



# Telemedicine and virtual respiratory care in the era of COVID-19

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The #COVID19 pandemic has forced a dramatic shift to remote care and accelerated multiple telemedicine initiatives. As they evolve into the new norm, these initiatives must accommodate preferences and address the risk of increasing the digital divide. <https://bit.ly/3sj5WYL>

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## Abstract

The World Health Organization defines telemedicine as “an interaction between a healthcare provider and a patient when the two are separated by distance”. The coronavirus disease 2019 (COVID-19) pandemic has forced a dramatic shift to telephone and video consulting for follow-up and routine ambulatory care for reasons of infection control. Short message service (“text”) messaging has proved a useful adjunct to remote consulting, allowing the transfer of photographs and documents. Maintaining the care of noncommunicable diseases is a core component of pandemic preparedness and telemedicine has developed to enable (for example) remote monitoring of sleep apnoea, telemonitoring of COPD, digital support for asthma self-management and remote delivery of pulmonary rehabilitation. There are multiple exemplars of telehealth instigated rapidly to provide care for people with COVID-19, to manage the spread of the pandemic or to maintain safe routine diagnostic or treatment services.

Despite many positive examples of equivalent functionality and safety, there remain questions about the impact of remote delivery of care on rapport and the longer term impact on patient/professional relationships. Although telehealth has the potential to contribute to universal health coverage by providing cost-effective accessible care, there is a risk of increasing social health inequalities if the “digital divide” excludes those most in need of care. As we emerge from the pandemic, the balance of remote *versus* face-to-face consulting, and the specific role of digital health in different clinical and healthcare contexts will evolve. What is clear is that telemedicine in one form or another will be part of the “new norm”.

## Introduction

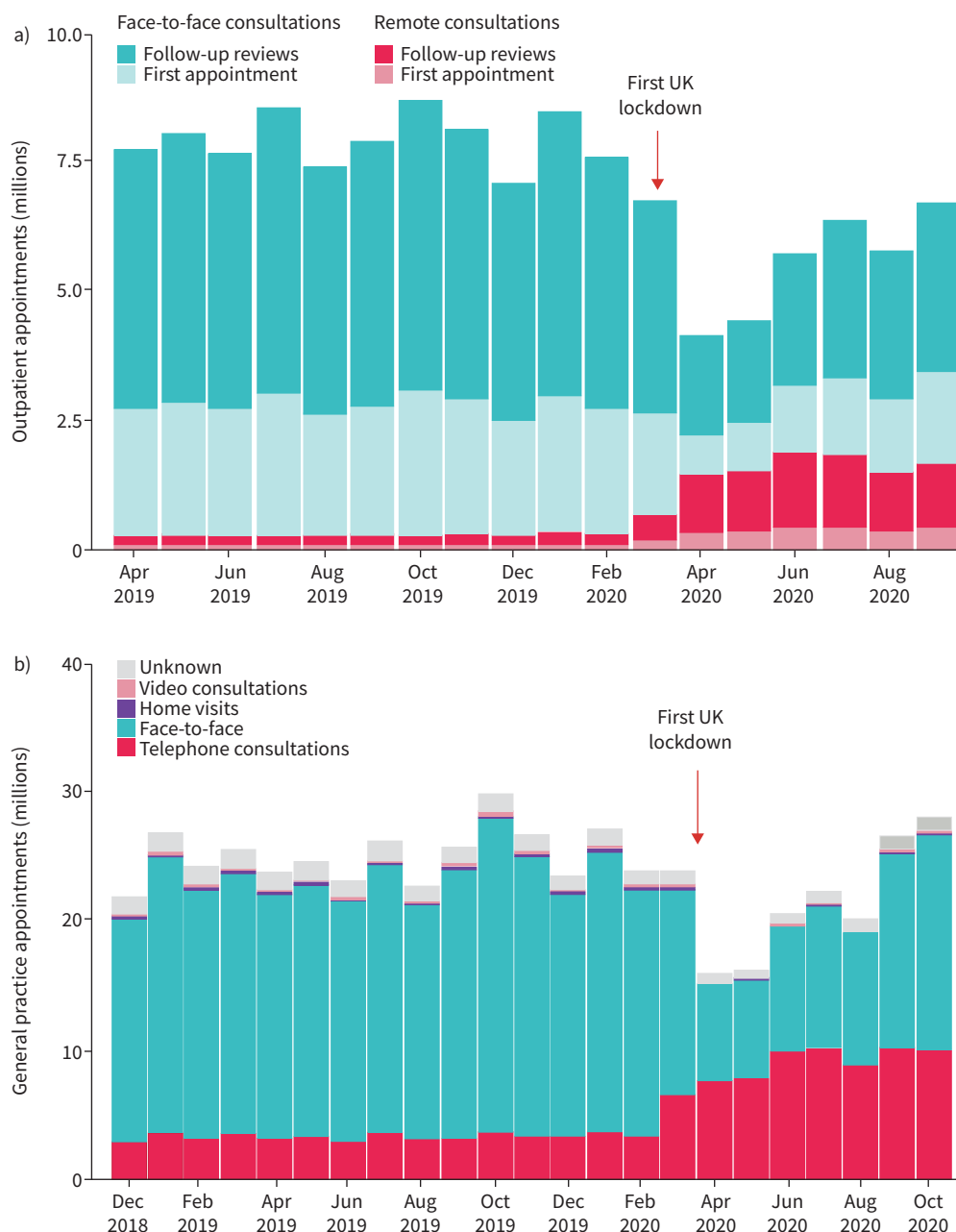
The World Health Organization (WHO) defines telemedicine (or telehealth; the WHO uses the terms interchangeably) as “an interaction between a healthcare provider and a patient when the two are separated by distance” [1], adding that this communication may be synchronous (as in telephone or video consultations) or asynchronous (when data, queries and responses are exchanged by email or short message service (SMS)) with the aim of providing clinical support and improving health outcomes [2]. Teleconsultations, telemonitoring, mobile health and remote delivery of interventions are all facets of digital healthcare that have been thrust into mainstream service by the requirement for social distancing in a pandemic, and are now a core focus of professional societies (for example, the European Respiratory Society [3]).

Telehealth is promoted as having the potential to contribute to universal health coverage by providing cost-effective accessible care [4], including for vulnerable and ageing populations and those living in remote areas [1]. Others have pointed to inequities arising from the “digital divide”, as the people most in need may be those least able to use, or without access to, essential technology [5]. In addition to enforcing remote clinical care, the coronavirus disease 2019 (COVID-19) pandemic has demonstrated the enormous value to public health and policy of the “big data” generated by digital health, although the need for



confidence in how personal data are protected and used remains a priority for the public [4]. Artificial intelligence (AI) can support respiratory care; for example, interpreting chest radiographs and sleep studies [6, 7], predicting acute exacerbations of COPD [8] and answering questions from people with lung cancer with chatbots [9]. However, effective implementation strategies are poorly developed [10], and the potential for AI to replace (as opposed to support) clinical decision-making [11] currently outstrips the trust of many patients and professionals [12, 13].

While we are mindful of this wider perspective, in this clinical review we focus on selected examples to provide an expert perspective on the potential of telemedicine to deliver virtual respiratory care. We consider how the COVID-19 pandemic has had a major influence on this story, promoting implementation



**FIGURE 1** Shift to remote consulting in hospitals and primary care in the United Kingdom (UK) in response to the coronavirus disease 2019 pandemic. a) Hospital outpatient consultations; b) general practice consultations. Reproduced and modified from [22] with permission.

of remote ways to monitor the progress of COVID in people at risk [14–18], highlighting the potential of safely maintaining the care of people with noncommunicable respiratory diseases [19, 20] and of supporting self-management during times of lockdown [21]. The imperative to contain the spread of infection resulted in an overnight shift to remote consulting (figure 1) [22, 23]; as COVID-19 gradually moves to endemic rather than pandemic status, we will discuss the “new norm” and the legacy that the pandemic has given to telemedicine.

### Remote access to consultations

Remote consulting is not new. The medical literature of the late 19th century contains a number of reports of innovative practice using the recently invented telephone to (for example) listen to a child’s breath sounds and reassure a mother that their child did not have croup, enable transmission and amplification of heart sounds to a remote specialist, facilitate organisation of rural general practices and to communicate within and between hospitals [24]. Some of the barriers that have held back widespread adoption of telephone (and other remote) consulting were being described in letters to the editor of *The Lancet* 100 years ago [24], including inadequate fees in comparison to face-to-face consultations [25–27] and the fear of being swamped by anxious patients. In contrast to the pandemic role of remote consulting in supporting infection control, an early scare was the risk of contracting infection from unhygienic public telephones [24].

### Telephone consulting for acute problems

A century later, the telephone had become the norm for providing access to acute medical advice with out-of-hours services in many countries reporting that the majority of calls could be managed safely without the need for a face-to-face consultation [28–31]. Respiratory infections are one of the commonest reasons for out-of-hours and primary care same-day contacts [32–34], so (even pre-COVID-19) telephone consultations were a core component of front-line respiratory care. Whether “telephone triage” is an efficient strategy for managing acute demand in routine practice is unclear [35]. Although some [31, 36, 37], but not all [38], studies have shown that telephone triage reduces professional time and costs on the day of the request, there is evidence that consultation rates increase over the 4 weeks after the index call [31, 38–43]. Compensating for lack of confidence in decisions made in remote consultations has been suggested as a reason for increased rates of follow-up [31]. However, safety evidence is reassuring, with systematic reviews demonstrating no significant increase in poor outcomes such as emergency department visits, hospitalisations or deaths [39, 41–43].

Another possibility is a qualitative difference in telephone consultations compared to those undertaken face-to-face. Analysis of the content of consultations shows that telephone consultations are shorter, mainly because they only address one problem (typically at least half of primary care face-to-face consultations deal with two or more presenting problems [44]), suggesting that additional problems are deferred in focused telephone calls. Several studies have concluded that doctors undertaking telephone consultations devote less time to rapport building, data gathering, provision of education and counselling and provide less opportunistic healthcare [44–47]. Reassuringly, patients’ recall of important advice (such as treatment instructions, or safety-netting advice) does not appear to be compromised by remote modes of communication [48].

