A mixed methods evaluation of remote home monitoring models during the COVID-19 pandemic in the UK

DRAFT STUDY PROTOCOL (v2.4 22nd July 2020)

Principal Investigator:
Prof Naomi Fulop, UCL (NIHR RSET)

Research team:
Dr Chris Sherlaw-Johnson, Nuffield Trust (NIHR RSET)
Dr Theo Georghiou, Nuffield Trust (NIHR RSET)
Dr Cecilia Vindrola, UCL (NIHR RSET)
Dr Sonila Tomini, UCL (NIHR RSET)
Dr Kelly Singh, University of Birmingham (NIHR BRACE)
Pei Li Ng, UCL (NIHR RSET)

BACKGROUND

Delays in the escalation of patient cases during the COVID-19 pandemic has led to the admittance of patients with advanced course of the disease, requiring invasive treatment and potential admission to ICU. Remote home monitoring models (sometimes referred to as 'virtual wards') seek to remotely monitor patients considered high-risk of deterioration at home to: 1) avoid unnecessary hospital admissions (appropriate care at the appropriate place), and 2) escalate cases of deterioration at an earlier stage to avoid invasive ventilation and ICU admission. Remote home monitoring models have been implemented in the US, Australia, Greece and UK, with some variation in the frequency of patient monitoring, modality (telephone or video calls and use of applications or online portals), patient criteria and use of pulse oximetry (Margolius et al. 2020; Karampela et al. 2020; Thornton 2020; Hutchings et al. 2020; Kricke et al. 2020; Annis et al. 2020; O'Keefe et al. 2020; Ford et al. 2020).

In the UK, at least 10 remote home monitoring models have been documented with the aim outlined above (this does not include models operating as a step-down service following hospital inpatient stay). These models have mainly involved the following processes: 1) patient triage through 111, GP practice, hot hub (or ED for those pilots in secondary care), 2) patient provided with pulse oximeter, patient information (including escalation warning signs and what to do) and mechanism for recording observations regularly (app or paper diary) (potential observations being symptoms, pulse, heart rate, temperature, O2)., 3) patient receives regular monitoring calls from staff (either primary or secondary care depending on pilot). Symptoms and trends of O2 saturations are monitored. Modality/frequency of surveillance at clinician discretion. Calls are used to identify cases of deterioration and inform patient of next steps, and 4) Patients expected to 'check out' around 14 days mark (when recovery expected) - follow up to check symptoms and have oximeter and diary returned.

Despite previous research on the use of remote home monitoring models for other conditions, there is a lack of studies on the implementation of these models for remote home monitoring during the COVID-19 pandemic. This mixed-methods evaluation of remote home monitoring models in the UK will seek to address this gap in two phases: (i) by capturing the lessons learnt during the implementation of these models during wave 1 of the pandemic and (ii) evaluating the implementation of the models during wave 2.

This protocol has been developed during a four-week scoping exercise which has included initial scope of the literature (see appendix 2), discussions with each of the proposed sites (n=11), documentary analysis, and discussions with colleagues at PHE and NHSE. From discussions with a team from Imperial, our understanding is that they will be analysing retrospective data from sites operating during wave 1 of the pandemic provided to them by NHS Digital; therefore we are not proposing a quantitative analysis of outcomes in phase 1.

PHASE ONE

STUDY AIMS

The aims of this study will be to: develop a conceptual map of remote home monitoring models (including their key characteristics), explore the experiences of staff implementing these models during the COVID-19 pandemic, understand the use of data for monitoring progress against outcomes, and document variability in staffing and resource allocation. We will focus on models with the following characteristics:

- Implemented during the COVID-19 pandemic (retrospective in the case of sites implemented during wave 1 of the pandemic)

- Focused on monitoring patients prior to hospital admission (although including one site using step-down ward)
- Delivered from primary and secondary settings
- Include some element of patient recording of oxygen saturation using pulse oximetry

RESEARCH QUESTIONS FOR PHASE 1

1. What are the conceptual models guiding the implementation of remote home monitoring models during the COVID-19 pandemic?
2. What are 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 have the sites used 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 learnt from implementing remote home monitoring models during wave 1 of the pandemic? Can some of these lessons be used for planning care delivery during the winter months?

