Introduction

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Respiratory care is embracing digital transformation. This *Monograph* discusses technological opportunities, explores societal implications and describes exemplar applications. We hope these expert views stimulate interest and discussion. https://bit.ly/ERSM102intro

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The potential and challenges of digital healthcare

Information and communication technology has revolutionised most aspects of contemporary life [1]. Healthcare systems are also undergoing major changes as they (relatively cautiously) embrace the digital transformation [2]. Time-honoured approaches to delivering care are being challenged by technology-based initiatives offering potential benefits in terms of functionality, efficiency and reach [3]. The World Health Organization (WHO) promote technology as contributing to achieving universal health coverage by providing accessible care to those living in remote areas [4], and enhancing support for vulnerable and ageing populations [5]. An increasing literature addresses the potential for digital healthcare to: monitor disease progress and medication adherence; support assisted living; implement cloud-based healthcare information systems; and enable personalised health and preventive medicine [3]. The need for infection control in a pandemic forced a dramatic move to remote consulting [6], virtual wards [7], home treatments and therapy [8, 9], and digital support for self-management [10], which seems likely to have established a new norm for those who welcome the convenience of not needing to travel [11, 12].

Counterbalancing the many positives of digital healthcare is the risk of exacerbating inequities, as the most needy may be the least able to access/use essential technology [13]. Whether the barrier is unreliable infrastructure or individual limited e-health literacy (or both), the concern is that the “digital divide” may be the 21st century expression of the inverse care law, which states that the availability of good medical care tends to vary inversely with the need for care in the population served [14]. Policymakers and healthcare professionals must ensure that “fairness” is a pre-requisite of the implementation of digital healthcare [15].

Insights from the analysis of “big data” and the value of “data-enabled healthcare” were amply demonstrated during the coronavirus disease 2019 (COVID-19) pandemic, but the public need confidence in how their personal data are protected and used [3]. Data security, privacy, design, performance, efficiency, heterogeneity, interoperability and legal issues are recurring themes in the literature [3]. Cross-border harmonisation is currently being addressed in Europe by the

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European Health Data Space [16], and is widely welcomed by professional societies such as the European Respiratory Society (ERS) as an opportunity for better healthcare, research and policymaking [17]. With the launch of OpenAI resources such as ChatGPT [18], artificial intelligence (AI) has become a major talking point for the public and policymakers. AI is already supporting professionals to make healthcare decisions, but there is evidence that wider use may be outstripping the trust of patients and professionals [19].

A priority for respiratory healthcare

Digital respiratory care is of interest to both professional and patient respiratory organisations. The theme of the ERS Presidential Summit 2021 [20], a research seminar and three successive Congresses [21–23], the creation of the m-Health/e-health ERS Group [24], and the commissioning of reviews [11], all reflect the significance of digital health to ERS members. Similarly, the European Lung Foundation (ELF) adopted digital health as the theme for their Patient Organisation Networking Day 2021 [25] and have run workshops on digital health to explore the potential benefits and concerns.

Patients report being keen to use apps to monitor and learn about their condition, access timely advice and reduce travel time for consultations. They are interested in using remote monitoring and consultations to develop new kinds of relationships with their healthcare team, and to maintain disease control. They want to understand how their data could be used by others but have concerns about data privacy and security. Healthcare professionals embraced remote consulting for reasons of infection control in the pandemic [6], and in many contexts have been convinced of the utility (though not necessarily the time/cost efficiency) of telephone/videoconsultations [26]. Both patients and professionals have highlighted the potential loss of empathy and "human-ness" in remote consultations, and that remote consulting "worked better" when interaction built on existing relationships [27–29].

CONNECT Clinical Research Collaboration

More recently, an ERS Clinical Research Collaboration (CRC) has been established to promote research relevant to the implementation of digital respiratory healthcare [30]. Whatever the policy or disease context, significant organisational changes are needed to establish and sustain digital healthcare (*e.g.* practical resources, skills training, proper reimbursement, integration with existing patient management systems, transferability of data across settings, privacy issues) [12, 31].