### Telephone consulting for routine review of known conditions

A recurring theme (from patients [49] and healthcare professionals [50]) is that remote consulting may be particularly appropriate for the review of known problems, when there is no requirement to make a diagnosis [50], and potentially a relationship already exists between the patient and healthcare professional [51].

20 years before the COVID pandemic forced remote consultations, several trials investigated the potential of telephone reviews for asthma [52, 53]. A key aim of these primary care studies was to increase the (historically low [54]) proportion of people with asthma who received at least an annual review. Reassured by a randomised controlled trial (RCT) that showed that telephone reviews could be cost-effectively substituted for traditional face-to-face reviews with no loss of control [52, 55], different strategies have been tested to implement this in routine practice. Using proactive telephone calls to triage the need for a face-to-face review increased review rate from 64% to 87%, with no between-group difference in control or use of healthcare resources [53]. Incorporating the offer of a telephone review (about a fifth of patients chose review by telephone) and opportunistically calling nonresponders increased the proportion reviewed from 54% to 66% [56]. A Cochrane review in 2016 (six studies) concluded that offering telephone consultations could increase the proportion of people with asthma who received a review, with no evidence

of harm in terms of asthma control, although impact on unscheduled care was uncertain because these events were uncommon in primary care populations [57].

Similarly, there was already evidence that remote consulting, informed by usage data, was effective and more convenient than traditional face-to-face consulting for reviewing obstructive sleep apnoea and hypopnoea syndrome (OSAHS) [58]. With the COVID-19 pandemic, remote consulting became the norm for routine reviews of most long-term conditions [59].

#### *Telephone consulting for hospital outpatients*

While historically less widely adopted in hospitals than primary care practice (until the pandemic mandated a move to remote consulting), observational studies have shown the potential utility of telephone calls to replace face-to-face follow-up consultations [60, 61], and also as a preliminary contact to streamline future hospital consultations [62]. A telephone call to take a history and arrange necessary investigations prior to the first respiratory outpatient attendance reduced the need for follow-up appointments [62]. Post-discharge telephone follow-up has been tried in a range of conditions (although not specifically in respiratory conditions), but while appreciated by patients, benefits in terms of reduced complications or readmissions have not been demonstrated clearly [63]. About a third of respiratory outpatient follow-up appointments were considered suitable for telephone reviews because there was no need for a physical examination or hospital-based tests [60, 61].

#### *Video consulting*

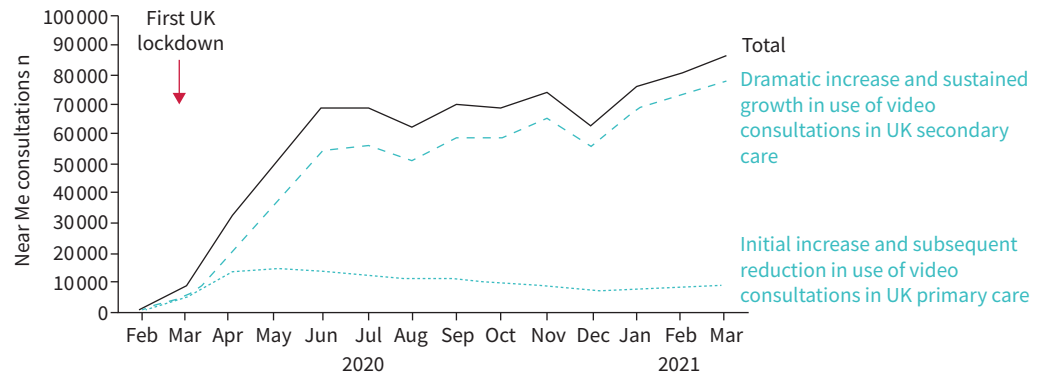
Video consultations offer the potential to overcome some of the limitations of telephone reviews by enabling visual communication [64], but in contrast to telephone consulting were rarely part of routine practice until COVID-19 forced social distancing [65, 66]. While supporting the feasibility of video consultations [67], the pre-COVID-19 evidence base is therefore limited with respect to effectiveness, safety and cost [68, 69]. Anticipated benefits compared to telephone consultations are the ability to pick up nonverbal clues, avoid misunderstandings and improve rapport [70]. More specifically, in the respiratory context there was already interest in the potential to observe and demonstrate inhaler technique [70], improve adherence to tuberculosis therapy with remote directly observed therapy [71], deliver breathlessness training for COPD [72], share completion of an asthma action plan [73], undertake remote spirometry [74], provide supportive and palliative care in cancer [75] and follow-up OSAHS [59].

Early exploratory work highlighted that the perceived benefits of having a visual component were tempered by practical problems with the technical infrastructure, as either the patient or the clinician had inadequate bandwidth, or an unstable connection, and sometimes just a lack of basic equipment such as a webcam [66, 70, 75–78]. Although many of technical hitches were minor (such as failure to “unmute” or “enable video”), “technical talk” occupied a significant proportion of video consultations [25, 26, 68, 75, 76], which disrupted the flow of the conversation and in the context of a busy clinical environment could be prohibitive [26, 78, 79].

The dramatic increase in video consultations during the first few months of the pandemic was particularly evident and maintained in secondary care [77, 80–82] (figure 2). Reports from a range of clinical settings and healthcare systems emphasise the significant organisational changes that were needed to establish a practical and safe outpatient video-consulting service [83], typically including upgrading infrastructure, revising billing arrangements and service workflow, ensuring suitable consulting space and staff training, developing processes for appointment handling (including identifying patients for whom remote consulting was inappropriate) and allowing additional time to resolve technical problems [25, 70, 76–79, 82, 84]. Pandemic changes to global and local policies promoted acquisition of necessary infrastructure, facilitated the development and approval of hardware and software systems for managing video calls and e-consultations [81] and promoted the organisational changes required to implement “digital-first” healthcare systems [27, 81, 82, 85].

#### *Asynchronous consulting: SMS, e-consultations and automated telephone calls*

A decade ago, qualitative interviews with patients [64] and general practitioners [86], and a survey of practice managers [87] revealed that email and SMS text messaging were perceived as useful for sending appointment reminders and sharing specific information (such as results of investigations), but were not acceptable alternatives to face-to-face consultations. A Cochrane review (132 studies) concluded that automated telephone calls could increase uptake of immunisation and screening, reduce nonattendance at appointments and promote adherence to medications or tests, although evidence of health benefits in specific respiratory conditions (asthma, COPD, sleep apnoea and nicotine dependence) was inconclusive [88].



**FIGURE 2** Growth in use of a United Kingdom (UK) National Health Service video-conferencing platform (Near Me) at the beginning of the coronavirus disease 2019 pandemic. Reproduced and modified from [81] with permission.

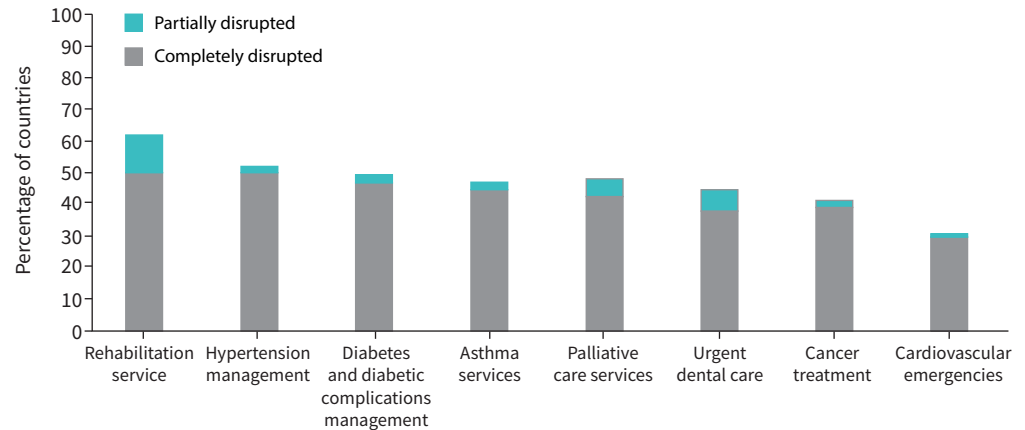
A systematic review including 57 primary/community care studies from a range of countries concluded that e-consultations were convenient and valued for routine queries on nonserious conditions [89]. Despite this, pre-pandemic use of e-consultations was very low and largely used for administrative requests (certification or prescription requests; test results) [90]. Although seen by early adopters as an “inevitable” innovation in a digital era, dealing with e-consultations was not necessarily time efficient [91], despite the potential to divert requests to appropriate members of the team. Approximately two-thirds of clinical e-contacts were converted to a telephone or face-to-face consultation, especially when the query related to a new problem [91], and, echoing the findings of acute telephone consultations, a quarter of online consulters had further consultations in the following month [90]. A Cochrane review in 2012 (nine studies) found insufficient evidence of the impact of e-consultations on resource use, and quality of communication [92].

E-consultations typically use a template to structure the clinical history and ensure relevant information is collected [91]. These may be generic templates for acute consultations, potentially interactive depending on initial choices, or may be tailored to disease-specific follow-up. For example, the template may request standardised information such as completion of control questionnaires in reviews of asthma or COPD (<https://www.ardens.org.uk/>). While offering convenience for patients with clearly defined problems, concerns have been raised about how “empathy” and “emotional work” are marginalised by asynchronous e-consultations [91].

In the context of the pandemic, the facility of attaching photographs and documents has been widely used to avoid face-to-face contact. Enabled by bespoke software linked to the electronic health record (<https://www accurx.com/who-we-support/general-practice/>), photographs of rashes or other visible problems can be requested by SMS to supplement a telephone consultation, or documents can be sent to the patient reinforcing information [93]. Medicolegal concerns about confidentiality, timelines for responding to e-consultations or the risk of missing an important diagnosis are ongoing concerns in the context of communication reliant on written information with no auditory or visual clues [87, 89].