DESIGN FOR PHASE 1

This is a multi-site study that will combine qualitative and quantitative approaches to analyse the implementation and impact of remote home monitoring models implemented during the COVID-19 pandemic. Phase 1 will involve a rapid qualitative study to retrospectively capture the lessons learnt during the implementation of remote home monitoring models during wave 1 of the pandemic.

Methods for phase 1

Phase 1 will be divided in two main workstreams: a scoping review of the literature and a rapid qualitative study to capture the lessons learnt during wave 1 of the pandemic.

Scoping review

We will conduct a rapid literature review of the use of remote home monitoring during the COVID-19 pandemic following the rapid review method proposed by Tricco et al. (Tricco et al. 2017). The rapid review method follows a systematic review approach, but proposes adaptations to some of the steps to reduce the amount of time required to carry out the review (i.e., the use of large teams to review abstracts and full texts, and extract data; in lieu of dual screening and selection, a percentage of excluded articles is reviewed by a second reviewer, and software is used for data extraction and synthesis, as appropriate (Tricco et al. 2017)).

The review will be divided into two parts: 1) an evidence mapping exercise to rapidly map the landscape on this topic, develop a draft conceptual map of remote home monitoring models, capture lessons learnt during implementation and develop a formal search strategy to be used in the systematic review, 2) a systematic review of the literature on remote home monitoring during COVID-19, including grey literature and peer-reviewed articles.

We will use the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Moher et al. 2009) to guide the reporting of the methods and findings. The review protocol will be registered with PROSPERO.

Review research questions

The review will seek to answer the following questions:

Evidence mapping

1. What are the key terms used to define remote home monitoring models?
2. What are the main characteristics of the current evidence base on remote home monitoring models? (i.e. type of publication, country, patient population)
3. What are the main types of remote home monitoring reported in the literature? (app-based, paper-based, primary-are-led, secondary care-led, etc.)
4. What are the lessons learnt from implementing remote home monitoring models during the COVID-19 pandemic?

Scoping 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?

The detailed scoping review methods can be found in Appendix 1.

Rapid qualitative study of first wave

Qualitative fieldwork will be based on telephone semi-structured interviews with a purposive sample of staff from the four pilot sites implemented during wave 1 of the pandemic and documentary analysis of internal documents developed by these sites (Table 1). Data collection will follow a rapid qualitative research design involving teams of field researchers, participatory approaches, and iterative data collection and analysis (McNall and Foster-Fishman 2007). The interviews will focus on capturing the theories of change and logic models guiding the design and implementation of the remote home monitoring models, staff experiences of implementing the models during wave 1 of the pandemic, and processes used to implement the models (including factors that acted as barriers and enablers). In order to start this study rapidly, we are not including patient experiences directly so that the study could be classed as a service evaluation. We will however ask staff about their perceptions of patient experience and include any data they have on this.

As part of the fieldwork, we will obtain information on the data collected during wave 1 (including the data fields, numbers of patients covered and their outcomes, and the extent to which the sites used both bespoke and standard data collection). We will also collect data on the staffing models used during wave 1 and different approaches for the allocation of resources. We will gather information on whether they have used other available quantitative evidence to help inform clinical decisions. We will use this information to assess the value of the data in helping the sites monitor progress against outcomes as well as identify the resources used in the implementation of each of the sites. This will lead to recommendations about data collection, methodology, resource allocation, staffing models and evidence sourcing to assist with wave 2.

Documentary analysis will be used to develop the theories of change and logic models guiding the pilot sites as well as capture changes in design and implementation over time. The documentary analysis will also allow us to identify if there were instances of cross-fertilisation or sharing of information across pilot sites.

Documentary analysis and interviews will be used to understand key broad contextual factors such as population served, geography and availability of other services.

