Evidence relating to technology-enabled remote monitoring for COPD patients

Findings from a scoping review of published literature

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Working paper

The DECIDE (Digitally Enabled Care in Diverse Environments) centre is a new programme of work for rapid evaluation of technology-enabled remote monitoring in health and care. Funded by the NIHR Health and Social Care Delivery Research (HSDR) programme, the programme is a partnership between the University of Oxford and RAND Europe.

Disclaimer: This is a working paper summarising insights from a literature review that forms part of a wider rapid evaluation of technology-enabled remote monitoring of COPD. The full report will be available in early 2025, after the NIHR peer review process. Until that time, the contents presented here should be treated as a working project document.

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Summary

This paper presents findings from a scoping review of published evidence on technology-enabled remote monitoring in chronic obstructive pulmonary disease (COPD) pathways. It sets out the context for the review, including the prevalence of COPD, use of health and care services and experiences of patients, as well as policy relating to the use of technology to support remote monitoring for COPD patients in the UK. It sets out findings about how technology is used for remote monitoring for COPD patients in research and clinical settings, the evidence on its impact on patient outcomes, cost effectiveness and user experience, and presents brief reflections on these findings. The findings are summarised in executive summary, and presented in full further in this document.

The work presented here forms one part of a rapid evaluation of technology-enabled remote monitoring for COPD, running from March to September 2024. The evaluation consists of this review alongside qualitative interviews with four NHS sites that are using (or planning to use) technology-enabled remote monitoring for COPD. The qualitative work is on-going and will be reported, along with recommendations for policy and practice, separately. Findings from the review are presented as an interim piece of work, to identify and potentially address evidence gaps and inform policy and decision-making in this rapidly evolving field.

The rapid evaluation of technology-enabled remote monitoring for COPD, including this review, is being conducted by DECIDE (Digitally Enabled Care In Diverse Environments), a partnership between the University of Oxford and RAND Europe, and funded by the National Institute for Health and Care Research (NIHR) Health and Social Care Delivery Research programme to support a programme of work evaluating technology-enabled remote monitoring in health and social care. Further information on this and other rapid evaluation projects is available via the DECIDE website,[a] which is updated as new findings become available.

[a] As of 19 December 2024: https://www.phc.ox.ac.uk/research/decide

Abbreviations

COPD	Chronic Obstructive Pulmonary Disease
DECIDE	Digitally Enabled Care in Diverse Environments
EVA	Early Value Assessment
GP	General Practitioner
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NIHR	National Institute for Health and Care Research
NIV	Non-Invasive Ventilation

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1. Executive summary

1.1. Introduction

1. **The executive summary presents the headline findings from a scoping review conducted as a part of a rapid evaluation of technology-enabled remote monitoring for chronic obstructive pulmonary disease (COPD) patients**. The wider evaluation is funded by the NIHR Health and Social Care Delivery programme and forms one part of the work of DECIDE, a partnership between the University of Oxford and RAND Europe building the evidence base on technology-enabled remote monitoring through rapid evaluation. A detailed account of the evaluation will be found in the full report, which will be available via the DECIDE website.[b]

1.2. Context and methods for the scoping review

2. **COPD presents a major burden for patients and the health care system.** COPD is a chronic condition that can result in acute exacerbations, leading to sudden and often unpredicted worsening in symptoms and health care use. Interest in innovative ways to optimise COPD care and improve patient outcomes is growing, including the use of digital technologies to support remote monitoring. Remote monitoring and self-management technologies hold potential benefits for empowering patients, building patients' confidence to self-manage their care, and helping to predict and potentially prevent exacerbations.
3. **Technology-enabled remote monitoring for COPD generally includes the collection of patient health data at a patient's home** (or another non-healthcare provider location) **combined with remote transmission of that information for evaluation by a healthcare professional with the purpose of disease or condition management**. Remote monitoring technologies typically consist of a platform where data is stored and analysed, as well as separate interfaces for patients (e.g. a smartphone application) and a dashboard for healthcare professionals. Many technologies include educational resources and support for self-management. The purpose of such technology-enabled services is typically to support people with COPD to live in their own homes and free up resources and capacity in the wider system (e.g. by preventing exacerbations and hospitalisation).
4. **A range of technologies are available in the UK for remote monitoring**, offering slightly different functionalities, most of them covering a combination of functions, such as education, pulmonary rehabilitation programmes, subjective monitoring of symptoms, approved assessment tools, and vital signs. Remote monitoring applications can be used both in **chronic** (e.g. regular monitoring or

[b] As of 19 December 2024: https://www.phc.ox.ac.uk/research/decide

pulmonary rehabilitation) and **acute** (e.g. detection of new exacerbations and their management) COPD phases.

5. **We conducted a rapid and focused scoping review** of the literature on technology-enabled remote monitoring for COPD patients focusing on the reported function of the technology; evidence on implementation and spread; clinical effectiveness in improving COPD patient outcomes; cost-effectiveness; and staff and user experience.
6. **We prioritised systematic reviews and meta-analyses, and studies based in the UK**. We included evidence collected by two relevant NICE Early Value Assessment calls, on digital pulmonary rehabilitation and self-management for COPD. This process provided a total of 29 papers. We used thematic synthesis to group the insights and evidence from the identified literature.

1.3. Key findings from the scoping review

7. **Existing literature and high-quality evidence in this field is limited.** The quality of the evidence base was flagged as low in many of the reviews. The terms *technology-enabled remote monitoring* and *remote monitoring* are often used interchangeably making it challenging to understand how technology is (and is not) used. The technology is also rapidly evolving, with implications for interpretation of past evidence for current services.
8. **Pre-pandemic studies on the clinical effectiveness of technology-enabled remote monitoring for COPD patients have not yet shown significant clinical benefits**. Studies have typically been underpowered and involved heterogeneous patient populations. They have provided limited evidence of effect on patient or economic outcomes, although the absence of such evidence does not mean that benefits will not be demonstrated in future, better designed study.
9. **Some evidence is emerging that remote monitoring technologies may reduce hospitalisation and readmission risk in COPD patients.** However, it remains inconclusive due to the low quality of studies; benefits demonstrated in observational studies tend to be larger than those in randomised trials. Many remote monitoring interventions include various elements of education and exercise training, which makes it difficult to disentangle the mechanisms of change in health outcomes.
10. **Evidence is currently lacking on how technology-enabled remote monitoring should be integrated within COPD care pathways to bring the best outcomes.** Evidence on which patient groups would benefit from remote monitoring the most is also lacking, although some remote monitoring technologies are expected to be more effective among severe, post-exacerbation rather than stable, community-based COPD patients. This is reflected in NICE Early Vale Assessments which highlight potential benefits of remote monitoring technologies for moderate to severe COPD patients and patients discharged after an exacerbation.
11. **Patients engage with remote monitoring and technologies in different ways**. There is no one size fits all. Remote monitoring is situated in the continuum between 'self-care' and 'health care dependency'. Some patients report that telehealth removes the burden of deciding when to seek help and justifying their health needs, by providing direct evidence for their health care provider or by putting the responsibility to initiate the contact on the health care provider. Patient's engagement with technology is likely to be shaped by the patient's illness, knowledge, goals and social networks, motivational features of the technology and service, and the integration of self-management activities into patient's everyday live. The value provided by such technology that patients and providers name

is also diverse and varies from person to person. Patients often mention that communicating with a clinician and data being monitored by a provider brings the most value.