### *Training and advice for remote consulting*

Given the dramatic rise in use of remote consulting during the pandemic, it is unsurprising that numerous articles have been published with advice on consulting in the context of the COVID-19 pandemic [59, 68, 94, 95]. While telephone consultations are relatively well practised [51, 96], advice on video consulting often include detailed “checklists” for clinicians of organisational, technical and medicolegal tasks, “video-conference etiquette”, generic consultation skills to build rapport, establish trust and safety-net [68, 94, 95], even before specific clinical tasks are considered. Home monitoring devices are increasingly available, or can be lent to monitor an acute illness or for a specific task [94]. An important priority during the pandemic was assessing breathlessness remotely without access to measurements [95]. Despite much discussion [97], most clinicians continued to use the pragmatic approach of asking the patients if they felt more breathless than usual combined with listening for evidence of shortness of breath as the patient was speaking.



**FIGURE 3** Percentage of countries reporting disruption to noncommunicable disease (NCD) services during the pandemic. This “snapshot” of the disruption to NCD care from a World Health Organization survey of 163 countries worldwide was conducted in June 2020, so represents the early impact of the pandemic. Reproduced from [19] under the Creative Commons Attribution ShareAlike 3.0 InterGovernmental Organization licence.

Video conferencing became a norm for many people to maintain social contact during the pandemic, but patients may still benefit from advice about using the medium for consultations [68]. In particular, ensuring a suitable setting (private, well lit, quiet and with adequate internet connection) is important advice [68].

### Maintaining care for respiratory noncommunicable diseases

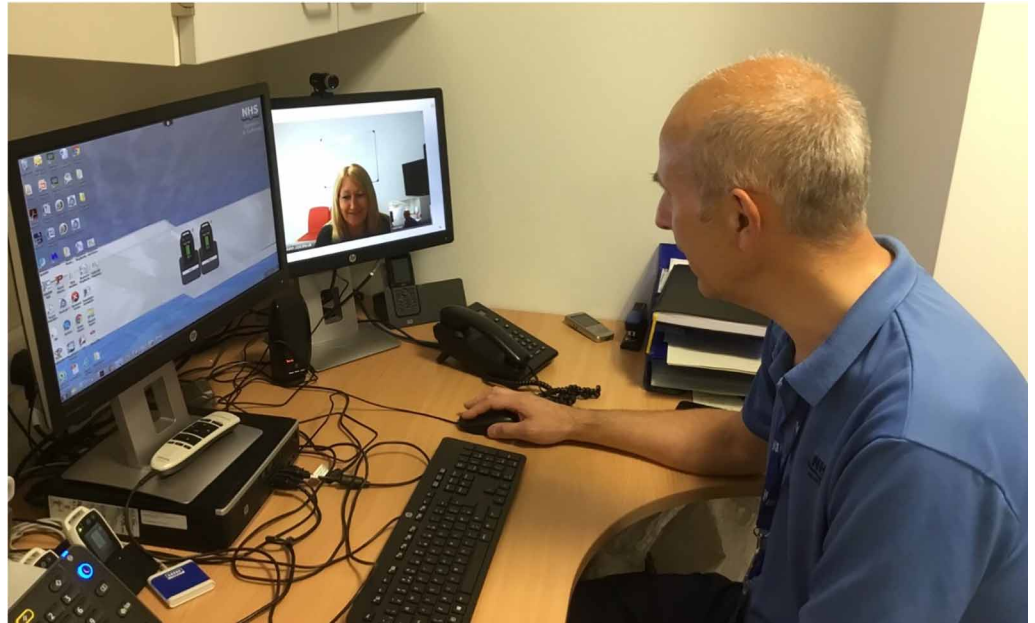
Maintaining the care of noncommunicable diseases (NCDs) is a core component of pandemic preparedness, although a global WHO survey revealed significant disruption of NCD-related care in many countries, including a number of respiratory services (figure 3) [19]. A survey of 39 European countries revealed the potential of remote solutions for maintaining access to prescription drugs and other essential services [98], despite restricted outpatient and primary care consultations in 90% of countries [20]. Interactive telemedicine has been advocated to support the care of a broad range of NCDs with an extensive (and often positive) evidence base in the context of heart failure, diabetes and hypertension [99]. We here consider five diverse exemplars of remote care for respiratory NCDs. These are selected as being relatively common respiratory challenges with an evidence base that can inform delivery of care.

### Monitoring to support remote consulting in OSAHS

OSAHS affects an estimated billion people globally and optimised diagnostic and treatment pathways are necessary to deliver cost-effective healthcare and reduce health impacts [100]. Remote consultations have been an option for people with OSAHS who are using continuous positive airway pressure (CPAP) therapy for more than two decades [101]. People can be seen at distance from the main sleep centre, with discussions informed by telemonitoring data from their CPAP devices viewed on cloud-based platforms that allow adjustment of prescribed settings if issues such as poor adherence or high mask leaks are identified [102]. There is increasing evidence that this approach is at least as effective as face-to-face reviews and may enable more timely management. In terms of service delivery, telemonitoring has been deemed feasible in a range of healthcare systems [103–106], facilitating access to CPAP initiation [103], promoting timely titration of therapy [104, 107, 108] and troubleshooting of technical problems [104, 109]. A meta-analysis (11 RCTs; 1440 patients) concluded that overall telemedicine improved adherence compared to centre-based care [110]. Clinical outcomes (*e.g.* Epworth Sleepiness Scale score) were generally reported as similar between groups [58, 103, 107, 111], and there is evidence that telehealth is more cost-effective than traditional in-person follow-up [106, 108, 111, 112].

Telemonitoring and video consultations (figure 4) are generally well accepted by patients using CPAP therapy [101, 105–108, 112–114]. The time savings reduce the impact on work productivity and the reduced travel and fuel consumption costs are valued as environmentally friendly [58].





**FIGURE 4** Remote consulting in a sleep apnoea service (Dumfries and Galloway, UK).

#### *Remote monitoring to reduce exacerbations of COPD*

Key objectives of COPD telemonitoring are to reduce exacerbations (especially severe exacerbations resulting in distressing and costly admissions) and improve quality of life. It is therefore disappointing that a Cochrane review in 2021 (29 studies from 11 countries) concluded that remote monitoring is ineffective at reducing exacerbations, admissions and deaths even when provided as part of a multifaceted intervention [115]. For example, in a meta-analysis of three studies (400 participants) comparing telemonitoring supported by usual care with usual care alone, there was no significant reduction in hospital admissions or improvement in quality of life at 6 months [115]. The trials included in this meta-analysis were heterogeneous, and the review authors suggest that the intensity of clinical contact associated with the intervention may have been a factor in determining effectiveness.

These interventions are typically monitored asynchronously by healthcare professionals at a substantial resource cost to healthcare systems [116, 117]. Although there was no evidence of benefit from telehealth, importantly there was no evidence of harm [115], and there may be clinical, social, geographic and (especially in a pandemic) infection control reasons for providing telemonitoring to some individuals.

The reasons for this disappointing lack of effect in COPD are likely to be multifactorial, but a key factor is that there are no clear predictors of exacerbations [118]. Symptom scores are poorly predictive [119], reflecting the difficulty many people with COPD have in differentiating early exacerbations from day-to-day fluctuations in symptoms [120]. Similarly, background variation in physiological measures (oxygen saturation, heart rate and respiratory rate) make it difficult to detect small changes associated with exacerbations [121–123]. Innovative biomarkers that could change the utility of telemonitoring are yet to be translated into clinical practice [124].

Rather than involving healthcare professionals in regular monitoring of telehealth data, there is some evidence that digitally supported self-management may improve breathlessness and (at least in the short term) quality of life [125–127].

#### *Digital support for asthma self-management*

Supported self-management of asthma is an effective complex intervention that reduces acute attacks and improves asthma control [128, 129]. Peaks in prescribing of inhaled steroids and emergency packs of steroids immediately prior to the first lockdown, suggests that an increased focus on self-management may have contributed to the reduction in asthma attacks and emergency department attendances observed during the pandemic [130]. Novel strategies for supporting self-management became important as both acute consultations and routine reviews shifted to remote delivery [59].

Support for people living with asthma encompasses clinical, practical, information and social support [131], much of which can be delivered remotely [21]. From a clinical perspective, the key component is the self-management discussion summarised in an agreed action plan. Integrated within ubiquitous mobile technology, digital action plans can be available whenever and wherever timely action is needed. In addition, sharing of logged data could facilitate remote medical advice in the event of an attack [132].

A Cochrane review (18 studies) comparing telemonitoring interventions with usual care, showed that health outcomes (acute attacks, healthcare resource use, asthma control) were similar in both groups [133], although a review of interactive telehealth concluded that there may be a small improvement in quality of life in adults [134]. Multifaceted interventions using combinations of remote case management, telemonitoring, teleconsultations, reminders and education may be effective [135]. Other systematic reviews echo these findings, emphasising that while telemonitoring may not be consistently more effective than usual care, there was no evidence of harm [99, 136–139]. The decision on their use might therefore be based on patient preference and organisational routines.

Most asthma applications (apps) are monitoring devices, with few apps including an interactive action plan that responds to asthma status by prompting the user to follow their healthcare professional's personalised advice [140]. Existing algorithms are based on symptoms and peak flows [141], but as patient and professional trust in artificial intelligence grows [12], digital action plans will be able to incorporate data from novel wearables and environmental sensors into personalised “living with asthma” action plans.

#### *Remote delivery of pulmonary rehabilitation*

Telerehabilitation is the delivery of rehabilitation services at a distance, using technology to provide exercise training, self-management education and information regarding disease management remotely [142]. Telerehabilitation can incorporate a number of technological modalities including telephone (audio calls; text messaging), web-based platforms, mobile applications or interactive video-conferencing. Importantly, participation may depend on patients having an appropriate device (*e.g.* telephone, smartphone, tablet or computer).