Table 1. Sample of remote home monitoring pilot sites included in the rapid qualitative study

	Pilot site name	**Location**	**Setting**	**Implementation stage**	**Main outcomes of interest**	**Patient-reported data**
1.	ED led ambulatory pathway to enable safe discharge and monitoring of patients attending the ED with COVID 19	Royal Free London Hospital	Secondary care (ED)	Started 23 March	Reattendance ED Admission 30 day mortality Patient satisfaction	Paper-based
2.	Winchester City	Winchester City PCN.	Primary care	Started 6 April	O2 saturation Use of antibiotics Admission hospital ICU admission 30 day mortality	Paper-based
3.	Model for remote monitoring led by primary care	Hampshire – 11 GP practices	Primary care	Remote monitoring without pulse oximetry implemented since 6 April (will be shut down 17 July). Might implement a later model with PO if numbers increase.	TBD	AccuRx: Electronic system based (SMS, online questionnaires)
4.	Winchester SDEC Covid Virtual Ward pilot - Same Day Emergency Care COVID Virtual Ward	Royal Hampshire County Hospital (RHCH)	Secondary care (ED)	Implementation (started 14 May)	Ventilation Mortality Reattendance to ED Admission ICU admission 999 call	Paper-based
5.	Royal Berkshire Hospital (TICC-19)	Reading	Secondary care (ED)	2 April	Re-admission rate Patient experience	Paper-based
6.*	West Hertfordshire (Watford)	Hertfordshire	Secondary care (ED)	14 March	Readmission ICU admission Mortality	App (Medopad) and paper-based
7.	Manchester Royal Infirmary	Manchester	Secondary care (step down model)	19 March	Mortality Re-attendance Avoid unnecessary admissions	Paper-based

**Shaded row currently being explored as potential site and additional ones may be added.*

Sampling

The interviews will be carried out with a purposive sample of study participants that will be designed in relation to the sampling framework outlined in Table 2 and will grow throughout the study due to snowball sampling. We will aim to carry out interviews with 3-5 participants

at each pilot site for a total sample of 18-24 telephone interviews. The documentary analysis will include all documents on the remote home monitoring models developed by pilot sites.

Table 2. Sampling framework for interviews with pilot site participants

Participant category	**Number of interviews**
Pilot site lead	6 (1 per site)
Staff in charge of monitoring	6-12 (1-2 per site)
Staff with knowledge of data collection/use	6 (1 per site)
Total	18-24 interviews

Recruitment
An informed consent process using participant information sheets and written consent will be used for recruitment to ensure informed and voluntary participation. The researcher will contact potential participants via email and will send them a participant information sheet. Participants will then be given 48 hours to review the information and ask questions about the study. If the participant agrees to take part in the study, they will be asked to sign the consent form. The researcher will then arrange a time to carry out the interview over the phone.

ETHICS AND DISSEMINATION

The study protocol and materials for phase 1 of the evaluation will be reviewed by the UCL/UCLH Joint Research Office. This phase 1 was classified as a service evaluation based on the HRA decision tool, thus not requiring research ethics committee approval (although protocol and materials are being reviewed by University of Birmingham Humanities and Social Sciences ethics committee). We are aware of the sensitive nature of this research for organisations and individuals. The research team has experience in conducting research on similar sensitive topics. We will maintain the independence of the research, follow an informed consent process, and maintain the anonymity of participants and organisations.

We will regularly share feedback with stakeholders on: (1) the conceptual models guiding the design and implementation of remote home monitoring models; (2) lessons learnt during the implementation of the models during wave 1 of the pandemic; and (3) data collection by pilot sites and their use, and (4) staff views and experiences with processes of implementation. We also aim to publish the findings from the scoping review and the empirical research conducted in phase 1 in peer-reviewed journals.

OUTPUTS OF PHASE 1 OF THE EVALUATION

During phase 1 of the evaluation we will generate the following outputs:

1. A conceptual map of remote home monitoring models implemented around the world (based on the evidence map and early findings from the scoping review).
2. A synthesis of main lessons learnt during the implementation of remote home monitoring models during wave 1 of the pandemic (including use of data and staffing models).

TIMELINE FOR PHASE 1

Evidence mapping exercise: complete
Scoping review: July-October 2020
Rapid qualitative study: July-September 2020
Sharing of findings from phase 1 with stakeholders and discussion about phase 2 design: early Sept 2020

PHASE 2

In phase 2, we will seek to evaluate the models implemented during wave 2 of the pandemic using a mixed-methods study design. The final research questions and design of phase 2 of the evaluation will be informed by the findings from phase 1 and discussions with colleagues at PHE and NHSE, and with colleagues at Imperial in relation to their proposed study.

