Remote management of covid-19 using home pulse oximetry and virtual ward support

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What you need to know
- Pulse oximeters used at home can detect hypoxia associated with acute covid-19
- Home oximetry requires clinical support, such as regular phone contact from a health professional in a virtual ward setting
- More research is needed to understand the safety and effectiveness of home oximetry and to optimise service models and referral pathways

Oxygen levels in covid-19

Low blood oxygen—technically, hypoxaemia but often referred to as hypoxia can be defined as a measured oxygen saturation below 94% in the absence (or below 88% in the presence) of chronic lung disease.[1] In most patients who die of acute covid-19, the initial illness advances insidiously, sometimes with "silent hypoxia" (hypoxia without clinically perceptible symptoms of dyspnoea[2 3]), leading to pneumonia followed by acute respiratory distress syndrome, usually in week 2.[4] The underlying pathology in covid-19 related hypoxia is probably a ventilation-perfusion mismatch,[5] caused by a combination of intrapulmonary shunting, loss of lung perfusion regulation, intravascular microthrombi. and reduced lung compliance leading to alveolar collapse.[2 6 7]

Many patients hospitalised with acute covid-19 have severe hypoxia.[4 7 8] Hypoxia, silent hypoxia, and the need for supplementary oxygen are all independent predictors of worse outcomes in covid-19.[8-16] Novel prognostic tools such as the 4C score have shown the importance of identifying hypoxia early,[9 17] and there are physiological reasons for managing the complication promptly and actively.[1 18]

For all these reasons, UK guidelines recommend that assessment and monitoring of breathless, unwell, or high risk patients with suspected covid-19 should include pulse oximetry.[19 20] Guidance published in January 2021 by the World Health Organisation includes a provisional recommendation for "use of pulse oximetry monitoring at home as part of a package of care, including patient and provider education and appropriate follow-up."[21]

Pulse oximeters: practicalities and cautions

Home pulse oximeters have long been used in primary care settings—most usually for monitoring chronic lung disease and heart failure.[22] Devices cost £15-35 ($20-48, €17-40) when sold commercially, but substantial savings can be made on bulk purchases. They are relatively simple and quick to use, though not everyone is able to understand or operate them.

Finger pulse oximeters are generally accurate and reliable (provided they have evidence of a quality standard such as ISO 80601-2-61:2017); however, most smartphone oximeters are unreliable and should not be used.[23 24] The Apple watch (Series 6 and above) has an inbuilt oximeter that operates on similar principles to a standard finger oximeter but is not designed (or licensed) for medical use (Tarassenko L, personal communication).

Pulse oximeter readings should be taken on a warm finger, with the patient in the upright (sitting) position and resting. The instrument should be left to stabilise for a minute before use. Falsely low readings may occur if the patient's peripheries are cold, if there is poor perfusion owing to (for example) hypotension, hypovolaemic shock, or cardiac failure, if the patient has tattoos, nail polish, or false nails, when the patient is supine (see below), and **at low levels of oxygen saturation**.[23 24] Readings may also be falsely low in patients with anaemia, sickle cell disease, and other haemoglobinopathies.

A study of hospital inpatients found that those with black or brown skin were three times as likely as those with white skin to have occult hypoxia—that is, pulse oximeter readings in the normal range but arterial blood gas levels in the hypoxic range. The oximeter reading gave false reassurance in 11.7% of patients with black or brown skin and 3.6% of those with white skin.[25] However, other authors have found that inaccuracy of pulse oximeters in those with darker skin relates mainly to saturations below 90%—substantially below the level that

would trigger a hospital referral.[26 27] For the purposes of home monitoring, we suggest some rules of thumb to mitigate skin colour bias. First, ensure that the patient is using a quality-marked oximeter, since cheaper products marketed directly to the public may be less accurate. Second, take account of deviation from the patient's own baseline if known. Third, take particular care to assess the patient holistically rather than relying solely on the oximeter readings. Finally, **be prepared to act on** any reading below the normal range in a patient with darker skin, regardless of ethnicity.

What is an abnormal pulse oximeter reading?