Terminology

One of the challenges in such a fast-moving field is the evolving terminology. Definitions vary – see the European Commission study on health data, digital health and AI in healthcare for a discussion on European and worldwide definitions [2]. The relationship between these modalities is illustrated in chapter 11 of this *Monograph* in the context of digital transformation of healthcare services in the European Union (EU) [32]. For clarity, we have summarised the key definitions in table 1, and have taken an editorial decision to standardise terminology throughout the *Monograph*.

Using this *Monograph*

The Monograph is divided into three complementary sections, as follows.

Technological and regulatory challenges and opportunities

In the first section (chapters 1–6), we present an overview of the extensive range of technology that can potentially support digital respiratory healthcare [39–44]. Some of the technology is

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TABLE 1 Digital health terminology and definitions used in this *Monograph*	
Terminology	**Definitions**
Big data	Extremely large datasets, which may be complex, multidimensional, unstructured and heterogeneous and which may be analysed computationally to reveal patterns, trends and associations [33]
Digital health	An umbrella term that refers to technologies that assist in providing healthcare services and information
Digital health framework	A structured strategy for digital transformation of healthcare services aiming to establish an efficient interaction among information coming from informal care, formal care and biomedical research, both for healthcare delivery and other purposes (*e.g.* quality assurance, research) [34]
Digital health literacy	The ability to seek, find, understand and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem [35]; sometimes referred to as e-health literacy
e-Health	Electronic health comprises the provision of healthcare products and services using information and communication technology [2]
Electronic health record	Electronic records of interactions with healthcare systems; often used interchangeably with electronic medical records and electronic patient records
Internet of Things	A network of physical devices and other items, embedded with electronics, software, sensors and network connectivity, which enables these objects to collect and exchange data [36]; the application of the Internet of Things to medicine is termed the "Medical Internet of Things"
m-Health	A sub-segment of e-health, m-health can be considered as the use of smart or mobile communication devices, such as smartphones and tablets, for the provision of health and well-being services and information [2]
Medical assistive robot	An autonomous or semi-autonomous machine equipped with advanced sensors, actuators and artificial intelligence modules, employed in healthcare contexts to perform assistive functionalities; social robots are designed with anthropomorphic features to improve their ability to interact with humans
Medical device	An instrument, apparatus, appliance, software, implant, reagent, material or other article intended by the manufacturer to be used, alone or in combination, for human beings for one or more of the following specific medical purposes: diagnosis, prevention, monitoring, prediction, prognosis, treatment or alleviation of disease; diagnosis, monitoring, treatment, alleviation of, or compensation for, an injury or disability [37]
Personal health records	Online systems that include collections of patient healthcare and medical data, which utilise health informatics standards to enable patients to share, organise and manage these data according to their own views [38]; often linked with m-health
Telehealth	Often used interchangeably with telemedicine, but telehealth encompasses a broader scope of technologies and healthcare providers than telemedicine, which refers specifically to clinical health services [2]
Telemedicine	The provision of healthcare services and medical information using innovative technologies, especially information and communication technologies, in situations where the health professional and patient (or two health professionals) are not in the same location; it includes any remote interaction between patients and healthcare professionals, and between healthcare professionals themselves, whether synchronous or asynchronous [2]
Telemonitoring, teleconsultations, telerehabilitation	Specific modalities within telehealth

already familiar and is beginning to be used in routine clinical care (for example, smart inhalers, oximeters, hand-held spirometers) while other devices (such as activity trackers) are familiar in day-to-day life but have useful medical application. Medical assistive robots are already familiar aids for surgeons and when designed with anthropomorphic features, are demonstrating their potential to support social tasks for the frail or housebound [40].

We also consider the range of technology in the pipeline that could be deployed in the future to support clinical practice. These offer exciting opportunities but may also present major challenges whilst current practice adapts to new ways of working. The increasing collection of data offers opportunities for observing real-world practice and may be used to improve the quality, safety and efficiency of healthcare delivery, but collation from multiple sources is challenging, and the format of feedback is crucial if it is to effect change [42]. AI, already a feature of imaging and radiology, is set to "feed" on this explosion in data and will increasingly play a role in healthcare, reassuringly facilitating rather than replacing healthcare professionals [43]. Virtual, augmented and mixed reality is another powerful tool to improve diagnostics.