RESEARCH QUESTIONS FOR PHASE 2

1. Have the conceptual models guiding the implementation of remote home monitoring models during the COVID-19 pandemic changed during wave 2 of the pandemic?
2. What are the processes that acted as barriers and facilitators in the design and implementation of pilots of these models during wave 2 of the pandemic?
3. Are the benefits of the home monitoring approach being realised during a second wave?
4. How were resources allocated (including staffing models) to implement the remote home monitoring pilots during wave 2 of the pandemic?
5. What are the lessons learnt from implementing remote home monitoring models during wave 2 of the pandemic? What are the potential lessons for other conditions that may be amenable to remote monitoring at home?

METHODS FOR PHASE 2

The findings from phase 1 will be used to design a mixed-methods evaluation capturing the processes of implementation and impact of remote home monitoring models that are in operation during wave 2 of the pandemic.

Qualitative study of implementation during wave 2 of the pandemic

Qualitative fieldwork will be based on telephone semi-structured interviews with a purposive sample of staff from the eight pilot sites implemented during wave 2 of the pandemic and documentary analysis of internal documents developed by these sites (Table 3). The interviews will focus on capturing the theories of change and logic models guiding the design and implementation of remote home monitoring models, staff experiences of implementing the models during wave 2 of the pandemic, processes used to implement the models (including factors that acted as barriers and enablers), the allocation of resources during implementation and decisions made in relation to the collection of patient data and expected outcomes.

The documentary analysis will be used to develop the theories of change and logic models guiding the pilot sites as well as capture changes in design and implementation over time. The documentary analysis will also allow us to identify if there were instances of cross-fertilisation or sharing of information across pilot sites.

Documentary analysis and interviews will be used to understand key broad contextual factors such as population served, geography and availability of other services.

Table 3. Sample of remote home monitoring pilot sites included in the rapid qualitative study

	Pilot site name	**Location**	**Setting**	**Implementation stage**	**Main outcomes of interest**	**Patient-reported data**
1.	ED led ambulatory pathway to enable safe discharge and monitoring of patients attending the ED with COVID	Royal Free London Hospital	Secondary care (ED)	Started 23 March	Reattendance ED Admission 30 day mortality Patient satisfaction	Paper-based

	19					
2.	Winchester City	Winchester City PCN.	Primary care	Started 6 April	O2 saturation Use of antibiotics Admission hospital ICU admission 30 day mortality	Paper-based
3.*	Model for remote monitoring led by primary care	Hampshire – 11 GP practices	Primary care	Remote monitoring without pulse oximetry implemented since 6 April (will be shut down 17 July). Might implement a later model with PO if numbers increase.	TBD	AccuRx: Electronic system based (SMS, online questionnaires)
4.	Winchester SDEC Covid Virtual Ward pilot - Same Day Emergency Care COVID Virtual Ward	Royal Hampshire County Hospital (RHCH)	Secondary care (ED)	Implementation (started 14 May)	Ventilation Mortality Reattendance to ED Admission ICU admission 999 call	Paper-based
5.	Slough covid-19 BAME pilot project*	Slough - The Frimley Health & Care ICS	Primary care	Planning (implementation planned for second week July)	Mortality Morbidity Ventilation ICU admission	Paper-based but might use an app in the future
6.	NHS Tees Valley CCG COVID-19 Virtual Ward Vanguard Bid*	Tees Valley	Primary and secondary care	Early implementation (started 8 June only for secondary care) Primary care to start early July.	Unplanned admissions Mortality Protected hospital capacity	App (My M Health)
7.	Dorset Pilot – Pulse Oximetry and Digital Remote Monitoring	Dorset	Primary care	Early scoping (to start in 6 weeks)	Length of stay Admission	App (My M Health)
8.	Covid-19 Virtual Ward – Remote monitoring with pulse oximetry in patients with suspected COVID-19	One Gloucestershire-Churchdown Surgery	Primary care with support from secondary care	Early testing (planned rollout in late August)	TBD	Paper-based
9.	Royal Berkshire Hospital (TICC-19)	Reading	Secondary care (ED)	2 April	Re-admission rate Patient experience	Paper-based
10.	West Hertfordshire (Watford)	Hertfordshire	Secondary care (ED)	Mid-March	Readmission Admission to ICU Mortality	App (Medopad) and paper-based

**Shaded row currently being explored as potential sites and additional ones might be added.*

Sampling
The interviews will be carried out with a purposive sample of study participants that will be designed in relation to the sampling framework outlined in Table 4 and will grow throughout the study due to snowball sampling. We will aim to carry out interviews with 3-5 participants at each pilot site for a total sample of 24-32 telephone interviews. The documentary analysis will include all documents on the models developed by pilot sites.