12. **Most patients included in evaluations find use of the technology convenient**, with increased self-care and sense of security, and largely improved communication between patients and providers. Key issues largely relate to when the technology is experienced as inflexible, impersonal, and with limited interoperability.
13. **Using technology in place of, or to supplement, in-person care changes the interaction between patients and providers**, the frequency of interactions, and level of surveillance. For some patients this offers reassurance of being 'looked after'. For others it can reinforce a sense of dependency. Use of technology for remote monitoring can bring risks if monitoring is different or substandard, as compared to in-person care.
14. **There is a need to ensure equity of access to tech-enabled remote monitoring services for COPD patients.** Evidence on this is slim, and focuses largely on digital literacy and skills, as well as availability of data/devices. Barriers to adopting digital health interventions for COPD management identified by patients include poor digital literacy, perceptions that care delivery is impersonal, and a concern with oversurveillance. The voices of patients who don't use technology are rarely captured or considered.
15. **Clinical staff typically regard the use of technology to support remote monitoring as largely empowering for many patients, but many feel burdened** by this new responsibility, use of new (and sometimes inconvenient) equipment, limited interoperability with existing systems, and the accompanying increased (clinical and administrative) workload.
16. **Implementation of new technology might initially increase, rather than reduce staff workload**, especially if technologies are used as adjunct, rather than replacement of usual care. Other provider related barriers to adoption of technology for remote monitoring, include lack of interoperability, limited funding and capacity (particularly dedicated, trained personnel).
17. **Evidence on implementation and spread of technology-enabled remote monitoring for COPD in the UK is extremely limited.** What few studies there are typically focus on individual adopting sites, are small in size and scope and do not cover different technologies or regions.
18. **Evidence on the cost-effectiveness of remote monitoring technologies for COPD patients is inconclusive,** partly as the clinical effectiveness and the use-case for most of the technologies is not clearly demonstrated yet. Few studies have examined cost-effectiveness and none of these have found a difference between patients using remote monitoring versus standard care. Many of the studies are also embedded in short-term trials, rather than evaluating an ongoing clinical practice.

1.4. Summary reflections

19. **A range of technologies are now being used to support remote monitoring for COPD patients. These are variably described** (e.g. remote patient monitoring, technology-enabled remote monitoring, telemonitoring), with limited clarity on functionality, purpose and use (which overlaps with e.g. self-monitoring, self-management, digital pulmonary rehabilitation, education). This complicates drawing consolidated conclusions from current evidence.
20. **Interventions often include multiple features and functionalities**. The range of functionalities includes self-monitoring, self-management, digital pulmonary rehabilitation, behaviour change,

psychological intervention and patient education. These mixed interventions make it challenging to draw conclusions regarding mechanisms of change and requires nuanced interpretation of evidence.

21. **Pre-pandemic interventions may not be easily compared with more recent approaches.** Earlier interventions differ from current models in important ways regarding functionality, scope and outcomes of interest.
22. **Large gaps in evidence exist on identifying which COPD patient populations and settings might benefit from remote monitoring.** The focus on clinical severity is not well grounded in evidence and the implementation of remote monitoring is often determined and refined locally, based on understanding of patient population.
23. **Staff and patients typically see the use of technology to support remote monitoring as being overall positively experienced by patients, though its use can be burdensome on staff.** There is also no one size fits all approach for patients. Some patients value the access, review and reassurance that technology-enabled remote monitoring provides them; others struggle. Clinical staff sometimes feel burdened by the additional responsibility and workload that new tech-enabled services can bring.
24. **Existing evidence supports further development of using remote monitoring technologies for patients with COPD, but it must be carefully monitored and evaluated to understand its benefits.** In order to establish the clinical effectiveness, patient experience, and value for money of implementing such technologies for COPD patient care, well-design, sufficiently powered and transparently reported studies will be required.
25. **There remain key gaps in the evidence relating to the provision of technology-enabled remote monitoring in the COPD care pathway.** Particularly, the models of delivery, clinical and cost-effectiveness, implications for the workforce, the patient experience of using such technologies, and equity of access are understudied. Larger and longer studies are required to determine acceptability and impact (clinical, behavioural, economic) over time.

2. Background to the review: the context for technology-enabled remote monitoring for COPD

Chronic obstructive pulmonary disease (COPD) presents a major burden for patients and the health care system. An estimated 1.2 million people in the UK had a COPD diagnosis in 2012, with nearly 30,000 people dying from COPD annually.[1] The prevalence of COPD is estimated to increase from 1.8% to 2.2% of the population from 2011 to 2030 in England, with an also rising number of deaths.[2] The increasing prevalence of COPD means that the health care system will need to adapt to the higher demands for patient care.

COPD exacerbations often lead to repeated hospitalisations, driving the costs of care. COPD patients with exacerbations experience impaired quality of life and are at risk of repeated hospitalisations.[3] Exacerbations that require a hospitalisation are associated with increased risk of death.[4] Hospitalisations due to exacerbation constitute the highest share of direct health care costs for COPD patients.[5] In England, annual direct healthcare costs of COPD are expected to increase from £1.5 billion to £2.3 billion from 2011 to 2030.[2] COPD is the second most frequent cause of emergency hospitalisations, accounting for 1 in 8 admissions in the UK.[4] Additionally, COPD leads to indirect costs due to loss of productivity, absence from work, and short-term disability, which can result in reduced income.[5]