Several studies have investigated the feasibility and efficacy of telerehabilitation delivered *via* different modes of delivery. One option is group exercise *via* a videoconference software system installed on a tablet or personal computer. Patients watch the on-screen instructor and use their own minimal equipment at home to exercise [143]. Other approaches allow patients to access an interactive web-based programme that includes home exercises, an individualised action plan and education material. Patients interact with the healthcare professionals by entering information on the dedicated webpage for asynchronous review by the professional [144]. Another option installs exercise videos and educational material onto a tablet as a resource for patients exercising at home. Telemonitoring, often *via* wearable technology, may complement telerehabilitation by enabling patients to monitor vital signs using Bluetooth-enabled wearables that transmit data to a cloud-based platform *via* an app installed on the tablet. The healthcare professional reviews vital signs and patient-reported outcomes and provides feedback to the patient (figure 5) [145].

A recent Cochrane review [146] compared telerehabilitation to centre-based rehabilitation in patients with chronic respiratory diseases, concluding that there was “probably little or no difference” (moderate-certainty evidence) between the modes of delivery in their effect on exercise capacity (6-min walk distance, incremental shuttle walk test, cycling tests). Similarly, there was no between-group difference in dyspnoea or quality of life, although anxiety (but not depression) favoured telerehabilitation [146]. Adverse effects were similar in both delivery modes. Importantly, participants were more likely to complete a programme of telerehabilitation compared to centre-based rehabilitation (completion rate 93% compared to 70%). The review concluded that telerehabilitation could provide a clinically effective and safe alternative to centre-based pulmonary rehabilitation [146].

#### *Telephone delivery of psychosocial interventions for lung cancer*

A Cochrane review (32 studies) of telephone support for cancer care concluded that telephone reviews were convenient for patients, but the impact on symptom control varied [147]. Three of the studies in this review recruited people with lung cancer with variable outcomes [148, 149]. A psychosocial intervention delivered in four telephone calls did not improve symptom management or caregiver burden [148], although a six-session intervention designed specifically for people with advanced lung cancer improved depression, anxiety and caregiver burden [149]. Caregiver support provided in 14 telephone calls not only reduced anxiety and improved the self-efficacy of the caregivers, but also improved patient outcomes (pain, depression, quality of life) [150]. These studies tested specific interventions in addition to routine





**FIGURE 5** Telerehabilitation. Patients monitor vital signs using Bluetooth-enabled wearable monitors that transmit data to a cloud-based platform *via* an application installed onto the tablet. Health professionals can log in and see if the patient has uploaded data, and provide feedback [145].

respiratory/oncology follow-up; none pre-empted the pandemic context in which traditional face-to-face follow-up was replaced by remote consulting [76].

#### Digital innovation to manage COVID-19 infections

Qualitative data from eight European countries described the central role of telephone triage in providing safe access to primary care in the context of the pandemic, and specifically highlighted the challenge of managing respiratory infections remotely with no (or very limited) access to COVID-19 testing [151]. Patients generally accepted the need for remote consulting, even if some would have preferred a face-to-face appointment, and had confidence in their primary care professional's advice, especially if there was a pre-existing relationship. The professionals described the uncomfortable tension of needing to avoid face-to-face contact to prevent spread of infection and wanting a physical examination to provide reassurance. Ensuring clear safety-netting and making arrangements for review if things deteriorated was a priority. Supporting the social consequences of the pandemic (loss of income, fears of essential workers of being unable to isolate, comforting the bereaved unable to attend funerals) were core roles for primary care during the pandemic, which general practitioners and nurses felt was made more difficult because of the lack of "touch" in remote consultations [151].

#### Telehealth support for community management of COVID-19

There are multiple examples of telehealth, instigated rapidly to provide care for people with COVID-19, to manage the spread of the pandemic, or to maintain services.

Community-based telemonitoring of symptoms scores, temperature, oximetry and blood pressure supported by self-management information and/or remote monitoring proved to be a cost-effective alternative to hospitalisation [15, 16, 18, 152–156]. Although a rapid systematic review was unable to confirm safety due to lack of standardised reporting [18], mixed-method evaluation of individual programmes concluded that

they were reassuring to patients (especially the oximetry) [15, 153, 156], acceptable to clinicians [15, 152, 156], able to detect signs of deterioration [15, 156, 157] and a safe approach for selected high-risk patients with mild-to-moderate COVID-19 [15, 16, 18, 155–157]. Economic analysis was limited to reporting resources used and the amount spent per patient monitored [18].

Contact tracing smartphone-based applications potentially helped control the spread of COVID-19, but the effectiveness of this technology depended on high levels of adoption among the population [158]. Different age groups had different perceptions of contact tracing technologies: older people were motivated by their concern about health risks, but less convinced about using an app; middle-aged adults were concerned about security and privacy of health data; younger generations were motivated by attachment to their community and were influenced by social media [159, 160].

Maintaining allied health professional services (physiotherapy, dietetics, occupational therapy, psychology, speech therapy, social care) required rapid implementation of telehealth that was generally positively received, although some patients preferred a blended model of telehealth and in-person care [161]. Substantial administrative staff support was required to manage the demand for telehealth [161]. The COVID-19 pandemic accelerated the implementation of electronic mental health services to address pandemic-related stress (including post-COVID traumatic stress) and problems of social isolation, as well as a range of specific mental health disorders [162].

AI techniques have been applied to COVID-related epidemiology, therapeutics (drug discovery), clinical research (predictive modelling), social and behavioural studies [163]. Specific examples include development of automated tools for interpreting computed tomography scans, chest radiographs and lung ultrasound diagnostics [164–168], although clinical trials to establish the benefits and safety of image analysis in clinical practice are awaited [169].

#### **Perspectives on empathy and developing rapport in remote consultations**

Concerns about the potential loss of empathy when healthcare professionals and patients cannot see and “feel” each other (maybe akin to the “laying on of hands” of traditional images of medical consultations) has been the subject of discussion for many years [102, 170], and remains a theme in current research [151, 171]. One physician observed in the context of breaking bad news, that “you can’t offer a tissue in a remote consultation” [70], and others have commented on the lack of touch and smell [93], and the loss of “human-ness” in e-consultations [172]. A common observation was that remote consulting “worked better” when the patient and clinician knew each other and the interaction was building on an existing relationship [25, 173]. Communication skills, such listening, encouraging questioning, emphasising choice and investing time in developing rapport may help develop relationships in remote consultations [102, 173], and the increased use of video consulting may overcome some of these “distance” problems [102, 174].

#### **Concerns about digital inequities**

The WHO highlights the potential of telehealth to contribute to universal health coverage by providing cost-effective accessible care [1, 4], but there are concerns about the risk of increasing social health inequalities [5]. Although video consultations have been promoted as improving access for the housebound or those living at a distance from healthcare facilities [69], an inflexible policy of remote consulting excludes those who cannot afford [89], or do not have the skills to use required technology [28, 65, 81]. Most studies are conducted in high-income countries, with a paucity of evidence from deprived communities or low and middle-income countries (LMICs), heightening concerns about increasing the digital divide [99]. For example, provision of wearable connected devices and cloud-based technologies are suggested as improving access to diagnostics [147], and providing remote access to pulmonary rehabilitation [146], but insecure electricity and technology infrastructure mean this is unlikely to benefit rural communities in LMICs [175], or those from deprived communities whose use of technology is, of necessity, “frugal” [176]. “Digital-by-default” policies, accelerated during the pandemic, risk leaving behind the most marginalised [176]. In addition, in many LMICs, there is a significant gender gap in mobile ownership, so that women with respiratory disease may not have access to remote pulmonary rehabilitation or support for their asthma self-management, for example [177].

Language barriers in ethnic minority groups are a significant barrier to remote consulting [64, 65]. Ethics frameworks recommend that all digital innovation should address “fairness” as an overarching principle (along with transparency and accountability) [178]. Suggested approaches to reducing “unfairness” include ensuring access to the required infrastructure, and engaging populations at risk of being excluded by virtue of limited e-health literacy or for cultural reasons in the development of digital health initiatives [5].

Older age is often cited as a barrier to use of telehealth, although older patients with reduced mobility may appreciate the ease of telephone access [32], and with appropriately designed interfaces telehealth has been acceptable to people with COPD and associated multimorbidity [116, 179]. Familiarity with video-conferencing software has increased dramatically during the pandemic as families relied on video calls to keep in contact with vulnerable parents and grandparents, which may facilitate telemedicine in the future [180].

People with multimorbidity or general frailty benefit from holistic approaches that may be more appropriately conducted face-to-face [181]. Observational studies suggest that clinicians tend to triage older patients to face-to-face consultations [89, 182], reflecting awareness of the severity or complexity of their healthcare problems [31, 171].

### Conclusions and perspectives on the new post-COVID-19 norm

The COVID-19 pandemic has resulted in a major change in perceptions of telemedicine. In many situations, remote consulting has been the only safe option [14, 22]. Incentives and resources have enabled rapid scaling-up of telehealth capacity; “light touch” regulation has enabled practical and perceptual barriers to be overridden [26, 81]. Policy, clinical and research questions arise about how this will evolve post-COVID-19, with tightening of regulations and the imperative to address digital inequalities [81], and e-health literacy [183]. Remote consultations can improve access, reduce costs and travel [27] and offer environmental benefits [82], and are likely to persist as a flexible option, but (patient and professional) preference will become an increasing consideration when choice is not over-ridden by infection control requirements [184]. Evidence-based guidance will be needed on what is clinically safe for remote consulting [65, 82], and the acceptability of an increasing role of AI in interpreting investigations, identifying risk, informing clinical decisions and advising patients on self-management actions [11].

While the exact balance of remote *versus* face-to-face consulting, and the specific role of digital health in different clinical and healthcare contexts will evolve as we emerge from the pandemic, what is clear is that telemedicine in one form or another will be part of the new norm.