Table 4. Sampling framework for interviews with pilot site participants

Participant category	**Number of interviews**
Pilot site lead	8 (8 per site)*
Staff in charge of monitoring	8-16 (1-2 per site)
Staff with knowledge of data collection/use	8 (1 per site)
Total	24-32 interviews

*Numbers will depend on the confirmation of sites in Table 3.

Recruitment
An informed consent process using participant information sheets and written consent will be used for recruitment to ensure informed and voluntary participation. The researcher will contact potential participants via email and will send them a participant information sheet. Participants will then be given 48 hours to review the information and ask questions about the study. If the participant agrees to take part in the study, they will be asked to sign the consent form. The researcher will then arrange a time to carry out the interview over the phone.

Economic analysis
The aim of the economic analysis is to quantify the costs of different pilot sites from an NHS perspective, using a cost analysis (CA) approach. The cost analysis will be focused on the costs of implementing remote home monitoring models without looking at the ultimate outcomes. This approach is an important first step to determine the feasibility of implementing these models at a larger scale. The CA will be conducted separately for each of the pilot sites and we will potentially compare the cost categories between sites. This approach will form a basis for any future analyses and will be an effective tool to identify the most significant cost categories and gaps as well as any initial improvements in terms of resource allocation.

The CA will consist in a retrospective analysis that will consider all the resources (including staff's costs) that all sites have engaged in implementing remote home monitoring models. All the sites will be able to bid for potential funding from NHS. In this respect, the CA will also be able to help identify the potential cost categories that are more in need for funding (or where funding could be extended further) therefore help in the future implementation of the remote home monitoring models.

Measuring Costs
Each of the sites will be costed using data on resource use during the first and second waves. We will calculate the costs of all the used or planned resources, medical equipment (e.g. number of pulse oximeters) and appointed or internal medical staff (e.g. hours spent by each staff's categories). The costing will be based on staff's unit costs and the costs of other resources employed, accounting for whether and how these costs may be shared across different sites. For each site, we will also identify where these costs are utilised. In addition, we will also try to include possible costs that could be attributed exclusively to remote home monitoring models (e.g. misdiagnosis due to remote assessing of patients materialised by double referrals or patients getting back to the services after an initial referral is made). This

will be done by identifying such possible uses of resources through the telephone interviews mentioned above. Total costs will be compared in terms of average costs per patient using the throughput number of patients for each site during the duration of the pilots.

Quantitative analysis
The aims and design of the quantitative analysis will be informed by the findings from phase 1 of the evaluation. This may include collection and analysis data collected prospectively from the sites to inform analysis of the potential benefits of the home monitoring approach and how they compare against what would have been expected.

ETHICS AND DISSEMINATION FOR PHASE 2
Requirements for the ethical review of phase 2 of the evaluation will depend on the research questions and study design (to be determined after phase 1).

TIMELINE FOR PHASE 2
Study set-up: September 2020
Qualitative study data collection: October 2020-January 2021
Quantitative study: TBC
Cost analysis: TBC
Qualitative study submission of final report: February 2021

REFERENCES

Gale N, Health 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; 13:117.

Karampela, I. et al. Remote Monitoring of Patients in Quarantine in the Era of SARS-CoV-2 Pandemic. 2020 doi:10.3233/SHTI200486

Margolius D., et al. On the Front (Phone) Lines: Results of a COVID-19 Hotline in Northeast Ohio. Preprint 2020. https://doi.org/10.1101/2020.05.08.20095745

Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 2009; 339: 332-336.