Exacerbations can sometimes be prevented. Early diagnosis is crucial but can be missed in the UK. For example, according to a 2010 study by Bastin et al[6], a substantial proportion of COPD patients in North London are first diagnosed only after experiencing an acute exacerbation. Early treatment of exacerbations is associated with faster recovery and better health-related quality of life, and a potential to avoid emergency hospitalisations.[7] While evidence remains mixed, systematic reviews on the effectiveness of pulmonary rehabilitation,[8] including home-based programmes,[9] show that it improves COPD patient outcomes (such as quality of life and exercise capacity) and that self-management programmes may reduce hospital admissions.[3,10]

In the UK, interest is growing to find innovative ways to optimise COPD care and improve patient outcomes, including by using digital technologies. Increasing prevalence of the disease means that unless NHS capacity is significantly expanded, many patients will not receive timely services; thus there is increased interest in both policymaking and clinical practice, to examine the potential in using technologies that can support remote care.[11] For example, the NHS Long Term Plan flags ambitions to detect and diagnose

respiratory diseases earlier, improve pulmonary rehabilitation and COPD discharge bundle (see footnote[c]) efficiency, including through digital tools.[12] Improving self-management capacity and reducing the need for healthcare services could also release resources for other priority health policy and clinical practice areas.[13]

Technology-enabled remote monitoring (also referred to in the literature as remote patient monitoring and tele-monitoring) for COPD is variably defined.[14,15,16,17] It generally includes the following common components: collection of patient health data (often continuous and automatic); at a patient's home (or another non-healthcare provider location), without a physical presence of a healthcare professional; the remote transmission of information for evaluation by a healthcare professional; and with the purpose of disease or health condition management.[18,19] Remote monitoring technologies typically consist of a platform where data is stored and analysed, as well as separate interfaces for patients (e.g., available as a computer, tablet, or smartphone application) and a dashboard for healthcare professionals. The aim of technology-enabled remote monitoring is typically to support people with COPD to live in their own homes and to free up resources and capacity across the wider health system. However, there remain key gaps in the evidence relating to the provision of technology-enabled remote monitoring in the COPD care pathway, particularly in relation to models of delivery, implications for the workforce, the patient experience of using such technologies, and equity of access.

The National Institute for Health and Care Excellence (NICE) has recently launched a new programme of Early Value Assessment (EVA) for medical technologies. Two of the current (as of August 2024) EVAs focus on technologies supporting pulmonary rehabilitation and self-management for COPD [11,20] and a third topic (virtual wards in COPD exacerbations) is identified as a priority area but, at the time of writing, no documentation has been published.[21] While these EVAs do not explicitly focus on evaluating remote monitoring functionalities (that is, direct information exchange between patients and healthcare professionals and remote care services), such functions are provided by many of the evaluated technologies.

[c] The National Institute for Health and Care Excellent recommends that COPD patients discharged from hospital after an acute exacerbation receive a care bundle. Such care bundle can include education on inhaler and medication use, self-management plan, smoking cessation support, pulmonary rehabilitation referral, and follow-up care. As of 18 December 2024:

https://www.nice.org.uk/guidance/qs10/chapter/Quality-statement-8-Hospital-discharge-care-bundle

3. Scoping review: approach and methods

We conducted a rapid and focused scoping review of the literature on technology-enabled remote monitoring for COPD patients. Specifically, we searched for literature that addressed:

- The definition and description of the remote monitoring technology and its functions;
- Clinical effectiveness in improving COPD patient outcomes, such as hospitalisations;
- Evidence on user (patient and health care provider) experience;
- Evidence on implementation and scale; and
- Studies on cost-effectiveness of such technology.

Our approach followed the principles of scoping review methodology,[22] with further simplifications and restrictions due to the rapid nature of the project. We first identified the relevant systematic reviews from our pre-existing collection of literature on technology-enabled remote monitoring for any chronic disease, to form a preliminary idea of the range of technologies and their applications in the remote monitoring for COPD scope.

Next, we ran Google Scholar searches, with one reviewer screening the first five pages of entries, restricting the date to 2019 or later, using search query ("remote monitoring" OR “virtual ward*” OR “hospital at home”) AND technology AND ("COPD" OR "chronic obstructive pulmonary"). In addition, one reviewer also screened the first five pages of the same query with (“England” OR “UK” OR “Great Britain”) added with “AND”, to capture specifically papers relevant for England or the UK. The search and title screening were done on 15 March 2024, and repeated on 9 July 2024 to capture new publications and to add an additional search term “remote patient monitoring”. The search was again repeated on 2 October 2024, specifically focusing on evidence from qualitative and implementation research. Protocols, conference abstracts and preprints were excluded. A total of 22 titles were selected for abstract screening and 12 papers for full text reading in March 2024, with seven more papers identified for full text reading in July 2024, and 14 in October 2024. We checked the references of the full text papers to identify any other key papers on the topic. Given the short timeline, pragmatic approach and focus on the UK of this review, we first reviewed the identified systematic reviews and meta-analyses, and then complemented their evidence with notable studies based in the UK, in cases when they were not already included in the systematic reviews and were considered to provide high-quality relevant evidence or insights.

We also read the evidence collected by NICE EVAs on digital pulmonary rehabilitation and self-management for COPD, including the available documents on the final scope and draft guidance. We searched manually for reports and evaluations of remote monitoring for COPD patients in England and

the UK via Google searches, with the aim of gathering further examples of remote monitoring applications for COPD in England (rather than capturing all such case studies).

This process provided a total of 29 papers included in the review (see Appendix 1). We used thematic synthesis to group the insights and evidence from the identified literature under our pre-specified topics.

The following caveats are relevant in considering the nature of the evidence reviewed and findings presented below.

a) The terms *technology-enabled remote monitoring* and *remote monitoring* are often used interchangeably in the literature. A lot of the literature is not entirely precise on what constitutes "remote monitoring", and hence it is not always possible to make clear deductions on levels of tech-enablement, especially when sufficient details about them were not provided in the included literature (e.g. on studies that informed the included systematic reviews).

b) This is a rapidly changing field, where technology is constantly evolving. This has implications for studies and evaluations and the interpretation of the evidence they provide (e.g., generalisability of results). Studies conducted several years ago are likely to describe interventions with different or lower levels of tech-enablement, and a different set of hardware and software instruments (e.g., a set of separate sensors, information display and a modem, instead of integration in an online or smartphone app).

c) The quality of the evidence base has been flagged as low in many of the identified systematic reviews. We did not systematically assess the quality of the evidence presented in the individual example studies reported here, although we flag some of their caveats (e.g., small sample sizes or the retrospective nature of research conducted).

d) We focused primarily on UK studies and international systematic reviews. It was beyond the scope of the current work to analyse the geographic scope of studies included in each systematic review covered here, but we highlighted cases when notable studies from the UK were included in them.