The normal range of oxygen saturation is 94-98% at rest in patients without chronic lung disease.[1] A pulse oximeter reading of 92% or lower is one defining feature of "severe" disease in acute covid-19 (requiring urgent referral to hospital). Depending on the patient's own normal range, a reading of 93-94% may indicate "moderate" disease (requiring prompt assessment, for example in a community clinic).[19] Trend is important: a reading that is borderline and falling is far more concerning than one that is borderline and stable or rising. The pulse oximeter reading is part of a wider assessment of the patient; if there are red flags (such as central chest pain or blue lips), the patient should be fast-tracked to urgent care whatever the oximeter reading.[19]

Patients with chronic lung disease often have a degree of hypoxaemia, in which case target saturation rates generally fall between 88% and 92%.[1] These patients are often aware of what is normal for them. A drop of 3% or more below what is normal for the patient warrants further assessment and a drop of 4% or more may require hospital admission.

Nocturnal desaturation (a fall in the patient's oximeter reading at night) of up to 3% occurs commonly; up to five brief episodes per night are considered normal (especially if there is some pre-existing lung disease) because of variation in depth of breathing during sleep.[28] More prolonged or frequent desaturations may indicate obstructive sleep apnoea, though more specialist monitoring when not acutely unwell would be required to diagnose this.

Who should use a pulse oximeter at home?

Many people have purchased their own pulse oximeter for self-monitoring in the absence of risk factors or symptoms.[29] Others already own an oximeter for monitoring a pre-existing condition such as heart failure. In a straw poll of 15 000 social media followers by the lead author, more than 60% said they had a pulse oximeter at home. Many patients with acute

covid-19 appear able to learn how to use a pulse oximeter and are willing to take regular readings (see accompanying Patient Perspective).[12]

Despite widespread enthusiasm for, and ownership of, pulse oximeters by lay people, official policy takes a more restrictive view of who needs to use one for covid-19 monitoring (eg, those over 65 and with relevant risk factors and comorbidities such as obesity, diabetes, or frailty).[30] WHO guidance states that oximeters for home use should be considered "in symptomatic patients with covid-19 and risk factors for progression to severe disease who are not hospitalized."[21]

There is a hypothetical risk that use of a home oximeter may exacerbate anxiety. In the authors' clinical experience, this is rare, and indeed home oximetry may be introduced to help manage anxiety during acute covid-19.[31] A previous qualitative study by our own team found that both patients and relatives were reassured by home oximetry in long term condition monitoring.[32] If patients find that home oximetry worsens their anxiety, they should not use it.

Virtual wards: a service model to support home monitoring

Pulse oximeters do not save lives; good clinical care does. There is a world of difference between the patient who is given a pulse oximeter and symptom diary and told to contact the health service if they deteriorate and the patient who is given the same equipment, shown how to use it, and who then receives regular calls from a healthcare professional.

This is the rationale behind the virtual ward remote monitoring model for covid-19, which has been introduced in some settings (including, in England, the Covid Oximetry@Home service led from primary care[19] and post-hospital assessment models led from secondary care[33 34]). Figure 1 shows a virtual ward consultation occurring by video. Figure 2 shows a flowchart for selecting patients for, and supporting them in, a home oximetry and virtual ward service.

Fig 1 Virtual ward care. The clinician reviews a patient's record while conducting a video consultation with the patient, who is self-monitoring her symptoms and pulse oximeter readings at home

Fig 2 Flowchart for home oximetry with virtual ward monitoring

Box 1 provides more detail on clinical assessment when considering a patient for virtual ward monitoring.

Box 1 Clinical assessment of patients with suspected or confirmed covid-19 who are being considered for home pulse oximetry and virtual ward support
1. Take a history, especially the nature, severity, and duration of symptoms. Ask about exertional breathlessness (but note: absence of breathlessness does not exclude hypoxia)

2. Assess baseline risk of severe outcome from covid-19. NHS England recommends virtual ward monitoring only for those over 65 or classed as clinically severely vulnerable.[35] Current risk prediction tools all have limitations, for example:

- 4C score[9] requires blood tests which may not be available
- QCovid[36] does not incorporate acute variables so will underestimate severity in sick patients who lack known risk factors
- NEWS2[37] is not covid-19 specific and the score may change only at a late stage of deterioration
- RECAP[38] is a new instrument being developed as a covid-19 specific early warning score[39]

3. Evaluate any other symptoms—which may or may not be related to covid-19:

- Unwell patients may have dehydration, eg, resulting from diarrhoea or poor fluid intake
- Be alert to rare but serious complications, eg, sepsis, new neurological symptoms
- Assess face to face if clinically indicated, eg, confusion, chest pain, dizziness, collapse, dysuria