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### References

- 1 World Health Organization. Global Diffusion of eHealth: Making Universal Health Coverage Achievable. Report of the Third Global Survey on eHealth. 2019. Available from: <https://www.who.int/publications/i/item/9789241511780>/ Date last accessed: 16 February 2022.
- 2 World Health Organization. Telemedicine: Opportunities and Developments in Member States: Report on the Second Global Survey on eHealth. 2009. Available from: <https://apps.who.int/iris/handle/10665/44497>/ Date last accessed: 16 February 2022.
- 3 European Respiratory Society. Digital Respiratory Medicine – Realism vs Futurism. Presidential Summit. 2021. <https://www.ersnet.org/past-advocacy-events/digital-health-summit-2021-digital-respiratory-medicine-realism-vs-futurism/> Date last accessed: 24 April 2022.
- 4 World Health Organization (WHO). Report on the WHO Symposium on the Future of Digital Health Systems in the European Region. Available from: <https://apps.who.int/iris/bitstream/handle/10665/329032/9789289059992-eng.pdf>/ Date last accessed: 16 February 2022.
- 5 Latulippe K, Hamel C, Giroux D. Social health inequalities and eHealth: a literature review with qualitative synthesis of theoretical and empirical studies. *J Med Internet Res* 2017; 19: e136.
- 6 Poly TN, Islam MM, Li YC, *et al*. Application of artificial intelligence for screening COVID-19 patients using digital images: meta-analysis. *JMIR Med Inform* 2021; 9: e21394.
- 7 Hwang J, Lee T, Lee H, *et al*. A clinical decision support system for sleep staging tasks with explanations from artificial intelligence: user-centered design and evaluation study. *J Med Internet Res* 2022; 24: e28659.
- 8 Wu CT, Li GH, Huang CT, *et al*. Acute exacerbation of a chronic obstructive pulmonary disease prediction system using wearable device data, machine learning, and deep learning: development and cohort study. *JMIR Mhealth Uhealth* 2021; 9: e22591.
- 9 Kataoka Y, Takemura T, Sasajima M, *et al*. Development and early feasibility of chatbots for educating patients with lung cancer and their caregivers in Japan: mixed methods study. *JMIR Cancer* 2021; 7: e26911.

- 10 Gama F, Tyskbo D, Nygren J, *et al.* Implementation frameworks for artificial intelligence translation into health care practice: scoping review. *J Med Intern Res* 2022; 24: e32215.
- 11 Kaplan A, Haenlein M. Siri, Siri, in my hand: who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. *Bus Horizons* 2019; 62: 15–25.
- 12 Hui CY, McKinstry B, Fulton O, *et al.* Patients and clinicians perceived trust in internet-of-things (IoTs) system to support asthma self-management: a qualitative study. *JMIR Mhealth Uhealth* 2021; 9: e24127.
- 13 Boillat T, Nawaz FA, Rivas H. Readiness to embrace artificial intelligence among medical doctors and students: questionnaire-based study. *JMIR Med Educ* 2022; 8: e34973.
- 14 Vindrola-Padros C, Singh KE, Sidhu MS, *et al.* Remote home monitoring (virtual wards) for confirmed or suspected COVID-19 patients: a rapid systematic review. *EClinicalMedicine* 2021; 37: 100965.
- 15 McKinstry B, Alexander H, Maxwell G, *et al.* The use of telemonitoring in managing the COVID-19 pandemic: pilot implementation study. *JMIR Form Res* 2021; 5: e20131.
- 16 Silven AV, Petrus AH, Villalobos-Quesada M, *et al.* Telemonitoring for patients with COVID-19: recommendations for design and implementation. *J Med Internet Res* 2020; 22: e20953.
- 17 Greenhalgh T, Knight M, Inda-Kim M, *et al.* Remote management of COVID-19 using home pulse oximetry and virtual ward support. *BMJ* 2021; 372: n677.
- 18 Casariego-Vales E, Blanco-López R, Rosón-Calvo B, *et al.* Efficacy of telemedicine and telemonitoring in at-home monitoring of patients with COVID-19. *J Clin Med* 2021; 10: 2893.
- 19 World Health Organization (WHO). The Impact of the COVID-19 Pandemic on Noncommunicable Disease Resources and Services: Results of a Rapid Assessment. 2020. <https://www.who.int/publications/i/item/9789240010291/> Date last accessed: 16 February 2022.
- 20 Ágh T, van Boven JFM, Wettermark B, *et al.* A cross-sectional survey on medication management practices for noncommunicable diseases in Europe during the second wave of the COVID-19 pandemic. *Front Pharmacol* 2021; 12: 685696.
- 21 Pinnock H. Connecting professionals and patients: how technology can support asthma self-management. *Respir Drug Deliv Europe* 2017; 1: 43–52.
- 22 Health Foundation, Nuffield Trust. The Remote Care Revolution During Covid-19. <https://www.nuffieldtrust.org.uk/files/2020-12/QWAS/digital-and-remote-care-in-covid-19.html#1/> Date last accessed: 18 February 2022.
- 23 The Health Foundation. How Has the COVID-19 Pandemic Impacted Primary Care? <https://www.health.org.uk/news-and-comment/charts-and-infographics/how-has-the-covid-19-pandemic-impacted-primary-care/> Date last updated: 27 May 2021. Date last accessed: 16 February 2022.
- 24 Aronson SH. *The Lancet* on the telephone 1876–1975. *Med Hist* 1977; 21: 69–87.
- 25 Greenhalgh T, Shaw S, Wherton J, *et al.* Real-world implementation of video outpatient consultations at macro, meso, and micro levels: mixed-method study. *J Med Internet Res* 2018; 20: e150.
- 26 Keesara S, Jonas A, Schulman K. Covid-19 and health care's digital revolution. *N Engl J Med* 2020; 382: e82.
- 27 Kichloo A, Albosta M, Dettloff K, *et al.* Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA. *Fam Med Community Health* 2020; 8: e000530.
- 28 Lattimer V, George S, Thompson F, *et al.* Safety and effectiveness of nurse telephone consultation in out of hours primary care: randomised controlled trial. The South Wiltshire Out of Hours Project (SWOOP) Group. *BMJ* 1998; 317: 1054–1059.
- 29 Christensen MB, Olesen F. Out of hours service in Denmark: evaluation five years after reform. *BMJ* 1998; 316: 1502–1505.
- 30 Poole SR, Schmitt BD, Carruth T, *et al.* After-hours telephone coverage: the application of an area-wide telephone triage and advice system for pediatric practices. *Pediatrics* 1993; 92: 670–679.
- 31 Huibers L, Moth G, Carlsen AH, *et al.* Telephone triage by GPs in out-of-hours primary care in Denmark: a prospective observational study of efficiency and relevance. *Br J Gen Pract* 2016; 66: e667–e673.
- 32 Gonzalez F, Cimadevila B, Garcia-Comesaña J, *et al.* Telephone consultation in primary care: a retrospective two-year observational analysis of a public healthcare system. *J Health Organ Manag* 2018; 32: 321–337.
- 33 Fielding S, Porteous T, Ferguson J, *et al.* Estimating the burden of minor ailment consultations in general practices and emergency departments through retrospective review of routine data in North East Scotland. *Fam Pract* 2015; 32: 165–172.
- 34 Leutgeb R, Engeser P, Berger S, *et al.* Out of hours care in Germany – high utilization by adult patients with minor ailments? *BMC Fam Pract* 2017; 18: 42.
- 35 Newbould J, Abel G, Ball S, *et al.* Evaluation of telephone first approach to demand management in English general practice: observational study. *BMJ* 2017; 358: j4197.
- 36 McKinstry B, Walker J, Campbell C, *et al.* Telephone consultations to manage requests for same-day appointments: a randomised controlled trial in two practices. *Br J Gen Pract* 2002; 52: 306–310.
- 37 Jiwa M, Mathers N, Campbell M. The effect of GP telephone triage on numbers seeking same-day appointments. *Br J Gen Pract* 2002; 52: 390–391.