4. Findings from the review

4.1. Why, for what and how is technology-enabled remote monitoring used in the COPD space?

Technology-enabled remote monitoring and related patient-supporting technologies such as digital self-management tools have the potential to improve COPD care and prevent exacerbations; however, the evidence base on the extent to which this is achieved in practice is nascent and inconclusive.

Remote monitoring applications can be used in chronic (regular monitoring or pulmonary rehabilitation) and acute (detection of new exacerbations and their management) COPD phases.[14] According to a review by Bourbeau et al (2020),[23] which looks at COPD care pathways more broadly and also considers remote monitoring and other uses of digital technologies that can support care (such as technologies to support pulmonary rehabilitation as a treatment intervention), technologies could be implemented across the continuum of COPD care pathways: support for chronic care (e.g., self-management interventions), domiciliary care during an exacerbation (e.g., virtual wards), and discharge bundles. According to a review by Tomasic et al (2018) and supported by evidence in other studies, there are four opportunities/scenarios for remote monitoring of COPD patients[15]: 1) during daily activities for prediction and early detection of exacerbations, 2) during home treatment of mild exacerbations (such as through virtual wards/hospital at home), 3) monitoring oxygen therapy, and 4) monitoring exercise (including pulmonary rehabilitation).

Applications of various technologies across the continuum of COPD care illustrate the potential to improve COPD patient outcomes at these different time-points:

- Intensive monitoring in a virtual ward (hospital at home): a systematic review (2016) of early supported discharge and hospital at home models of care, as compared to usual care post-discharge, for patients with COPD found a trend towards lower mortality and fewer readmissions as well as lower costs, although the structure of virtual wards varied considerably across studies.[24]
- Remote monitoring of non-invasive ventilation (NIV): remote monitoring of NIV (i.e. oxygen therapy) was tested in a small retrospective feasibility study in Scotland using ResMed Lumis device for NIV and ResMed AirView technology in 2017,[25] demonstrating the feasibility of this technology.
- Digital pulmonary rehabilitation: a study by Bourne et al (2017) in a single centre in the UK showed that remote, digitally-supported pulmonary rehabilitation delivered similar results to standard face-to-face programmes.[26] However, this study did not include remote information exchange between patient and provider.

A range of technologies are available in the UK that can support varied approaches to remote monitoring for COPD (including self-management, and through to more active and proactive remote monitoring). These technologies offer slightly different functionalities, with most covering a combination of functions, such as education, pulmonary rehabilitation programmes, subjective monitoring of symptoms and vital signs. A review by Coutu et al (2023) found that wearables or other devices used for remote monitoring capture physiological information including heart rate and its variability, blood pressure, respiratory rate and its variability, oxygen saturation, activity, body temperature and metabolic function, sleep metrics, and others.[14] A systematic review of telemonitoring interventions by Jang et al (2021) reported that oxygen saturation and symptoms were recorded most often, followed by vital signs and spirometry.[16] In a systematic review of telemonitoring effectiveness, Hong et al (2019) noted that many remote monitoring interventions include various elements of education and exercise training, which can make it difficult to disentangle the mechanisms of change in health outcomes.[17] A prospective study on feasibility and acceptability of comprehensive multimodal remote monitoring for 60 pulmonary patients (20 of them with COPD) in England found that the lowest-burden passive data collection methods had the highest adherence, engagement and retention.[27]

The NICE EVAs on digital self-management[11] and pulmonary rehabilitation[20] technologies for COPD patients recommended several technologies for use in the NHS while more evidence is being generated. Box 1 lists these recommended technologies, noting also if they provide remote monitoring capabilities. As Box 1 illustrates, digital technologies supporting COPD care often incorporate several functionalities that are not necessarily clearly separated and often include remote monitoring capabilities. At the time of writing, in many cases it is not clear how widely the technologies are in routine use or in testing phases across England.

Box 1: Digital technologies for COPD patients recommended for use in NHS in the NICE EVAs on self-management and digital pulmonary rehabilitation

- **Active+me REMOTE** (Aseptika): cloud-based platform for **self-management and remote monitoring** of adults with COPD, collecting data via add-on sensors and including an educational programme; recommended for self-management.
- **COPDhub** (The Institute of Clinical Science and Technology): digital personalised care plan app including educational content and features to support **self-management**, COPD symptom assessment and recorded healthcare data; recommended for self-management.
- **Clinitouch** (Spirit Health): **remote monitoring** platform with patient education, digital pulmonary rehabilitation exercises, subjective and vital sign tracking, and clinician dashboard for real time risk scoring; recommended for self-management. As of October 2023, the technology was being used in in Staffordshire, with clinical use alongside evaluation.[28]
- **Lenus COPD Support Service** (Lenus Health): **remote management** solution offering standardised and personalised care plans, with an option for clinicians to activate a rescue plan when necessary. It also records patient-reported outcomes measures, and offers self-management resources, while clinicians can access a dashboard, integrating data from electronic health records, patient reported outcome measures , and wearable devices; recommended for self-management. As of September 2022, it was reported by the technology provider to be used across NHS in Scotland and being piloted in England.[29,30]
- **Luscii** (Luscii): **self-monitoring** patient-facing app, integrating monitoring devices for vital sign tracking, education resources, and possibility to contact healthcare team via the app; recommended for self-management.
- **myCOPD** (my mhealth Ltd): **self-management** platform with educational resources, a six-week digital pulmonary rehabilitation programme, prescription assessment, symptom tracking, and possibility for clinicians to remotely monitor and support patients; recommended both for self-management and digital pulmonary rehabilitation. In October 2023, the developer of the technology reported it being used in 30 Integrated Care Boards, and in use within the NHS since 2017.[28]
- **Space for COPD**: structured **self-management** programme of exercise, education, and psychosocial support, including possibility for clinician monitoring of patients' progress and answering posted questions; recommended both for self-management and digital pulmonary rehabilitation. In October 2023, it was reported by to be used by 73 trusts during the COVID-19 pandemic, with use in NHS since 2018.[28]

4.2. Evidence base for technology enabled remote monitoring for COPD

Evidence on clinical effectiveness, patient outcomes and health service impacts

A NICE EVA on digital self-management technologies identified that digital technology *could* (i.e. has the potential to) improve outcomes for people with COPD through[13]: 1) reducing the risk of an initial exacerbation; 2) reducing the likelihood of repeated exacerbations and rehospitalizations; 3) improving symptoms; 4) improving knowledge of COPD medication, exercise use, and awareness of changes and deterioration; and 5) reducing health inequalities in access and outcomes.

