Most patients were not given a choice about the way they could submit readings, though were happy with the option given.

The finding of lower enrolment onto tech-e pathways in care home residents or those with a learning disability, chronic neurological disease or severe mental illness (based on the national dataset described in slide 8) may suggest specific barriers exist to the use of tech-e platforms among these patient groups, or appropriate matching of pathways to the needs of patients.

Patient survey respondents rated both tech-e and analogue monitoring very positively, with 95% using tech-e vs 91% using analogue monitoring rating the service as good/excellent. However, assistance from family/caregivers was essential for many patients in taking and submitting readings, particularly when very unwell/tired. 21% of patients using tech-e and 29% of patients using analogue monitoring had support from family/friends.

Patients enrolled onto tech-e pathways remained enrolled for around 3 days longer than those on analogue pathways. A modal duration on the programme of 14 days was particularly evident for technology-enabled patients, suggesting a more consistent implementation of the pathways for 14 days than analogue pathways.

22. Care homes

Pulse oximeters (along with other diagnostic tools) were in use in many, but not all, responding care homes before the pandemic and use widened during the pandemic.

Pulse oximeters are reported by care home managers and staff to provide reassurance to residents and their families, and to staff. Using pulse oximeters was not a major challenge for care home staff, and usually did not add to staff workload or stress levels.

Use of pulse oximeters is thought by care home managers to have reduced the average number of A&E attendances and hospital admissions of residents.

Additional support provided through CO@h was welcomed at the care homes offering it, but over half of survey respondents were not aware of the programme. In some cases support from the NHS, including training, was sought but was not always available to the desired extent.

The above findings are based on small samples and should be interpreted with caution.

CO@h uptake in care homes was lower than expected and also when compared to the wider population. Of the 72,711 care home residents with a positive COVID-19 test in 87 CCGs in England between October 2020 and April 2021, 817 (1.1%) were onboarded onto a CO@h programme, compared to 2.1% of all eligible patients.

Male care home residents, those identified as CEV, overweight or obese or with a learning disability were significantly more likely to be enrolled into a CO@h programme, after accounting for other risk factors ($p < 0.05$). Patients of Asian ethnicity had 65% lower odds of onboarding compared to patients of White ethnicity. There was a statistically non-significant trend towards other ethnicities having lower odds of onboarding compared to patients of White ethnicity.

These findings suggest that despite low rates of uptake in general, there appears to be preferential enrolment in populations identified to be at greater risk from COVID-19. Lower rates of onboarding of care home residents not of White ethnicity may warrant further investigation.

23. Limitations

Limitations common to all evaluation approaches

Despite the evaluators being involved from early stages, allowing selection of carefully designed study designs based on the standard operating procedures and influence over the data collection, the sample size may have been too small to understand the real impact of the programme.

Delay of data collection from front-line teams (understandable given the pressure on NHS services during the pandemic) has resulted in a delay of the evidence becoming available, and may have impacted the ability of these analyses to shape policy.

Low reported uptake of the CO@h programme was a major limitation to all quantitative analyses.

Eligibility criteria for enrolment changed over the study period and was different between CCGs. This precludes use of a single eligibility threshold that meaningfully reflects practice nationally.

The rapid nature of the evaluation, where quantitative and qualitative methods were used at the same time, does not allow for some of the hypotheses from the qualitative work to be tested quantitatively and, similarly, does not allow for qualitative follow-ups to understand some of the findings/test assumptions from the quantitative work.

The eligible population for the CO@h programme is based on COVID-19 testing. Geographical and temporal variation in testing may impact the characteristics and size of the eligible population over time, and impact subsequent uptake of the intervention, as well as outcomes.

For more information on limitations of each of the studies, see the analysis protocols in slides A1, A2 and A3.

24. Lessons learnt (1/2)

Implementation:

- When developing and rapidly implementing national roll-out, considering the context and priorities of local organisations may facilitate implementation. Key considerations identified in the study of 28 services included: providing strategies to proactively identify cases and onboard eligible patients, providing an indication to local services of the level of clinical oversight and staffing needed, supporting local services to work collaboratively across settings and providing guidance on the resources needed to implement remote monitoring services.

- In implementing national programmes it should be acknowledged that the eligible population may vary between sites and over time, and that clinician discretion may play an important role in enrolment decisions.