4. Evaluate comorbidities:

- In particular—but not limited to—control of diabetes, cardiac disease including heart failure, neurological disease, renal function (clinical and laboratory tests will vary with setting)
- Agree with patient how comorbidities will be monitored alongside covid-19 symptoms and oxygen levels

5. Evaluate the social situation:

- Ascertain who else is at home and give advice on infection control (masks for patient and others when in contact, how to use a bathroom if you have only one)
- Confirm that a care package is in place, eg, someone to shop, ensure medication supplies
- Confirm that the patient is not a carer for someone else or is still able to do what is needed

6. Baseline and exertional oximetry:

- Oximetry is part of clinical assessment, not a substitute for it
- If oximeter reading at rest is 96% or above, do an exertional test (40 steps around the room or 1 minute sit-to-stand test if clinically supervised)[40]

7. Train the patient and carer to use the oximeter and diary:

- See training video and diary template (box 4)
- Encourage the patient to take readings (eg, three times daily) and have them ready for each appointment

8. Agree and arrange follow-up:

- Arrangements need not be complex (eg, a daily phone call) but must be in place
- Give safety netting advice: what to do if symptoms or oximeter reading deteriorate

9. Rules of thumb for onward referral:

- Treat the patient, not the oximeter reading. Share decisions about next steps.
- Consider trajectory over time: "the trend is your friend"

There is no "right" service model to support home oximetry. Rather, services should be shaped to local contexts and needs. A rapid systematic review of reports from around the world found that most virtual ward models for covid-19 were led by secondary care; most included clinically—as well as laboratory—diagnosed cases (hence, some patients were likely to have had other acute illnesses).[42] Monitoring was carried out using a range of different approaches, including online platforms, paper based systems with telephone calls, or (less frequently) through wearable sensors.

Various kinds of remote monitoring services in England were established rapidly and pragmatically in early 2020.[43] They were run from primary or secondary care; patients were referred to them from primary care, emergency departments, or post-discharge from hospital. The services supported patients in their own homes and also in care homes.[42] Low technology approaches to monitoring (phone and paper) tended to achieve lower data capture than electronic ones (apps, web portals, or wearable sensors) but also appeared to be more inclusive. Reassuringly, of 1737 patients referred for virtual ward care across six UK centres, only 20 deaths occurred (1.1%).[43 44]

In low-resource settings, home oximetry with virtual ward monitoring has occasionally been implemented cheaply at scale to take pressure off overstretched hospital services.[45] In one adaptation of the virtual ward model in Argentina, nurses visit patients at home to take readings as oximeters are in short supply.[46] We identified no formal evaluations of such initiatives.

The goal of supported home monitoring seems achievable based a range of different models, and a number of critical success factors have been identified (box 2).[42 43]

Regular human contact

Phone or video contact should be made regularly by a doctor or nurse practitioner with specialist training, or by less senior healthcare staff with basic training overseen by specialists.

Measures to compensate for inequalities

Virtual ward support is more challenging in people with low health literacy, low digital literacy, limited connectivity, or lack of technology. Using familiar, basic technologies (eg, telephone) and bespoke support will extend reach and accessibility.

Prioritising those most in need

Referral of any patient to a virtual ward should be a case based judgement incorporating clinical concern, patient preference, and local priority criteria. Guidance for virtual wards in England currently prioritises people over 65 and those classed as clinically extremely vulnerable, on the grounds that most people who go on to require intensive care support will meet these criteria.[35]

Safety measures

To assure patient safety, clear exclusion criteria, escalation pathways, and safety netting should be adhered to (fig 2).

Service evaluation

All virtual ward services should allow capture of high quality data on process and outcome that can be aggregated and followed over time to inform the quality improvement cycle. Shared databases would allow linkage of such data across providers and between primary and secondary care.

Covid-19 claimed more than a million lives worldwide in 2020. It also generated research findings and system learning which, if systematically applied, could significantly reduce the death toll as the pandemic continues. One aspect of such learning is the accurate detection and timely management of hypoxia. Home oximetry and virtual ward support could potentially save many lives by enabling patients requiring hospitalisation to be identified earlier, while also conserving hospital beds and reducing the risk of nosocomial infection. As the evidence base for the efficacy, safety, and acceptability of such models is now accumulating,[33 34 42-44] some unanswered questions remain, for which further research is needed, including the impact of home monitoring on patient outcomes (box 3).