Based on earlier, pre-pandemic evidence, remote monitoring technologies were not routinely recommended in the UK for COPD diagnostics or management. In 2018, NICE guidance on COPD management in adults recommended against offering routine telehealth monitoring of physiological status as part of management for stable COPD.[31] A systematic review by Bolton et al (2011)[32] concluded that studies evaluating the effectiveness of telemonitoring for patients with COPD were typically underpowered, had heterogeneous patient populations, and did not provide robust evidence on effect on outcome measures or economic evaluations.

Early evidence: studies before COVID-19 pandemic

Most pre-pandemic studies on the clinical effectiveness of remote monitoring technologies for COPD patients did not show significant benefits over standard care, although the "telemonitoring" component that was studied often looked somewhat differently from the remote monitoring applications available currently and was combined with other self-management, education, and care coordination services. Several of these earlier international randomised trials of COPD remote support interventions, such as self-management programmes including telemonitoring or telehealth (remote consultations), found little or no benefit compared to usual care:

1. Kessler et al (2018) study compared a package of self-management programme, home telemonitoring, care coordination and medical management with usual care did not show statistically significant reduction in all-cause hospitalisations but did show a reduction in acute care hospitalisation days and mortality in a study in several European countries[33];
2. Cartwright et al (2013) evaluation of monitoring of vital signs, symptoms and self-management behaviour with telehealth devices in England, did not find a benefit for health related quality of life or mental health symptoms[34];
3. Ancochea et al (2018) study of daily measurement of vital signs and remote patient management in Spain did not find an impact on the proportion of patients experiencing a severe exacerbation, or number of exacerbations or total duration of hospitalisation[35];
4. Walker et al (2018) study based in several European countries, including the UK, of vital sign monitoring and self-assessed lung mechanics daily, using an algorithm to identify deterioration and trigger a telephone contact, did not find an impact on time to first hospitalisation or other primary outcomes.[36]

Current evidence

More recent evidence on the clinical effectiveness of remote monitoring for COPD patient outcomes is inconclusive, primarily due to low quality of studies and their evidence, and arrives at mixed results and conclusions, depending on the studies and outcome measures considered. Several systematic reviews, reporting on an overlapping selection of studies, have analysed the effects of remote monitoring, telehealth interventions, telemonitoring, and home-based interventions:

- A Cochrane review conducted by Janjua et al (2021) of telehealth interventions for COPD patients, examining randomised controlled trialsup to 2020,[37] on the effectiveness of remote monitoring alone or as an add-on to usual care compared to usual care alone, found that evidence of benefit was informed mostly by low quality evidence, such that it is difficult to arrive at robust conclusions. Even in areas where some benefit was shown, such as reduction of hospitalisations, the conclusion was based on a single study of moderate quality. This review included three studies from the UK

(published in 2010, 2012, and 2017), none showing a benefit to the studied remote monitoring and self-management systems.[38–40]

- A systematic review by Nagase et al (2022), capturing studies up to 2018, identified multiple studies on effectiveness of remote monitoring in COPD patients, but the quality of evidence was low or very low as assessed by the authors using GRADE (the Grading of Recommendations, Assessment, Development and Evaluations) tool.[41] While remote monitoring appears to be safe, it did not appear to improve health-related quality of life, frequency of exacerbations, lung function, self-efficacy, or mental health symptoms. However, in the studies included in this review, patients reported high overall satisfaction with the technology, and some (but not all) of the studies reported improved exercise capacity and lower hospitalisations and outpatient visits in patients using remote monitoring technology.
- A systematic review by Taylor et al (2021)[42] on the impact of remote patient monitoring on acute care use by patients with chronic diseases, found that the majority of the 18 studies including COPD patients reported either a decrease or no change in hospitalisations. However, compared to remote monitoring for other chronic conditions, studies focused on patients with COPD more often showed a reduction in emergency presentation at hospital.
- A systematic review with a meta-analysis by Jang et al (2021)[16] identified 22 RCTs on the effectiveness of telemonitoring to prevent COPD exacerbations. Among patients with mostly moderate to severe COPD symptoms, telemonitoring modestly reduced hospital admissions and the number of emergency visits due to an exacerbation (the latter decrease was not statistically significant).
- A Europe-wide systematic review by Corcoran et al (2024)[43] exploring hospital readmission rates in COPD patients using home-based management (including virtual ward interventions) found 55% readmission rate compared to 67% in the control group. This was combined with a not statistically significant decrease in length of hospital stay and mortality. However, it's unclear the extent to which the results apply specifically to the use of technology to support remote monitoring technologies: the review included three studies without a telemedicine component. Furthermore, it reported that the majority of studies had a high risk of bias.

Notably, while some studies are included in multiple of these systematic reviews, their lists of included studies do not overlap completely. This partial overlap highlights that the scope of telehealth and remote monitoring interventions for COPD patients is somewhat loosely defined, with a range of definitions of the intervention and outcomes of interest. Overall, most of the systematic reviews report modest clinical benefits or are inconclusive due to limited and low quality of evidence. Lack of consistent improvement across measured outcomes, with generally low quality of evidence, was found in two other systematic reviews,[16,44] although individual studies sometimes report positive changes in specific health outcomes. A systematic review of randomised controlled trials of remote monitoring for COPD by Nagase et al. (2022) reported that most identified trials were potentially too short (12 months or less) to develop appropriate behaviour change leading to better disease management and reduced health care utilisation.[41]

Emerging evidence: observational and randomised studies

As new technologies are being developed, tested and implemented, evidence is still emerging. This means that, while there is currently a lack of high-quality evidence showing a benefit of remote monitoring technologies for COPD patients, this may well change. There is some indication of that in recent studies in the UK:

- A pre-post study by Cooper et al (2022) found that the use of the myCOPD app for self-management of COPD patients in remote and rural populations in the UK resulted in a trend towards reduced inpatient days and hospital admissions for patients with very high usage of the app, suggesting that outcomes could be related to the intensity of technology use.[45]
- A prospective observational study in 2019-2020 in Scotland of Lenus COPD support service, including remote monitoring, self-management tools, and remote clinical support, showed an improvement in time to death or hospitalisation when compared to a matched control group of patients.[46]
- Early findings from a small feasibility study by North et al (2020) for use by COPD patients discharged from acute hospital care showed lower re-exacerbation and readmission rates compared to standard practice.[47]
- In a validation study of a COPD prediction algorithm by Patel et al (2021), the digital application providing early warning of imminent exacerbation based on remote monitoring of COPD patients showed initial high sensitivity and high negative predictive value.[48]
- A small evaluation by the Eastern Academic Health Science Network, commissioned by NHSE, found some evidence that virtual wards could reduce the length-of-stay of hospitalised patients and could be cost-effective, when evaluating the outcomes of 46 COPD patients receiving care via the virtual ward in 2021-2022.[49]