- 38 Holt TA, Fletcher E, Warren F, *et al.* Telephone triage systems in UK general practice: analysis of consultation duration during the index day in a pragmatic randomised controlled trial. *Br J Gen Pract* 2016; 66: e214–e218.
- 39 Campbell JL, Fletcher E, Britten N, *et al.* Telephone triage for management of same-day consultation requests in general practice (the ESTEEM trial): a cluster-randomised controlled trial and cost-consequence analysis. *Lancet* 2014; 384: 1859–1868.
- 40 Salisbury C, Murphy M, Duncan P. The impact of digital-first consultations on workload in general practice: modeling study. *J Med Internet Res* 2020; 22: e18203.
- 41 Bunn F, Byrne G, Kendall S. Telephone consultation and triage: effects on health care use and patient satisfaction. *Cochrane Database Syst Rev* 2004; 4: CD004180.
- 42 Downes MJ, Mervin MC, Byrnes JM, *et al.* Telephone consultations for general practice: a systematic review. *Syst Rev* 2017; 6: 128.
- 43 Boggan JC, Shoup JP, Whited JD, *et al.* Effectiveness of acute care remote triage systems: a systematic review. *J Gen Intern Med* 2020; 35: 2136–2145.
- 44 McKinstry B, Hammersley V, Burton C, *et al.* The quality, safety and content of telephone and face-to-face consultations: a comparative study. *Qual Saf Health Care* 2010; 19: 298–303.
- 45 Hewitt H, Gafaranga J, McKinstry B. Comparison of face-to-face and telephone consultations in primary care: qualitative analysis. *Br J Gen Pract* 2010; 60: e201–e212.
- 46 Innes M, Skelton J, Greenfield S. A profile of communication in primary care physician telephone consultations: application of the Roter Interaction Analysis System. *Br J Gen Pract* 2006; 56: 363–368.
- 47 Derkx HP, Rethans JJ, Maiburg BH, *et al.* Quality of communication during telephone triage at Dutch out-of-hours centres. *Patient Educ Couns* 2009; 74: 174–178.
- 48 McKinstry B, Watson P, Elton RA, *et al.* Comparison of the accuracy of patients' recall of the content of telephone and face-to-face consultations: an exploratory study. *Postgrad Med J* 2011; 87: 394–399.
- 49 Pinnock H, Madden V, Snellgrove C, *et al.* Telephone or surgery asthma reviews? Preferences of participants in a primary care randomised controlled trial. *Prim Care Respir J* 2005; 14: 42–46.
- 50 McKinstry B, Watson P, Pinnock H, *et al.* Telephone consulting in primary care: a triangulated qualitative study of patients and providers. *Br J Gen Pract* 2009; 59: e209–e218.
- 51 van Galen LS, Car J. Telephone consultations. *BMJ* 2018; 360: k1047.
- 52 Pinnock H, Bawden R, Proctor S, *et al.* Accessibility, acceptability, and effectiveness in primary care of routine telephone review of asthma: pragmatic, randomised controlled trial. *BMJ* 2003; 326: 477–479.
- 53 Gruffydd-Jones K, Hollinghurst S, Ward S, *et al.* Targeted routine asthma care in general practice using telephone triage. *Br J Gen Pract* 2005; 55: 918–923.
- 54 Gruffydd-Jones K, Nicholson I, Best L, *et al.* Why don't patients attend the asthma clinic? *Asthma Gen Pract* 1999; 7: 36–39.
- 55 Pinnock H, McKenzie L, Price D, *et al.* Cost effectiveness of telephone or surgery asthma reviews: health economic analysis of a pragmatic primary care randomised controlled trial. *Br J Gen Pract* 2005; 55: 119–124.
- 56 Pinnock H, Adlem L, Gaskin S, *et al.* Accessibility, clinical effectiveness and practice costs of providing a telephone option for routine asthma reviews: phase IV controlled implementation study. *Br J Gen Pract* 2007; 57: 714–722.
- 57 Kew KM, Cates CJ. Remote versus face-to-face check-ups for asthma. *Cochrane Database Syst Rev* 2016; 4: CD011715.
- 58 Murphie P, Little S, McKinstry B, *et al.* Remote consulting with telemonitoring of continuous positive airway pressure usage data for the routine review of people with obstructive sleep apnoea hypopnoea syndrome: a systematic review. *J Telemed Telecare* 2019; 25: 17–25.
- 59 International Primary Care Respiratory Group. Desktop Helper No. 11 – Remote Consultations. <https://www.ipcrg.org/dth11/> Date last accessed: 18 February 2022.
- 60 Roberts NJ, Partridge MR. Telephone consultations in secondary care. *Respir Med* 2007; 101: 1665–1669.
- 61 Partridge MR. An assessment of the feasibility of telephone and email consultation in a chest clinic. *Patient Educ Couns* 2004; 54: 11–13.
- 62 O'Byrne L, Roberts NJ, Partridge MR. Preclinic telephone consultations: an observational cohort study. *Clin Med* 2012; 12: 140–145.
- 63 Mistiaen P, Poot E. Telephone follow-up, initiated by a hospital-based health professional, for postdischarge problems in patients discharged from hospital to home. *Cochrane Database Syst Rev* 2006; 4: CD004510.
- 64 van Baar JD, Joosten H, Car J, *et al.* Understanding reasons for asthma outpatient (non)-attendance and exploring the role of telephone and e-consulting in facilitating access to care: exploratory qualitative study. *Qual Saf Health Care* 2006; 15: 191–195.
- 65 Sinha S, Kern LM, Gingras LF, *et al.* Implementation of video visits during COVID-19: lessons learned from a primary care practice in New York City. *Front Public Health* 2020; 8: 514.



- 66 Morrison C, Beattie M, Wherton J, et al. Testing and implementing video consulting for outpatient appointments: using quality improvement system thinking and codesign principles. *BMJ Open Qual* 2021; 10: e001259.
- 67 Mallow JA, Petite T, Narsavage G, et al. The use of video conferencing for persons with chronic conditions: a systematic review. *Ehealth Telecommun Syst Netw* 2016; 5: 39–56.
- 68 Car J, Koh GC, Foong PS, et al. Video consultations in primary and specialist care during the COVID-19 pandemic and beyond. *BMJ* 2020; 371: m3945.
- 69 Ignatowicz A, Atherton H, Bernstein CJ, et al. Internet videoconferencing for patient–clinician consultations in long-term conditions: a review of reviews and applications in line with guidelines and recommendations. *Digit Health* 2019; 5: 2055207619845831.
- 70 Donaghy E, Atherton H, Hammersley V, et al. Acceptability, benefits, and challenges of video consulting: a qualitative study in primary care. *Br J Gen Pract* 2019; 69: e586–e594.
- 71 Lam CK, Pilote KM, Haque A, et al. Using video technology to increase treatment completion for patients with latent tuberculosis infection on 3-month isoniazid and rifapentine: an implementation study. *J Med Internet Res* 2018; 20: e287.
- 72 Nield M, Hoo GW. Real-time telehealth for COPD self-management using Skype™. *COPD* 2012; 9: 611–619.
- 73 Hamour O, Smyth E, Pinnock H, et al. Completing asthma action plans by screen-sharing in video-consultations: practical insights from a feasibility assessment. *NPJ Prim Care Respir Med* 2020; 30: 48.
- 74 McGowan A, Laveneziana P, Bayat S, et al. International consensus on lung function testing during COVID-19 pandemic and beyond. *ERJ Open Res* 2021; 8: 00602-2021.
- 75 Funderskov KF, Raunkjær M, Danbjørg DB, et al. Experiences with video consultations in specialized palliative home-care: qualitative study of patient and relative perspectives. *J Med Internet Res* 2019; 21: e10208.
- 76 Pardolesi A, Gherzi L, Pastorino U. Telemedicine for management of patients with lung cancer during COVID-19 in an Italian cancer institute: SmartDoc Project. *Tumori* 2021; in press [<https://doi.org/10.1177/030089162111012760>].
- 77 Johns G, Khalil S, Ogonovsky M, et al. Taming the chaos: NHS professionals' perspective of using video consulting during COVID-19 in Wales. *BMJ Open Qual* 2021; 10: e001318.
- 78 Wright RC, Partovi N, Levy RD. Necessity is the mother of invention: rapid implementation of virtual health care in response to the COVID-19 pandemic in a lung transplant clinic. *Clin Transplant* 2020; 34: e14062.
- 79 Tossaint-Schoenmakers R, Versluis A, Chavannes N, et al. The challenge of integrating ehealth into health care: systematic literature review of the Donabedian model of structure, process, and outcome. *J Med Internet Res* 2021; 23: e27180.
- 80 Watt T, Firth Z, Fisher R, et al. Use of Primary Care During the COVID-19 Pandemic. <https://www.health.org.uk/news-and-comment/charts-and-infographics/use-of-primary-care-during-the-covid-19-pandemic/> Date last updated: 17 September 2020. Date last accessed: 16 February 2022.
- 81 Shaw SE, Hughes G, Wherton J, et al. Achieving spread, scale up and sustainability of video consulting services during the COVID-19 pandemic? Findings from a comparative case study of policy implementation in England, Wales, Scotland and Northern Ireland. *Front Digit Health* 2021; 3: 754319.
- 82 Wherton J, Greenhalgh T. Evaluation of the Near Me Video Consulting Service in Scotland During COVID-19. Edinburgh, Scottish Government, 2020.
- 83 James HM, Papoutsis C, Wherton J, et al. Spread, scale-up, and sustainability of video consulting in health care: systematic review and synthesis guided by the NASSS framework. *J Med Internet Res* 2021; 23: e23775.
- 84 Lam AY, Chan EC, Quek CM, et al. Videoconsultation to overcome barriers during COVID-19. *Ann Acad Med Singap* 2021; 50: 77–83.
- 85 Bhaskar S, Bradley S, Chattu VK, et al. Telemedicine across the globe –position paper from the COVID-19 Pandemic Health System Resilience PROGRAM (REPROGRAM) International Consortium (Part 1). *Front Public Health* 2020; 8: 556720.
- 86 Hanna L, May C, Fairhurst K. The place of information and communication technology-mediated consultations in primary care: GPs' perspectives. *Fam Pract* 2012; 29: 361–366.
- 87 Hanna L, May C, Fairhurst K. Non-face-to-face consultations and communications in primary care: the role and perspective of general practice managers in Scotland. *Inform Prim Care* 2011; 19: 17–24.
- 88 Posadzki P, Mastellos N, Ryan R, et al. Automated telephone communication systems for preventive healthcare and management of long-term conditions. *Cochrane Database Syst Rev* 2016; 12: CD009921.
- 89 Mold F, Hendy J, Lai YL, et al. Electronic consultation in primary care between providers and patients: systematic review. *JMIR Med Inform* 2019; 7: e13042.
- 90 Edwards HB, Marques E, Hollingworth W, et al. Use of a primary care online consultation system, by whom, when and why: evaluation of a pilot observational study in 36 general practices in South West England. *BMJ Open* 2017; 7: e016901.
- 91 Casey M, Shaw S, Swinglehurst D. Experiences with online consultation systems in primary care: case study of one early adopter site. *Br J Gen Pract* 2017; 67: e736–e743.