Thornton, J. The “virtual wards” supporting patients with covid-19 in the community. BMJ 2020;369:m2119 doi: 10.1136/bmj.m2119

Tricco A., et al. Rapid reviews to strengthen health policy and systems: A Practical Guide. World Health Organization; 2017.

Appendix 1. Methods for the scoping review

Search strategy

Evidence mapping

The evidence mapping exercise will be broad and include a series of search waves where we gradually add search terms based on the keywords used in the literature we identify. Appendix 1 includes the strategies used for the waves carried out to date. These searches have been carried out on MEDLINE and TRIP to capture peer-reviewed articles and grey literature. The findings from the evidence mapping can be found in Appendix 2.

Scoping review

The scoping review will be targeted and use the search strategy developed as a result of the phased searching implementing during the evidence mapping exercise. We will conduct a review of published literature using multiple databases: MEDLINE, CINAHL PLUS, EMBASE, TRIP and Web of Science. Results will be combined into Mendeley and duplicates will be removed. The reference lists of included articles will be screened to identify additional relevant publications.

Selection

Following rapid review methodology (Tricco et al. 2017), one researcher will screen the articles in the title phase, and a second reviewer will cross-check exclusions in the abstract and full-text phases. Disagreements will be discussed until consensus is reached. The inclusion criteria used for study selection will be: 1) focus on the monitoring of confirmed or suspected patients with COVID-19), 2) focus on pre-hospital monitoring or monitoring after ED presentation, but not including early discharge, 3) focus on monitoring at home (excluding monitoring done while the patient is in healthcare facilities), and 4) published in English.

Data extraction and management

The included articles will be analysed using a data extraction form developed in REDCap (Research Electronic Data Capture). The form will be developed after the initial screening of full-text articles. It will then be piloted independently by two researchers using a random sample of five articles. Disagreements will be discussed until consensus is reached. The data extraction form will be finalised based on the findings from the pilot.

Data synthesis

Data will be exported from REDCap and the main article characteristics will be synthesised. The information entered in free text boxes will be exported from REDCap and analysed using framework analysis (Gale et al. 2013). The initial categories for the framework will be informed by our research questions but we will also be sensitive to topics emerging from the data.

Quality assessment

We will use the Mixed Methods Appraisal Tool (MMAT) to assess the quality of the articles published in peer-reviewed journals and the AACODS will be used for grey literature (Pluye et al. 2012). Two researchers will rate these articles independently. In cases of disagreement, the raters will discuss their responses until consensus is reached. Inter-rater reliability will be calculated using the kappa statistic (Landis and Koch 1977).

Appendix 2: A mixed methods evaluation of remote home monitoring models during the COVID-19 pandemic in the UK

Evidence mapping findings

- ***Key terms:*** Telehealth services, remote patient monitoring solution virtual ward, virtual health care, home monitoring, outpatient monitoring, telemedicine visits, telehealth, continuous virtual monitoring [all in relation to COVID-19]
- ***Main characteristics of the literature***
    - ***Type of literature***: 3 preprints, 4 accepted/published research articles, 1 published feature article
    - ***Countries***: 5 from US, 2 from UK, 1 Greece and 1 Australia
- ***Main types/characteristics of virtual wards***
    - 2 examples from primary care and 7 examples secondary care (ED presentation + 1 also used as step-down ward)
    - 4 paper-based + phone call, 3 app + phone call, 2 wearable sensors
    - Patient population included patients with COVID-19 symptoms and 2 examples only for confirmed COVID-19 cases
    - ***Main patient information recorded***:
        - Patient demographics (age, sex, race/ethnicity, insurance type)
        - Clinical variables (clinical signs and symptoms, medical history and medications)
        - Health data for risk assessment and vital signs data (body temperature, heart rate, respiratory rate and oxygen saturation)
    - ***Main outcomes of interest***:
        - Emergency room visit likely related to COVID-19 subsequent to hotline telehealth visit
        - Hospitalization due to COVID-19 subsequent to hotline telehealth visit
        - SARSCoV-2 PCR test ordered subsequent to telehealth visit
        - Positive SARS-CoV-2 PCR test
        - Mortality
        - Ambulance attendance
        - 911 activation help
        - Patient satisfaction
        - Referral for physician review
- ***Lessons learnt***
    - It was important to avoid framing the remote home monitoring model as an admission avoidance model and instead see it as an approach to maintain patients safe in the right setting.
    - The use of apps for monitoring allowed the follow-up of a higher number of patients (compared to paper-based models) but some of the studies indicated that models based on telephone calls were more inclusive (i.e. including patients without internet access or technological literacy).
    - One outcome of implementing the models has been patient reassurance that they are being cared for.
    - Patient physiological measures needed to be recorded several times a day to properly identify cases of deterioration.
    - Patient training is a key determining factor of the success of these models.
    - GPs should lead the monitoring of patients due to their knowledge of resources in the community and local emergency departments.