While these recent observational studies have shown potential clinical benefits, they are not always demonstrated in more robust, randomised trials. For example, a three-arm randomised study in Canada in 2020, comparing technology-enabled self-monitoring, with technology-enabled remote monitoring and with standard care, did not observe significant differences in patient outcomes or health care use among COPD patients.[50] Similarly, a randomised cross-over study in Sweden in 2024 of tablet-based remote monitoring for 26 weeks did not find an impact on health-related quality of life, clinical or mental health measurements compared to standard care, despite high adherence to the remote monitoring intervention.[51]

Key evidence gaps

Evidence is lacking on how technology-enabled remote monitoring should be integrated within COPD care pathways or which severity of the disease should be targeted to bring the best outcomes. A systematic review on remote monitoring and telehealth interventions for COPD patients by Janjua et al (2021) could not determine which COPD severity group would benefit from remote interventions the most, as study results were mostly not disaggregated by disease severity.[37] In the final scope documentation of NICE EVA on self-management tools, clinical experts stated that the greatest need for monitoring technologies might be for moderate to severe COPD patients and patients discharged after an exacerbation, to provide insights for both the patient and their clinical care team.[13]

4.3. Evidence on user and staff experience of technology-enabled remote monitoring for COPD and implications for implementation and spread

Patient and staff experiences

Qualitative studies on remote monitoring for COPD patients highlight the heterogeneous experience of users and staff – a single feature can be perceived positively in one scenario and negatively in another. Patients engage with the technology in different ways, as illustrated in a qualitative study by Wilde et al (2024)[52] of seven COPD patients using activity monitoring, with emerging themes of *motivational features; importance of setting achievable goals; developing knowledge and awareness*; and, *integrating self-management into everyday life*.

A systematic meta-synthesis by Brunton et al. (2015)[53] reviewed qualitative studies published before 2014 and primarily based in the UK, on user experience with telehealth (defined similarly to "remote monitoring" in this review) for COPD. These studies were often of somewhat limited quality and used different definitions of "telehealth", making it difficult to pinpoint "what works" in what circumstances. The remote interventions in the studies were also embedded in quite different pathways (e.g. contact initiated by provider when an abnormal reading is recorded vs more regular contact between patient and provider). Nevertheless, the authors identified three emerging themes:

1. **The influence of telehealth on the moral dilemmas of help seeking:** remote monitoring is situated in the continuum between "self-care" and "health care dependency". Some patients reported that telehealth removed the burden of deciding when to seek help and putting that in action, by providing evidence to show to their provider or by putting the responsibility to initiate the contact on provider.
2. **Conflicting consequences of interactional transformation in telehealth:** telehealth changed the interaction between patients and providers by shifting face-to-face consultations to remote care, changing the frequency of interactions, and providing remote monitoring as "benign surveillance", implying/reassuring patients of being "looked after". However, such reassurance could also reinforce a dependency in patients, create risk if monitoring is (or is perceived to be) substandard when compared to face-to-face care, and create extra workload for care providers.
3. **Telehealth as transforming the nature of work and the consequences for identity and burden:** while remote monitoring was recognised as empowering and activating for most of the patients, some felt burdened by this new responsibility. Equipment failure was another cited burden. The new role created by remote monitoring was experienced as more negative by the providers, primarily due to increased professional workload.

Similar themes emerged in a more recent meta-synthesis of qualitative studies of telemonitoring of various chronic diseases (including one study of COPD patients) by Creber et al (2023),[54] with both positive and negative experiences mentioned under most of the themes: 1) *improved care* – increased self-care and sense of security, 2) *communication* – mostly improved communication between patients and providers, with mixed effects on communication between providers, 3) *technology feasibility and acceptability* – while most users find technology convenient, issues were reported when it was inflexible, impersonal, and not-interoperable, 4) *intervention concerns* – common concerns were data security and potential demographic inequalities.

Different experiences with remote monitoring technology are often reported by different groups of patients and providers. In a meta-synthesis, Brunton et al. (2015) reported that patients' views were in general more positive than that of clinicians; while patients typically viewed the service as a useful extra benefit, clinicians often viewed it as an extra burden. The voices of non-users were not captured in this meta-synthesis, which potential partly explains the generally reported positive experience.

Perceived value of remote monitoring and care services

As remote monitoring tools are still being actively developed, the use cases and value that such tools could provide are not yet clearly defined. A qualitative study of interviews with COPD patients examined their perceived value of virtual care (including self-management and remote monitoring tools), compared to in-person care, in Denmark.[55] Patients expressed a wish for such tools to contribute to *coherent care*, to facilitate contact with clinicians (GPs) who would be familiar with their medical history and be engaged to support them. Continuous monitoring was also perceived to provide a sense of security, feeling of being understood, and trusting that the prescribed medications are more personalised to the patient. Patients expressed some concern that digital technologies should not be too difficult to use – either by being too complex or demanding too much effort from the patient (e.g., too frequent measurements). Privacy or potential misuse of personal data was a lesser concern for the participants, which might also reflect the cultural context and trust of institutions in Denmark rather than being specific to remote monitoring practices. Technology was also perceived to promote self-management, especially by providing feedback to monitor one's own condition and facilitating the patients to use targeted information on their condition – in contrast to the abundance of non-specific information available to patients online. Some patients expressed a concern that digital tools cannot replace the value of physical presence and contacts with clinicians and peers, such as in-person group rehabilitation activities.

A similar qualitative study by Debeij et al[56] examined the hypothetical use and value of a wearable monitoring bracelet among COPD patients and care providers. Patients mentioned that such a device or tool would bring value if it helped with the (very) early recognition of exacerbations and alerting when health parameters deviate from normal – especially, if these alerts were monitored by a clinician. Such monitoring device would also facilitate patient-provider discussions and support patients having ownership of their health. Patients and providers noted that the device could provide value in both acute and long-term management phases of the disease. Easy use and accuracy were mentioned as facilitators, while time and resources required to monitor the data (especially, by clinical staff) as potential barriers.