- Further evidence is needed on the self-monitoring model, including the groups of patients that this might be appropriate for and whether its use would enable services to onboard more patients.

Delivery:

- It is necessary to ensure that staff are able to deliver the service efficiently, eg 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.

- Managers and staff consider that using pulse oximeters in care homes has been beneficial to care home residents and should continue to be encouraged and supported. There remains a need for training at least some care home staff in the use of pulse oximeters, including when to escalate and seek NHS help. There is scope for increasing knowledge of the NHS CO@h programme in the care homes sector.

- Efficiency, utility and value functionality of tech-enabled solutions could be improved for staff by involving them in co-design and offering them opportunities to observe and test different platforms.

24. Lessons learnt (2/2)

Patient engagement:

- Some patients need support from family and friends to engage with the service, therefore consideration is needed of infection transmission, the caring burden and those living alone. Patients had a wish for human contact, especially in the context of safety netting – this needs to be taken into account when designing services.

- While there is evidence of preferential provision of the CO@h programme to patient groups that may be at higher risk from COVID-19, many of these at-risk groups were also more likely to report difficulties in engagement with these services, including older patients, those from non-white ethnic groups and patients with health problems. Barriers to engagement should be addressed when implementing these services in future.

Data collection:

- While a bespoke data collection was set up to support the evaluation of the CO@h programme, data completeness remained a big limitation for the quantitative elements of this evaluation. This was both in terms of coverage (not all areas in the country were collecting the information as intended) and completeness (not all information was complete in areas that were covered in the collection). In future, there may be benefit in concentrating data collection efforts in selected areas, to improve completeness.

- One of the major confounders of patient outcomes following enrolment onto the CO@h programme is acuity or severity of COVID-19 symptoms. Systematic collection of oxygen saturation levels at the point of onboarding and admission to hospital would have allowed the evaluation to take the impact of acuity into account.

25. Appendices

A1. Summary of methods used by and limitations of RSET/BRACE evaluation
A2. Summary of methods used by and limitations of ICL evaluation
A3. Summary of methods used by and limitations of IAU evaluation
A4. Contact details for all evaluation teams
A5. Definitions
A6. Further resources

A1. Methods used in the RSET/BRACE evaluation (1/2)

Effectiveness (work stream 1)	Cost effectiveness (work stream 2)	National survey (work stream 3)	In depth case studies (work stream 4)	Care home extension
•Effectiveness was evaluated using onboarding data aggregated at a CCG level and within broad age bands to explore relationships between population-level uptake and outcomes. •Analysis was undertaken for 37 CCGs where the onboarding data was assumed to be complete. •Multi-variate regression analyses were done to investigate the impact on overall mortality, in-hospital mortality, hospital admissions and lengths of hospital stay.	•Aggregate data was collected from 22 sites for the period October 2020 – April 2021 on the number of patients monitored, the staffing models and the allocation of resources. •A cost analysis of setting up and running the service for these 22 sites was conducted. •A cost analysis was also done to compare the costs of using tech-enabled (digital) and analogue models.	•A national survey of 1,069 patients and carers across 25 sites (17.5% response rate) was conducted, and a national survey of 292 staff across 28 sites (39.8% response rate). •The surveys helped in understanding processes of implementation and staff and patient experience. •Data collection took place between February and June 2021.	•Interviews were conducted with 62 patients and carers and 58 staff at 17 case study sites, and with 5 national leads. •Some case studies included think aloud interviews (digital extension only). •The in-depth case studies helped in understanding processes of implementation and staff and patient experience in more depth. •Data collection took place between February and June 2021.	•Online surveys captured the responses of the registered managers of all 15,000+ care homes in England registered with the Care Quality Commission. •Interviews were done with care home staff and some NHS staff at 6 care homes across England, with a mix of settings and resident populations; 31 interviews in total. •3 individuals with national oversight were also interviewed. •Data collection took place between March and June 2021.

More information on workstreams 1-4 can be found in the protocol here.
More information on the care home extension can be found in the protocol here.