- 92 Atherton H, Sawmynaden P, Sheikh A, *et al.* Email for clinical communication between patients/caregivers and healthcare professionals. *Cochrane Database Syst Rev* 2012; 11: CD007978.
- 93 Murphy M, Scott LJ, Salisbury C, *et al.* Implementation of remote consulting in UK primary care following the COVID-19 pandemic: a mixed-methods longitudinal study. *Br J Gen Pract* 2021; 71: e166–e177.
- 94 Bakhai M, Aw J, Ballard T, *et al.* Principles for Supporting High Quality Consultations by Video in General Practice During COVID-19. 2020. [www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/03/C0479-principles-of-safe-video-consulting-in-general-practice-updated-29-may.pdf](http://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/03/C0479-principles-of-safe-video-consulting-in-general-practice-updated-29-may.pdf) Date last accessed: 18 February 2022.
- 95 Greenhalgh T, Koh GC, Car J. Covid-19: a remote assessment in primary care. *BMJ* 2020; 368: m1182.
- 96 Car J, Sheikh A. Telephone consultations. *BMJ* 2003; 326: 966–969.
- 97 Greenhalgh T, Kotze K, Van Der Westhuizen H. Are There Any Evidence-Based Ways of Assessing Dyspnoea (Breathlessness) by Telephone or Video? 2020. <https://www.cebm.net/covid-19/are-there-any-evidence-based-ways-of-assessing-dyspnoea-breathlessness-by-telephone-or-video/> Date last updated: 2 April 2020. Date last accessed: February 18, 2022.
- 98 Kardas P, van Boven JFM, Pinnock H, *et al.* Disparities in European healthcare system approaches to maintaining continuity of medication for non-communicable diseases during the COVID-19 outbreak. *Lancet Reg Health Eur* 2021; 4: 100099.
- 99 Flodgren G, Rachas A, Farmer AJ, *et al.* Interactive telemedicine: effects on professional practice and health care outcomes. *Cochrane Database Syst Rev* 2015; 9: CD002098.
- 100 Benjafield AV, Ayas NT, Eastwood PR, *et al.* Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. *Lancet Respir Med* 2019; 7: 687–698.
- 101 Taylor Y, Eliasson A, Andrada T, *et al.* The role of telemedicine in CPAP compliance for patients with obstructive sleep apnea syndrome. *Sleep Breathing* 2006; 10: 132–138.
- 102 Pépin JL, Tamisier R, Hwang D, *et al.* Does remote monitoring change OSA management and CPAP adherence? *Respirology* 2017; 22: 1508–1517.
- 103 Fietze I, Herberger S, Wewer G, *et al.* Initiation of therapy for obstructive sleep apnea syndrome: a randomized comparison of outcomes of telemetry-supported home-based vs. sleep lab-based therapy initiation. *Sleep Breath* 2022; 26: 269–277.
- 104 Hoet F, Libert W, Sanida C, *et al.* Telemonitoring in continuous positive airway pressure-treated patients improves delay to first intervention and early compliance: a randomized trial. *Sleep Med* 2017; 39: 77–83.
- 105 Kooij L, Vos PJ, Dijkstra A, *et al.* Video consultation as an adequate alternative to face-to-face consultation in continuous positive airway pressure use for newly diagnosed patients with obstructive sleep apnea: randomized controlled trial. *JMIR Form Res* 2021; 5: e20779.
- 106 Smith CE, Daux ER, Clements F, *et al.* Telehealth services to improve nonadherence: a placebo-controlled study. *Telemed J E Health* 2006; 12: 289–296.
- 107 Contal O, Poncin W, Vaudan S, *et al.* One-year adherence to continuous positive airway pressure with telemonitoring in sleep apnea hypopnea syndrome: a randomized controlled trial. *Front Med* 2021; 8: 626361.
- 108 Lugo VM, Garmendia O, Suarez-Girón M, *et al.* Comprehensive management of obstructive sleep apnea by telemedicine: clinical improvement and cost-effectiveness of a virtual sleep unit. A randomized controlled trial. *PLoS One* 2019; 14: e0224069.
- 109 Carlier S, Bruyneel AV, Bruyneel M. Pressure adjustment is the most useful intervention for improving compliance in telemonitored patients treated with CPAP in the first 6 months of treatment. *Sleep Breath* 2021; 26: 125–132.
- 110 Hu Y, Su Y, Hu S, *et al.* Effects of telemedicine interventions in improving continuous positive airway pressure adherence in patients with obstructive sleep apnoea: a meta-analysis of randomised controlled trials. *Sleep Breath* 2021; 25: 1761–1771.
- 111 Turino C, de Batlle J, Woehle H, *et al.* Management of continuous positive airway pressure treatment compliance using telemonitoring in obstructive sleep apnoea. *Eur Respir J* 2017; 49: 1601128.
- 112 Garmendia O, Monasterio C, Guzmán J, *et al.* Telemedicine strategy for CPAP titration and early follow-up for sleep apnea during COVID-19 and post-pandemic future. *Arch Bronconeumol* 2021; 57: 56–58.
- 113 Fields BG, Behari PP, McCloskey S, *et al.* Remote ambulatory management of veterans with obstructive sleep apnea. *Sleep* 2016; 39: 501–509.
- 114 Bros JS, Poulet C, Arnol N, *et al.* Acceptance of telemonitoring among patients with obstructive sleep apnea syndrome: how is the perceived interest by and for patients? *Telemed J E Health* 2018; 24: 351–359.
- 115 Janjua S, Carter D, Threapleton CJD, *et al.* Telehealth interventions: remote monitoring and consultations for people with chronic obstructive pulmonary disease (COPD). *Cochrane Database Syst Rev* 2021; 7: CD013196.
- 116 Pinnock H, Hanley J, McCloughan L, *et al.* Effectiveness of telemonitoring integrated into existing clinical services on hospital admission for exacerbation of chronic obstructive pulmonary disease: researcher blind, multicentre, randomised controlled trial. *BMJ* 2013; 347: f6070.

- 117 London Respiratory Team. COPD Value Pyramid – Telehealth Position So Far. 2013. Available from: <https://www.networks.nhs.uk/nhs-networks/london-respiratory-network/key-documents/lrt-final-report-june-2013/Triangle1.jpg/view>. Date last accessed: 17 February 2022.
- 118 Pinnock H, McKinstry B. Telehealth for chronic obstructive pulmonary disease: promises, populations, and personalised care. *Am J Respir Crit Care Med* 2018; 198: 552–554.
- 119 Sanchez-Morillo D, Fernandez-Granero MA, Leon-Jimenez A. Use of predictive algorithms in-home monitoring of chronic obstructive pulmonary disease and asthma: a systematic review. *Chron Respir Dis* 2016; 13: 264–283.
- 120 Williams V, Hardinge M, Ryan S, et al. Patients' experience of identifying and managing exacerbations in COPD: a qualitative study. *NPJ Prim Care Respir Med* 2014; 24: 14062.
- 121 Hurst JR, Donaldson G, Quint JK, et al. Domiciliary pulse-oximetry at exacerbation of chronic obstructive pulmonary disease: prospective pilot study. *BMC Pulm Med* 2010; 10: 52–58.
- 122 Burton C, Pinnock H, McKinstry B. Changes in telemonitored physiological variables and symptoms prior to exacerbations of chronic obstructive pulmonary disease: analysis of telemonitoring data. *J Telemed Telecare* 2015; 21: 29–36.
- 123 Rubio N, Parker R, Drost E, et al. Home monitoring of breathing rate in people with chronic obstructive pulmonary disease: observational study of feasibility, acceptability and change after exacerbation. *Int J Chron Obstruct Pulmon Dis* 2017; 12: 1221–1231.
- 124 Koutsokera A, Kostikas K, Nicod LP, et al. Pulmonary biomarkers in COPD exacerbations: a systematic review. *Respir Res* 2013; 14: 111.
- 125 Janjua S, Banchoff E, Threapleton CJD, et al. Digital interventions for the management of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2021; 4: CD013246.
- 126 McCabe C, McCann M, Brady AM. Computer and mobile technology interventions for self-management in chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2017; 5: CD011425.
- 127 Hallensleben C, van Luenen S, Rolink E, et al. eHealth for people with COPD in the Netherlands: a scoping review. *Int J Chron Obstruct Pulmon Dis* 2019; 14: 1681–1690.
- 128 Pinnock H, Parke HL, Panagioti M, et al. Systematic meta-review of supported self-management for asthma: a healthcare service perspective. *BMC Med* 2017; 15: 64.
- 129 Hodkinson A, Bower P, Grigoroglou C, et al. Self-management interventions to reduce healthcare utilisation and improve quality of life among patients with asthma: a systematic review and network meta-analysis. *BMJ* 2020; 370: m2521.
- 130 Davies GA, Alsallakh MA, Sivakumaran S, et al. Impact of COVID-19 lockdown on emergency asthma admissions and deaths: national interrupted time series analyses for Scotland and Wales. *Thorax* 2021; 76: 867–873.
- 131 Pearce G, Parke H, Pinnock H, et al. The PRISMS taxonomy of self-management support: derivation of a novel taxonomy and initial testing of its utility. *J Health Serv Res Policy* 2016; 21: 73–82.
- 132 Hui CY, McKinstry B, Fulton O, et al. Patients' and clinicians' visions of a future internet-of-things system to support asthma self-management: mixed methods study. *J Med Internet Res* 2021; 23: e22432.
- 133 Kew KM, Cates CJ. Home telemonitoring and remote feedback between clinic visits for asthma. *Cochrane Database Syst Rev* 2016; 8: CD011714.
- 134 Snoswell CL, Rahja M, Lalor AF. A systematic review and meta-analysis of change in health-related quality of life for interactive telehealth interventions for patients with asthma. *Value Health* 2021; 24: 291–302.
- 135 Chongmelaxme B, Lee S, Dhippayom T, et al. The effects of telemedicine on asthma control and patients' quality of life in adults: a systematic review and meta-analysis. *J Allergy Clin Immunol Pract* 2019; 7: 199–216.
- 136 Hui CY, Walton R, McKinstry B, et al. The use of mobile applications to support self-management for people with asthma: a systematic review of controlled studies to identify features associated with clinical effectiveness and adherence. *J Am Med Inform Assoc* 2017; 24: 619–632.
- 137 Hanlon P, Daines L, Campbell C, et al. Telehealth interventions to support self-management of long-term conditions: a systematic meta-review of diabetes, heart failure, asthma, chronic obstructive pulmonary disease and cancer. *J Med Internet Res* 2017; 19: e172.
- 138 Morrison D, Wyke S, Agur K, et al. Digital asthma self-management interventions: a systematic review. *J Med Internet Res* 2014; 16: e51.
- 139 Marcano Belisario JS, Huckvale K, Greenfield G, et al. Smartphone and tablet self management apps for asthma. *Cochrane Database Syst Rev* 2013; 11: CD010013.
- 140 Huckvale K, Morrison C, Ouyang J, et al. The evolution of mobile apps for asthma: an updated systematic assessment of content and tools. *BMC Med* 2015; 13: 58.
- 141 Honkoop PJ, Taylor DR, Smith AD, et al. Early detection of asthma exacerbations by using action points in self-management plans. *Eur Respir J* 2013; 41: 53–59.
- 142 Kairy D, Lehoux P, Vincent C, et al. A systematic review of clinical outcomes, clinical process, healthcare utilization and costs associated with telerehabilitation. *Disabil Rehabil* 2009; 31: 427–447.