More broadly, a qualitative study by Alwashmi et al[57] examined the potential features of mobile health tools that COPD patients and their providers consider the most useful for successful implementation of such tools. Using semi-structure interviews with broad-ranging questions, the study identified features in the *patient and provider interfaces* of such tools. For the **patient interface**, educational content (such as correct inhalation techniques) was identified by both patients and providers; collecting baseline information, subjective patient information via surveys, and objective health data (such as pulse oximetry, spirometry, or further vital signs) was mentioned by providers; tracking the progress of their care and personalising the content was valued by patients. Providers were more vocal in this study about their preferred features and the **provider interface**, mentioning the ability to track patient's management progress, allowing direct

communication with patients, possible educational (such as information on the best practice in treatment) and more efficient time management functionalities.

Disparities, barriers and facilitators of remote monitoring use

Various patient- and provider-related barriers have been reported for remote monitoring adoption and spread, and could have implications for ensuring equity of access to the potential benefits provided by the technology. According to a NICE EVA on digital self-management technologies (2024),[13] COPD patients, who tend to be over the age of 50 and from lower socioeconomic backgrounds, might be less comfortable and less skilled at using digital technologies or having the required devices. Implementation of a new technology might also initially increase, rather than reduce staff workload, especially if technologies are used as an adjunct to, rather than a replacement of, usual care. On the other hand, in areas of high unmet need and challenges in accessing face-to-face services, technologies could increase access to services such as pulmonary rehabilitation.[58]

Based on a scoping review by Ramachandran et al (2023), major barriers to adopting digital health interventions for COPD management identified by patients include poor digital literacy, perceptions that care delivery is impersonal, and a fear of being "controlled" by telemonitoring data.[59] In the same study, care providers identified significant barriers relating to factors such as increased workload, lack of interoperability with existing health systems, a lack of funding and dedicated, trained personnel.[59] The study also identified facilitators such as improvement in patients' disease understanding and management, bi-directional communication between patients and healthcare providers, patient-led remote monitoring and feedback, and improved service and system efficiency.[59]

A qualitative study of clinician perceptions of digital technologies for COPD management[60] (although defined somewhat abstractly and broader than remote monitoring) identified as the main barriers to their uptake the lack of trust in the reliability and effectiveness of digital tools (e.g. low quality of collected data; lack of robust evidence demonstrating clinical effectiveness; lack of support for such tools in clinical guidelines) and constrained resources. In contrast, training, education, and improving digital literacy of both patients and clinicians as well as on-boarding conversations were named as potential facilitators for the uptake of such tools.

Evidence on implementation of remote monitoring and other digital tools for COPD patients

While evidence on implementing remote monitoring services at scale is lacking, a few studies have looked at the issues surrounding implementation of such services in clinical trials. For example, van Lieshout at al[61] examined the implementation of self-monitoring and remote-monitoring intervention for COPD patients at a randomised trial in Canada.[50] Using "Tool+Team+Routine" framework, the study used interviews with patients, providers and administrators to understand the value proposition of the service ("tool"), its implications for team relationships ("team"), and the new routines that emerged ("routine"). While the value of the tool was mostly reported as positive, it was primarily created through the new relationships between patients and providers that were sparked via the tool – rather than by the remote monitoring or self-management tool itself. The decision to implement the tool was established before its clinical value was fully elaborated with the clinical team, therefore it was initially met with scepticism and varying levels of

engagement. Indeed, it was the new relationships within the team of patients and clinicians that eventually had the biggest impact on the patients; some patients used the remote monitoring as an opportunity to engage the clinician behind the tool to support their overall care coordination – a "hidden function" that emerged as "technological scope creep". Finally, routines of clinical staff were drastically impacted by this additional hidden work, leading to excessive extra workload primarily due to lack of interoperability of the tool with other digital infrastructure.

Evidence on implementation in the UK

In the UK, several evaluations and case studies published by NHS England and other sources describe the experience of networks and individual adopting sites as being small in size and scope and typically not covering different technologies or regions. An evaluation conducted by Health Innovation Network South London of the WhatsApp-based Doctaly Assist platform in 33 GP practices in Lewisham, noted that while the users were generally satisfied with the technology, they noted a number of issues such as a lack of interoperability, a lack of clarity around healthcare professional's identity, and technical issues. Staff also noted the learning curve of adopting a new technology, and how remote assessments sometimes took longer to complete than face-to-face ones.[62] Individual case studies are reported on the NHS England Transformation Directorate[63] and in its Digital Playbook,[64] with various other implementation projects, including technologies such as Luscii,[65,66] CliniTouch Vie[67], Lenus[68], myCOPD[69], and Docobo.[70]

4.4. Evidence of cost-effectiveness of remote monitoring technologies for COPD patients

Evidence on the cost-effectiveness of remote monitoring technologies for COPD patients is inconclusive, partly as the clinical effectiveness and the use-case for most of the technologies is not yet clearly demonstrated. One study evaluating the cost effectiveness of a pilot telehealth (remote monitoring, BOSCH Health Buddy) program in 2018 in two primary care trusts in the UK, found it to be different across the two sites, resulting in an increase of costs of £10k in one, but savings of £140k in the other, with an average saving per patient per year of £1,023.[71] The study concluded that the differences were likely related to the specificities of how the technology was introduced and applied within the team and the subsequent care pathway. Another study evaluating the economic benefits of a remote patient monitoring intervention for COPD patients in Canada found significant savings from the reduced use of emergency visits and hospitalisations during the three months of the program; however, the authors acknowledged that one-group, pre-post design is not robust enough to have high confidence in these findings.[72] A systematic review in 2022 found that the few studies that examined cost-effectiveness found no difference between patients using remote monitoring versus standard care.[41] In contrast, a systematic review by Shi et al (2024)[73] identified two studies reporting positive cost-effectiveness of virtual ward and hospital at home interventions for COPD patients, both based on well-conducted trails in the UK, reporting 42% to 90% probability of cost-effectiveness at NICE threshold of £30,000 per quality-adjusted life year.[74,75]

5. Summary reflections

Technologies supporting remote monitoring for patients with COPD have developed rapidly in the last several years. A wide range of technologies are grouped under the overlapping umbrellas of "remote patient monitoring", "technology-enabled remote monitoring", "telemonitoring", and their functions further overlap with technologies used for self-monitoring, self-management, digital pulmonary rehabilitation, behaviour change, psychological intervention and patient education. These mixed interventions make it challenging to draw consolidated conclusions regarding mechanisms of change and requires nuanced interpretation of evidence.