A1. Limitations of these methods (2/2)

- The evaluation of effectiveness could only be carried out for CCGs where the onboarding data was believed to be complete, which was only one quarter of all CCGs.
- Incidence of COVID-19 was measured using data on people who reported a positive COVID-19 test. This meant that mortality and admission rates were likely to be overestimated and dependent on overall testing volumes. Low uptake meant that the chance of the analysis detecting any impact was lower than anticipated.
- A cost-utility analysis was not undertaken, given there was no evidence found of an effect of the CO@h programme on mortality or downstream hospital utilisation.
- For the cost analysis, cost data were collected at the aggregate (site) level, not the patient level, which meant patent-level variation in programme costs could not be examined.
- Cost and resource use data provided by sites were incomplete.
- Compared to patient onboarding data, the sample in the patient experience study was under-representative of some groups (eg older patients, BAME groups and most deprived) and over-representative of other groups. Additionally, the response rate for the patient/carer survey was fairly low (17.5%). For patient experience surveys and interviews, participants who had declined the service could not be recruited, nor those who were unable or did not want to take part in surveys and interviews. Therefore, the findings may not be representative of all patient groups and experiences.
- Across six care home case study sites, fewer than the intended interviews were completed due to participant availability. Response rate to the survey was low (1.5%). Throughout the pandemic, care homes may have been asked to complete a number of surveys from other research and/or regulatory bodies, which may have contributed to this low response rate. Due to anonymity, the team were unable to determine the range of care homes responding to the survey across variables such as location, financial budget and CQC rating.

A2. Methods used in the ICL evaluation (1/2)

Factors associated with onboarding onto the programme and duration of enrolment

- The clinical and demographic characteristics of all patients enrolled onto a CO@h programme were described.
- Duration on the programme was evaluated using multivariable quantile regression models where duration of enrolment was known.
- Multivariable mixed-effects logistic regression models were used to identify patient factors associated with enrolment onto a CO@h programme.
- A subgroup analysis using the above methods was undertaken of patients identified as care home residents.

Population-level analysis of impact of the programme on mortality and health care utilisation

- Study population: all people with a symptomatic COVID-19 positive PCR test, aged 65 or over or CEV (217,650 people).
- Primary endpoints: mortality and service utilisation within 28 days of a positive test.
- Stepped wedge design: comparing CCGs pre- and post-implementation, using two-level hierarchical logistic regression models, adjusted for patient risk factors and month of test.

Individual-level analysis of impact of the programme on mortality and health care utilisation in patients presenting to A&E

- Study population: all people attending A&E within 3 days before to 10 days after a positive COVID-19 test (PCR or LFT) who were not admitted or died within 24 hours of attendance (56,793 patients).
- Primary endpoints: mortality and service utilisation within 28 days of A&E attendance.
- Matched cohort design: cases onboarded to CO@h (639) matched to 14,982 controls not onboarded based on patient risk factors, month of presentation to A&E and time from test to A&E attendance. Logistic regression used to identify odds of outcomes in those onboarded compared to those not onboarded.

Factors associated with enrolment onto a technology-enabled CO@h programme

- Multivariable logistic regression models were used to identify patient factors associated with enrolment onto a technology-enabled CO@h programme compared to an analogue programme.
- Duration on the programme between technology-enabled and analogue programmes was evaluated using multivariable quantile regression models where duration of enrolment was known.

More information on the methods can be found in the protocol here.

A2. Limitations of these methods (2/2)

- Mortality and rates of admission were increasing at the time many sites were implementing CO@h programmes. This may confound the stepped wedge analysis.
- Receipt of data from some CCGs and not others may limit the generalisability of findings regarding the equity of access of the intervention.
- Oxygen saturations and other physiological parameters were not available at the time of hospital admission. It was therefore not possible to account for the severity of disease at the time of presentation to hospital.
- Some sites returned only technology-enabled onboarding records despite all sites also offering an analogue model. Analyses may therefore miss records for many patients onboarded to analogue pathways.
- The matched cohort study included only 639 enrolled patients and 14,982 patients who were not enrolled. Of those enrolled, only 9 patients died within 28 days.

A3. Methods used in the IAU evaluation (1/2)

Patient-level impact assessment (workstream 1)

- This analysis aims to quantify the extent to which patients in England of 65 years of age or over testing positive for COVID-19, who are onboarded onto a CO@h pathway, present different emergency hospital activity or mortality patterns than those aged 64 years or under.
- Motivated by the age cut-off for eligibility onto a CO@h pathway, the impact assessment employs a Regression Discontinuity Design around the 65 years of age threshold, whose range for patient inclusion is subjected either side to sensitivity analysis to account for non-adherence to protocol.
- The analysis is informed by individual-level hospital and mortality records on patients aged just below or over 65 years from January 2021 onwards.