- 143 Hansen H, Bieler T, Beyer N, *et al.* Supervised pulmonary tele-rehabilitation *versus* pulmonary rehabilitation in severe COPD: a randomised multicentre trial. *Thorax* 2020; 75: 413–421.
- 144 Chaplin E, Hewitt S, Apps L, *et al.* Interactive web-based pulmonary rehabilitation programme: a randomised controlled feasibility trial. *BMJ Open* 2017; 7: e013682.
- 145 Vasilopoulou M, Papaioannou AI, Kaltsakas G, *et al.* Home-based maintenance tele-rehabilitation reduces the risk for acute exacerbations of COPD, hospitalisations and emergency department visits. *Eur Respir J* 2017; 49: 1602129.
- 146 Cox NS, Dal Corso S, Hansen H, *et al.* Telerehabilitation for chronic respiratory disease. *Cochrane Database Syst Rev* 2021; 1: CD013040.
- 147 Ream E, Hughes AE, Cox A, *et al.* Telephone interventions for symptom management in adults with cancer. *Cochrane Database Syst Rev* 2020; 6: CD007568.
- 148 Mosher CE, Winger JG, Hanna N, *et al.* Randomized pilot trial of a telephone symptom management intervention for symptomatic lung cancer patients and their family caregivers. *J Pain Symptom Manage* 2016; 52: 469–482.
- 149 Badr H, Smith CB, Goldstein NE, *et al.* Dyadic psychosocial intervention for advanced lung cancer patients and their family caregivers: results of a randomized pilot trial. *Cancer* 2015; 121: 150–158.
- 150 Porter LS, Keefe FJ, Garst J, *et al.* Caregiver-assisted coping skills training for lung cancer: results of a randomized clinical trial. *J Pain Symptom Manage* 2011; 41: 1–13.
- 151 Wanat M, Hoste ME, Gobat NH, *et al.* Patients' and clinicians' perspectives on the primary care consultations for acute respiratory infections during the first wave of the COVID-19 pandemic: an eight-country qualitative study in Europe. *BJGP Open* 2022; in press [<https://doi.org/10.3399/BJGPO.2021.0172>].
- 152 Khalid I, Imran M, Imran M, *et al.* Telemedicine monitoring of high-risk coronavirus disease 2019 (COVID-19) patients by family medicine service after discharge from the emergency department. *J Fam Community Med* 2021; 28: 210–216.
- 153 Vaughan L, Eggert LE, Jonas A, *et al.* Use of home pulse oximetry with daily short message service messages for monitoring outpatients with COVID-19: the patient's experience. *Digit Health* 2021; 7: 20552076211067651.
- 154 Pimlott N, Agarwal P, McCarthy LM, *et al.* Clinical learnings from a virtual primary care program monitoring mild to moderate COVID-19 patients at home. *Fam Pract* 2021; 38: 549–555.
- 155 Shaw JG, Sankineni S, Olaleye CA, *et al.* A novel large scale integrated telemonitoring program for COVID-19. *Telemed J E Health* 2021; 27: 1317–1321.
- 156 Panicacci S, Donati M, Lubrano A, *et al.* Telemonitoring in the Covid-19 era: the Tuscany region experience. *Healthcare* 2021; 9: 516.
- 157 Dirikgil E, Roos R, Groeneveld GH, *et al.* Home monitoring reduced short stay admissions in suspected COVID-19 patients: COVID-box project. *Eur Respir J* 2021; 58: 2100636.
- 158 Dowthwaite L, Fischer J, Perez Vallejos E, *et al.* Public adoption of and trust in the NHS COVID-19 contact tracing app in the United Kingdom: quantitative online survey study. *J Med Internet Res* 2021; 23: e29085.
- 159 Scholl A, Sassenberg K. How identification with the social environment and with the government guide the use of the official COVID-19 contact tracing app: three quantitative survey studies. *JMIR Mhealth and Uhealth* 2021; 9: e28146.
- 160 Shoji M, Ito A, Cato S, *et al.* Prosociality and the uptake of COVID-19 contact tracing apps: survey analysis of intergenerational differences in Japan. *JMIR Mhealth Uhealth* 2021; 9: e29923.
- 161 Cottrell M, Burns CL, Jones A, *et al.* Sustaining allied health telehealth services beyond the rapid response to COVID-19: learning from patient and staff experiences at a large quaternary hospital. *J Telemed Telecare* 2021; 27: 615–624.
- 162 Ellis LA, Meulenbroeks I, Churruca K, *et al.* The application of e-mental health in response to COVID-19: scoping review and bibliometric analysis. *JMIR Ment Health* 2021; 8: e32948.
- 163 Xu Z, Su C, Xiao Y, *et al.* AI for COVID-19: battling the pandemic with computational intelligence. *Intell Med* 2021; 9: 13–29.
- 164 Alam MU, Rahmani R. Federated semi-supervised multi-task learning to detect COVID-19 and lungs segmentation marking using chest radiography images and Raspberry Pi devices: an internet of medical things application. *Sensors* 2021; 21: 5025.
- 165 Sadre R, Sundaram B, Majumdar S, *et al.* Validating deep learning inference during chest X-ray classification for COVID-19 screening. *Sci Rep* 2021; 11: 16075.
- 166 Delli Pizzi A, Chiarelli AM, Chiacchiaretta P, *et al.* Radiomics-based machine learning differentiates “ground-glass” opacities due to COVID-19 from acute non-COVID-19 lung disease. *Sci Rep* 2021; 11: 17237.
- 167 Haq AU, Li JP, Ahmad S, *et al.* Diagnostic approach for accurate diagnosis of COVID-19 employing deep learning and transfer learning techniques through chest X-ray images clinical data in e-healthcare. *Sensors* 2021; 21: 8219.
- 168 Dhont J, Wolfs C, Verhaegen F. Automatic coronavirus disease 2019 diagnosis based on chest radiography and deep learning – success story or dataset bias? *Med Phys* 2022; 49: 978–987.

- 169 Jungmann F, Müller L, Hahn F, *et al.* Commercial AI solutions in detecting COVID-19 pneumonia in chest CT: not yet ready for clinical implementation? *Eur Radiol* 2022; 32: 3152–3160.
- 170 Miller EA. The technical and interpersonal aspects of telemedicine: effects on doctor–patient communication. *J Telemed Telecare* 2003; 9: 1–7.
- 171 Turner A, Scott A, Horwood J, *et al.* Maintaining face-to-face contact during the COVID-19 pandemic: a longitudinal qualitative investigation in UK primary care. *BJGP Open* 2021; 5: BJGPO.2021.0036.
- 172 Boers SN, Jongsma KR, Lucivero F, *et al.* SERIES: eHealth in primary care. Part 2: Exploring the ethical implications of its application in primary care practice. *Eur J Gen Pract* 2020; 26: 26–32.
- 173 Orlando JF, Beard M, Kumar S. Systematic review of patient and caregivers’ satisfaction with telehealth videoconferencing as a mode of service delivery in managing patients’ health. *PLoS One* 2019; 14: e0221848.
- 174 Funderskov KF, Boe Danbjørg D, Jess M, *et al.* Telemedicine in specialised palliative care: healthcare professionals’ and their perspectives on video consultations – a qualitative study. *J Clin Nurs* 2019; 28: 3966–3976.
- 175 International Telecommunication Union. Data and Analytics: Taking the Pulse of the Information Society. <https://www.itu.int/itu-d/sites/statistics/> Date last accessed: 24 April 2022.
- 176 Hernandez K, Roberts T. Leaving No One Behind in a Digital World. K4D Emerging Issues Report. Brighton, Institute of Development Studies, 2018.
- 177 Global System for Mobile Communications. Connected Women: the Mobile Gender Gap Report 2021. <https://www.gsma.com/r/wp-content/uploads/2021/06/The-Mobile-Gender-Gap-Report-2021.pdf/> Date last accessed: 24 April 2022.
- 178 UK Government Digital Service. Data Ethics Framework 2020. Available from: <https://www.gov.uk/government/publications/data-ethics-framework/> Date last accessed: 17 February 2022.
- 179 Jakobsen AS, Laursen LC, Rydahl-Hansen S, *et al.* Home-based telehealth hospitalization for exacerbation of chronic obstructive pulmonary disease: findings from “the virtual hospital” trial. *Telemed J E Health* 2015; 21: 364–373.
- 180 Polgar O, Patel S, Walsh JA, *et al.* Digital habits of pulmonary rehabilitation service-users following the COVID-19 pandemic. *Chronic Respir Dis* 2022; 19: 14799731221075647.
- 181 Joy M, McGagh D, Jones N, *et al.* Reorganisation of primary care for older adults during COVID-19: a cross-sectional database study in the UK. *Br J Gen Pract* 2020; 70: e540–e547.
- 182 Johnston S, MacDougall M, McKinstry B. The use of video consulting in general practice: semi-structured interviews examining acceptability to patients. *J Innov Health Inform* 2016; 23: 493–500.
- 183 Norgaard O, Furstrand D, Klokke L, *et al.* The e-health literacy framework: a conceptual framework for characterizing e-health users and their interaction with e-health systems. *Knowl Manag E-Learn* 2015; 7: 522–540.
- 184 Pinnock H, Hoskins G, Neville R, *et al.* Triage and remote consultations: moving beyond the rhetoric of access and choice. *Br J Gen Pract* 2005; 55: 910–911.