Pre-pandemic studies (e.g. from 2000-2015) have mostly failed to show a clinical benefit of remote monitoring technologies compared to standard COPD patient care. However, the interventions described in these earlier studies (e.g. multi-model system of several devices, often without an integrated patient-facing interface) are quite different from those used currently. More recent trials are often small and of limited scope in terms of captured outcomes and time horizons, resulting in somewhat limited quality of evidence. Large gaps in evidence exist on implementation, clinical and cost effectiveness of remote monitoring interventions for COPD patients. Evidence is lacking in which COPD patient populations and settings within the clinical care pathway remote monitoring would deliver the largest positive impact. The focus on clinical severity is not well grounded in evidence and the implementation of technology enabled remote monitoring is often determined and refined locally, based on understanding of patient population. While remote monitoring technologies are often perceived positively by patients and, to some degree, by staff, larger and longer studies are required to determine acceptability and impact (clinical, behavioural, economic) over time.

The changing landscape of technology and current gaps in knowledge underscore the importance of clinical trials and studies with clearly defined remote monitoring intervention, COPD patient population, meaningful outcomes, and longer time horizons to inform further implementation efforts. Remote monitoring is typically a complex intervention with multiple interacting components, embedded in a complex system of health and care services. Variability in the remote monitoring service definition, its personalised use by the patients and integration with other local services means that both the intervention and its effects are difficult to codify and measure. It is likely that the same remote monitoring intervention could have different outcomes depending upon the nature of the existing care offer, team-working, patient experience, level of trust, and other factors. Larger, both in terms of populations and the scope of research questions included, and higher quality trials and evaluations would help to understand the effects of and the dynamic relationship between the remote monitoring services and the context in which they are

implemented. Both quantitative and qualitative research studies are needed to inform further development and implementation of remote monitoring interventions for COPD patients, to ensure they are acceptable and effective.

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Annex A. Papers included in the scoping review

Reference	Type of study
1. Shi C, Dumville J, Rubinstein F, et al. Inpatient-level care at home delivered by virtual wards and hospital at home: a systematic review and meta-analysis of complex interventions and their components. *BMC Medicine*. 2024;22(1):145. doi:10.1186/s12916-024-03312-3	Systematic review and meta-analysis
2. Sul AR, Lyu DH, Park DA. Effectiveness of telemonitoring versus usual care for chronic obstructive pulmonary disease: A systematic review and meta-analysis. *J Telemed Telecare*. 2020;26(4):189-199. doi:10.1177/1357633X18811757	Systematic review and meta-analysis
3. Hong Y, Lee SH. Effectiveness of tele-monitoring by patient severity and intervention type in chronic obstructive pulmonary disease patients: A systematic review and meta-analysis. *Int J Nurs Stud*. 2019;92:1-15. doi:10.1016/j.ijnurstu.2018.12.006	Systematic review and meta-analysis
4. Jang S, Kim Y, Cho WK. A Systematic Review and Meta-Analysis of Telemonitoring Interventions on Severe COPD Exacerbations. *Int J Environ Res Public Health*. 2021;18(13):6757. doi:10.3390/ijerph18136757	Systematic review and meta-analysis
5. Corcoran R, Moore Z, Avsar P, Murray B. Home-based management on hospital re-admission rates in COPD patients: A systematic review. *Journal of Advanced Nursing*. n/a(n/a). doi:10.1111/jan.16168	Systematic review
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11. Ramachandran HJ, Oh JL, Cheong YK, et al. Barriers and facilitators to the adoption of digital health interventions for COPD management: A scoping review. *Heart Lung*. 2023;59:117-127. doi:10.1016/j.hrtlng.2023.02.004	Scoping review
12. Clarke M, Fursse J, Brown-Connolly NE, Sharma U, Jones R. Evaluation of the National Health Service (NHS) Direct Pilot Telehealth Program: Cost-Effectiveness Analysis. *Telemed J E Health*. 2018;24(1):67-76. doi:10.1089/tmj.2016.0280	Original (quantitative) research

Reference	Type of study
13. Cooper R, Giangreco A, Duffy M, et al. Evaluation of myCOPD Digital Self-management Technology in a Remote and Rural Population: Real-world Feasibility Study. *JMIR Mhealth Uhealth*. 2022;10(2):e30782. doi:10.2196/30782	Original (quantitative) research
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21. Wilde LJ, Percy C, Ward G, Clark C, Wark PA, Sewell L. The experiences of people with chronic obstructive pulmonary disease (COPD) using activity monitors in everyday life: an interpretative phenomenological study. *Disabil Rehabil*. Published online January 18, 2024:1-11. doi:10.1080/09638288.2024.2304095	Original (qualitative) research
22. van Lieshout F, Yang R, Stamenova V, Agarwal P, Cornejo Palma D, Sidhu A, et al. Evaluating the Implementation of a Remote-Monitoring Program for Chronic Obstructive Pulmonary Disease: Qualitative Methods from a Service Design Perspective. J Med Internet Res. 2020 Oct 9;22(10):e18148.	Original (qualitative) research
23. Krag T, Jørgensen EH, Phanareth K, Kayser L. Experiences With In-Person and Virtual Health Care Services for People With Chronic Obstructive Pulmonary Disease: Qualitative Study. JMIR Rehabilitation and Assistive Technologies. 2023 Aug 14;10(1):e43237.	Original (qualitative) research
24. Debeij SM, Aardoom JJ, Haaksma ML, Stoop WAM, Isselt EF van D van, Kasteleyn MJ. The Potential Use and Value of a Wearable Monitoring Bracelet for Patients With Chronic Obstructive Pulmonary Disease: Qualitative Study Investigating the Patient and Health Care Professional Perspectives. JMIR Formative Research. 2024 Sep 13;8(1):e57108.	Original (qualitative) research
25. Alwashmi MF, Fitzpatrick B, Davis E, Farrell J, Gamble JM, Hawboldt J. Features of a mobile health intervention to manage chronic obstructive pulmonary disease: a qualitative study. Ther Adv Respir Dis. 2020 Jan 1;14:1753466620951044.	Original (qualitative) research
26. Slevin P, Kessie T, Cullen J, Butler MW, Donnelly SC, Caulfield B. Exploring the barriers and facilitators for the use of digital health technologies for the management of COPD: a qualitative study of clinician perceptions. QJM. 2020 Mar 1;113(3):163–72.	Original (qualitative) research

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27. Bourbeau J, Echevarria C. Models of care across the continuum of exacerbations for patients with chronic obstructive pulmonary disease. *Chron Respir Dis*. 2020;17:1479973119895457. doi:10.1177/1479973119895457	Review
28. Coutu FA, Iorio OC, Ross BA. Remote patient monitoring strategies and wearable technology in chronic obstructive pulmonary disease. *Front Med (Lausanne)*. 2023;10:1236598. doi:10.3389/fmed.2023.1236598	Review
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