CCG-level impact assessment (workstream 2)

- A separate analysis tackled the question as to whether the CO@h programme impacted differently at population level on a range of emergency hospital activity and mortality among eligible patients, between CCGs in England onboarding a high proportion of their eligible patients on a CO@h pathway relative to those instead onboarding a low proportion.
- CO@h onboarding proportions separating high- from low-onboarding CCGs, set at respectively 15% and 5%, were established from a visual inspection of onboarding records and subjected to sensitivity analysis.
- Selected outcome rates from the two resulting groups of 6 high-onboarding CCGs and 20 low-onboarding CCGs were contrasted via the Generalised Synthetic Control method over the period from 4 January 2021 to 9 May 2021.

More information on the patient-level evaluation can be found in the protocol here.
More information on the CCG-level evaluation can be found in the protocol here.

A3. Limitations of these methods (2/2)

Limitations related to workstream 1:

- Due to low uptake, and the absence of a discontinuity at the age of 65 in referral to the CO@h programme, the Regression Discontinuity Design was not feasible. A feasibility report has been published separately.

Limitations related to workstream 2:

- Due to the non-experimental nature of the CO@h programme, the risk of systematic (possibly unobserved) differences between the comparison groups of CCGs, other than the proportion of patients onboarded onto a CO@h pathway, affecting examined outcomes cannot be conclusively ruled out.
- It is assumed that, for any given outcome and high-onboarding CCG, adequate fit of the estimated counterfactual to the actual trend observed before the study period is indicative of reliable impact estimates throughout the subsequent study period. In reality this assumption, while commonplace, is untestable.
- It is unclear whether the inability of the evaluation to detect a significant impact across the examined outcomes is due to the low number of eligible patients onboarded onto a CO@h pathway during the evaluation period, or to a genuine lack of programme effectiveness on emergency hospital activity or mortality.
- Impact estimates were risk-adjusted to account for observed differences in case-mix between patients in receipt of the CO@h programme from the two comparison groups of CCGs. Unobserved differences (eg in the management of pulse oximeters or severity of underlying health conditions of their recipients), potentially skewing the findings from the evaluation, cannot be ruled out.
- The concurrent roll-out in the community of interventions complementary to CO@h (like COVID-19 Virtual Wards or enrolment onto the PRINCIPLE trial) may have indirectly impacted the programme's implementation over time and across CCGs, potentially resulting in a skewed assessment of its effectiveness.

A4. Contact details

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A5. Definitions

- **Analogue CO@h**

Analogue models are models in which patients receive a paper diary and provide readings via phone.

- **Tech-enabled CO@h**

Tech-enabled models are models in which patients enter readings via a tech-enabled solution, eg an app, text, automated phone call or email.

- **Onboarding**

Onboarding means that patients were referred onto the service.

- **Self-monitoring**

Self-monitoring refers to the model of care set out in national guidance (the term was used in the March 2021 version of the standard operating procedure). In this model, patients (or carers, where appropriate) monitor their readings and escalate their own care as necessary. They are given the option of having a prompt (or check-in calls) to take readings on certain days. This differs from remote home monitoring models whereby patients (or their carers) submit their readings (via phone or a tech-enabled solution), which are monitored remotely. However, the national guidance states that check-in calls should confirm readings are 95% or above. The range of models implemented in practice means that the distinctions between different models are not clear cut.

A6. Further resources

Findings from a study of remote home monitoring models for COVID-19 patients during the first wave:

Vindrola-Padros C, et al (2021). The implementation of remote home monitoring models during the COVID-19 pandemic in England. *Lancet EClinicalMedicine*, doi: https://doi.org/10.1016/j.eclinm.2021.100799.

Findings from a rapid systematic review of remote home monitoring for COVID-19 patients:

Vindrola-Padros C, et al (2021). Remote home monitoring (virtual wards) for confirmed or suspected COVID-19 patients: a rapid systematic review. *Lancet EClinicalMedicine*, doi: https://doi.org/10.1016/j.eclinm.2021.100965

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