Summary of virtual ward examples included in the evidence mapping exercise

	Author	Country	Type	Terms	Sector	Patient population	Triage process	Type patient info	Tool patient reporting	Tool patient monitoring	Outcomes
1	Margolius	USA	Pre-print	Telehealth services	PC	C19 symptoms	Patient referred to teleconsultation and follow-up call made 24 hours after	age, sex, race/ethnicity, insurance type, smoking status and clinical variables directly relevant to understanding the social epidemiology of the COVID-19 hotline (symptom protocols, visit disposition, visit diagnoses).	None	Telephone call	(1) emergency room visit likely related to COVID-19 subsequent to hotline telehealth visit, (2) hospitalization due to COVID-19 subsequent to hotline telehealth visit, (3) SARSCoV-2 PCR test ordered subsequent to telehealth visit, and (4) positive SARS-CoV-2 PCR test subsequent to telehealth visit.
2	Karampela	Greece	Article	Remote patient monitoring solution	PC	C19 symptoms	Patient with symptoms triaged to service via phone	patient-reported data (clinical signs and symptoms, medical history and medications) as well as important health data for risk assessment, and (2) vital signs data (body temperature, heart rate, respiratory rate and oxygen saturation)	smart phone or other wearable sensors communicating with the smart phone through Bluetooth technology	smart phone or other wearable sensors communicating with the smart phone through Bluetooth technology and sent to physician to identify cases of deterioration	NS
3	Thornton	UK (2 examples step-up and 1 step-down)	Feature article	Virtual ward	SC	Patients presenting at ED with symptoms	Patient assessed in ED and triaged to virtual ward with oximeter	symptoms, temperature, heart rate, respiratory rate, and their oxygen level.	Medopad app 1 case	Medopad app 1 case	ED reattendance, admission, mortality

4	Thornton	UK (2 examples step-up and 1 step-down)	Feature article	Virtual ward	SC	Patients presenting at ED with symptoms	Patient assessed in ED and triaged to virtual ward with oximeter	symptoms, temperature, heart rate, respiratory rate, and their oxygen level.	Phone call with physicians	Phone call with physicians	ED reattendance, admission, mortality
5	Hutchings	Australia	Preprint	Virtual health care, remote patient monitoring	SC	Patients in whom C19 is detected (certain inclusion and exclusion criteria apply)	Patients attend C19 testing clinic, those in whom C19 is detected are referred to the virtual care centre by the local public health unit. The care centre conducts an initial assessment to ascertain suitability for virtual health care.	vital signs - respiratory rate, oxygen saturation, pulse rate and temperature, assessment of other symptoms and signs of deterioration assessed by video call	Wearable temperature monitor provides continuous temperature monitoring, which feed into a dashboard	Wearable temperature monitor provides continuous temperature monitoring, which feed into a dashboard. Patients monitored three times a day, including a videoconference twice every 24 hours	Ambulance attendance, ED attendance, ED admission, mortality
6	Kricke	USA	Article	Home monitoring, outpatient monitoring	SC	Patients with pending/indeterminate/positive C19 test or presumed C19 presence based on clinical criteria. Later began only	Not clear but states that only nurses from C19 triage phone line, ED staff, and hospital medicine staff were able to add patients to the registry	Evaluation of 10 symptoms (cough, shortness of breath, sore throat, muscle aches, trouble sleeping, lack of energy, feeling ill, fever, diarrhoea, stomach pain), how they feel the infection is affecting them (feeling overwhelmed, worried about deterioration and worry about spreading infection), how many analgesic/antipyretic tablets they are taking, symptoms of others in the	Enrolled patients with an electronic health record portal account receive a questionnaire invitation where they evaluate symptoms, those not enrolled in the patient portal are called	They monitor and stratify responses to daily questionnaires, those with concerning symptoms are called	ED referrals (also anecdotal data about education, comfort, 911 activation help)