In this increasingly digital world, regulation is essential to set quality standards, enable interoperability and ensure safe use as well as protect individual privacy and prevent inappropriate access [44].

Social challenges of digital respiratory healthcare

Underpinned by rapid technological development, and promoted by policy, healthcare in Europe and globally is undergoing a major digital transformation [2] that will affect the historical dynamics between healthcare professionals and patients, and will impact on the way healthcare is delivered. The second section of the *Monograph* (chapters 7–12) addresses the social challenges of digital respiratory healthcare for the individual patient, their healthcare advisor and society at large [32, 45–49].

Increasing inequities and exacerbating the inverse care law [14] is a significant risk of implementing digital healthcare, and effort is required to ensure fairness and that no one is left behind in a digital world [13]. Optimising digital interfaces for individuals (which may include healthcare professionals as well as patients) who, for whatever reason, have limited ability to access and benefit from digital healthcare is challenging but essential. Despite being promoted by the WHO as contributing to universal healthcare coverage [5], this will only be achieved if the needs of remote and/or deprived communities or demographically disadvantaged groups are addressed as a pre-requisite of implementing digital healthcare [15].

From a societal perspective, the introduction of technology challenges traditional professional–patient relationships and raises fundamental questions about trust, regard, loyalty and knowledge in the context of a clinician–technology–patient relationship [50] and how important aspects of "humanness" can be optimised [47, 51]. Children and young people are a specific group in which the technical, ethical and societal challenges raised by implementing digital health technologies require specific consideration [48, 52]. The environmental benefits of remote healthcare need to be balanced against the potential of technology infrastructure to increase environmental pollution [48, 53].

Exemplars of digital respiratory healthcare

The final section of the *Monograph* (chapters 13–22) presents selected exemplars illustrating the breadth of digital health initiatives in respiratory conditions [54–63]. The utility of these digital health initiatives was particularly evident during the COVID-19 pandemic. The implemented

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digital solutions, whether for surveillance of epidemic progression, contact tracing or remote patient management from home, provide inspiration for controlling future epidemics [54]. In another epidemic, tuberculosis, for which nonadherence to treatment is associated with increased risk of poor outcome, drug resistance and infection transmission, digital adherence technologies have been utilised to both monitor and promote drug adherence [55].

It is likely that digital solutions could have a major impact in chronic respiratory disease management. In asthma, they can support patient adherence through varied solutions, including digital inhalers and spacers, self-management apps, web-based interventions, telehealth and text-messaging services [56], as well as enable self-management by allowing patients to monitor health status, receive timely feedback, avoid triggers and change lifestyle behaviours [57]. In COPD, telehealth is also employed for remote patient monitoring and self-management support, and has additionally been piloted for managing comorbidities (anxiety and depression) and end-of-life care [58]. Further, mobile apps can assist smoking cessation [59]. In sleep medicine, digital health applications are already enabling remote respiratory device monitoring and follow-up, but teleconsultations also have potential utility in screening and diagnosis, communicating test results and treatment options, and tele-education [60]. In cystic fibrosis, where the aim is to reduce care burden, teleconsultations integrating symptom and spirometry data could become the primary management approach for patients with access to the modulators of cystic fibrosis transmembrane conductance regulator [61]. For most chronic respiratory diseases, telerehabilitation represents a hope that the benefits of pulmonary rehabilitation (improved exercise tolerance, quality of life and symptom control) can reach more patients [62]. Finally, advances in AI suggest that screening, diagnosis and monitoring of respiratory diseases based on radiological imaging could be automated, such as in interstitial lung disease [63].

As the possibilities for digital health multiply, the foremost question remains their acceptability and efficacy. Within each chapter, the reader will find a literature review indicating key outcomes for each respiratory condition and application domain, plus one or more practical examples describing barriers and facilitators to implementation.

The future of digital respiratory healthcare

Digital transformation of healthcare is already underway with multiple and diverse initiatives. The question is no longer "Will it happen?" but "How can digital health be implemented so that connected care provides an optimal seamless service?" This was the question that inspired this *Monograph* and which the ERS CRC CONNECT aims to address [30].

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