Box 3 Unanswered questions and ongoing research

Questions to be answered through further research include:

• *Efficacy*—What is the impact of remote home monitoring on patient outcomes, and what elements of the service affect these outcomes?

• *Cost effectiveness*—How can the service be made more cost-effective (eg, through optimum use of different staff grades)? How might this have a knock-on effect other health services? What measures would enable primary care to deliver a home monitoring service for patients, reducing the demand on hospital services?

• *Patient experience*—What is the range of patients' and carers' experiences with home oximetry? How can we best engage and support patients from different demographic and ethnic groups?

• *Equity*—What tools and approaches might be used to reduce inequalities in the delivery of remote monitoring services?

- *Evaluation and adaptation*—What processes are used to implement and evaluate new models of care for remote monitoring? How might the implementation process be adapted based on the healthcare sector, patient population, size, wave of the pandemic, and approaches used for triage, monitoring, and escalation?
- *Sustainability*—How do remote monitoring models transform over time and become sustained beyond the pressures and resources made available during the first wave of the pandemic?
- *Data quality*—Research on remote home monitoring requires standardisation of data collection and appropriate comparators. Home oximetry does not yet have specific SNOMED-CT codes, but there are existing codes for "pulse oximeter" (object), "pulse oximetry" (procedure), and "peripheral oxygen saturation" (value).
- *Other conditions*—What other conditions might be monitored via home oximetry and virtual wards? How might the model be extended as remote care is introduced more widely?

Box end

Box start

Box 4 Resources for patients

A video explanation, intended for patients in the UK National Health Service, of how to use a pulse oximeter and keep a symptom diary: https://www.youtube.com/watch?v=jAeZVIAQ2sQ&feature=youtu.be [Author: link broken – please check and consider replacing or deleting]

How to use a pulse oximeter. YouTube videos in different languages:

Hindi: https://www.youtube.com/watch?v=e1ipiJY-zwk

Punjabi: https://www.youtube.com/watch?v=wU5V6wVEHoM

Urdu: https://www.youtube.com/watch?v=rkGRRLlumW4

Polish: https://www.youtube.com/watch?v=Lkd-BNeMvLs

English: https://www.youtube.com/watch?v=nx27Ck7xOgo

Example of a remote monitoring diary: https://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/06/C0445-remote-monitoring-in-primary-care-annex-2-diary.pdf

Resources for patients in multiple languages: https://healthinnovationmanchester.com/our-work/covid-oximetry-at-home-and-virtual-wards/

Rehabilitation website aimed at patients recovering from covid-19: https://www.yourcovidrecovery.nhs.uk/

General information for patients on covid-19: https://patient.info/coronavirus-covid-19

Box end

Box start

Resources for clinicians

Training resources on oximetry from Health Services Journal: https://training.hsj.co.uk/covid-early-warning-system-saves-lives

E-learning module on oximetry in care homes: https://elearning.rcgp.org.uk/course/view.php?id=383

Standard operating procedures for Covid Oximetry @ Home (CO@H) from NHS England: https://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/11/C0817-sop-covid-oximetry-@home-november-2020.pdf

Example of local guidance for those implementing the Covid Oximetry @ Home.
https://wessexahsn.org.uk/projects/388/covid-oximetry-at-home-toolkit

Box end

Box start

How patients were involved in the creation of this article

A patient contributed a parallel article about her experiences.

Box end

Box start

How this article was created

This article brings together the perspectives of authors from different sectors: academia (TG, NJF, CV), policymaking (MIK), professional bodies (JL) and clinical practice (JL, TG, MK, MIK, JL). We sought to include both academic literature and more pragmatic "grey literature" which reflected current best practice. We based the advice on extensive clinical experience, especially MK's role overseeing a large virtual ward for covid-19 patients, which has been formally evaluated.[44] We summarised and updated some rapid systematic reviews undertaken by TG, MIK, and MK and their teams early in the pandemic,[23 47 48] and also drew on a new systematic review[42] and empirical evaluation of virtual wards[43] undertaken by NJF and CV's team more recently. In addition, we refer to national guidance[19] and an educational video developed for patients (box 4) which MIK had been involved in writing for NHS England. Additional academic sources were identified using snowball searching of key papers from Google Scholar. The language in the article was extensively changed to improve accessibility following peer review.

Box end

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