						including those with positive C19 test.		household, and a measured temperature. In addition, the initial questionnaire asks about date symptoms began as well as information about the household and alternate contact person			
7	Annis	USA	Accepted manuscript	Remote patient monitoring, telehealth	SC	Patients with confirmed or suspected C19	Patients that were enrolled were either screened for C19 through virtual care platforms (online, phone, video) or at an urgent care or ED visit and referred. Providers were informed about the programme as a care option. Had a referral order within EHR to gather the patients' required information and developed a batch process to automate enrollment. Patients then received an email with information on how to activate and begin the programme (optional).	Daily check in questions to monitor/assess symptoms, later updated to include question that assessed pulse oximetry data	GetWell Loop - daily check in questions for patients to assess their symptoms, patients could also send comments and questions through scrolling newsfeed. Patients could also call the Mhealth triage line for alerts or comments outside 8am-5pm (before they expanded the workforce to inc 24/7 virtual care)	GetWell Loop - symptom monitoring questions were monitored - concerning answers routed to dashboard for action by member of first responder team. Physicians would also text or call patients if an alert or comment was concerning/complicated.	Hospital admissions, ED visits. Patient satisfaction data also collected
8	O'Keefe	USA	Prep	Telemedi	SC	Patients	Telemedicine visit	Reported symptom data	None described	Telephone calls -	This study focuses on

			rint	cine visits		with positive C19 PCR test	offered to patients with positive C19 PCR test performed at affiliated test site or ED			risk stratified	collecting symptom data so reports frequency by symptom. It does report on hospitalisation rate though.
9	Ford	USA	Accepted manuscript	Telehealthremote patient monitoring, continuous virtual monitoring	SC	Patients with confirmed C19	Used dedicated registry of C19 patients populated using the positive diagnostic test as the trigger as well as all patients using virtual urgent care for C19 suspicions. All nasopharyngeal testing submitted through centre pulled into registry for potential enrolment in home monitoring as were all positive tests regardless of entry point (virtual urgent care, drive up, ED, inpatient admission or pre-op testing). Nurses could enrol, triage and follow patients.	Patient reported outcome measures (five item survey querying changes in dyspnea - derived from validated community acquired pneumonia patient questionnaire), later extended in app to include pulse oximetry (for select groups inc post hospitalisation) and digital thermometers	Via patient portal (Epic MyChart electronic health record) or app - nurses could choose which to prescribe	Monitored responses through portal or app, nurses can reach out by phone if symptoms worsen	Referral for physician review, referral to ED, hospitalisation

Search strategies used in the evidence mapping:

Round 1

COVID-19
AND
“virtual ward” OR “remote monitoring” OR “virtual monitoring” OR “home monitoring” OR “community monitoring” OR “early monitoring”

Round 2

COVID-19 OR
AND
“virtual ward” OR “remote monitoring” OR “virtual monitoring” OR “home monitoring” OR “community monitoring” OR “early monitoring” OR “pre-hospital monitoring”
AND
“silent hypoxemia” OR “pulse oximetry”

Round 3

"COVID-19"[All Fields] OR "severe acute respiratory syndrome coronavirus 2"[All Fields] OR "severe acute respiratory syndrome coronavirus 2"[All Fields] OR "2019-nCoV"[All Fields] OR "SARS-CoV-2"[All Fields] OR (("Wuhan"[All Fields] AND ("coronavirus"[MeSH Terms] OR "coronavirus"[All Fields])) AND 2020[All Fields])
AND
“virtual ward” OR “remote monitoring” OR “virtual monitoring” OR “home monitoring” OR “community monitoring” OR “early monitoring” OR “remote patient monitoring” OR “pre-hospital monitoring” OR “Covidom” OR “My m health” OR “GetWell Loop” [All Fields]
AND
“silent hypoxemia” OR “pulse oximetry” [All Fields]

Study selection procedure