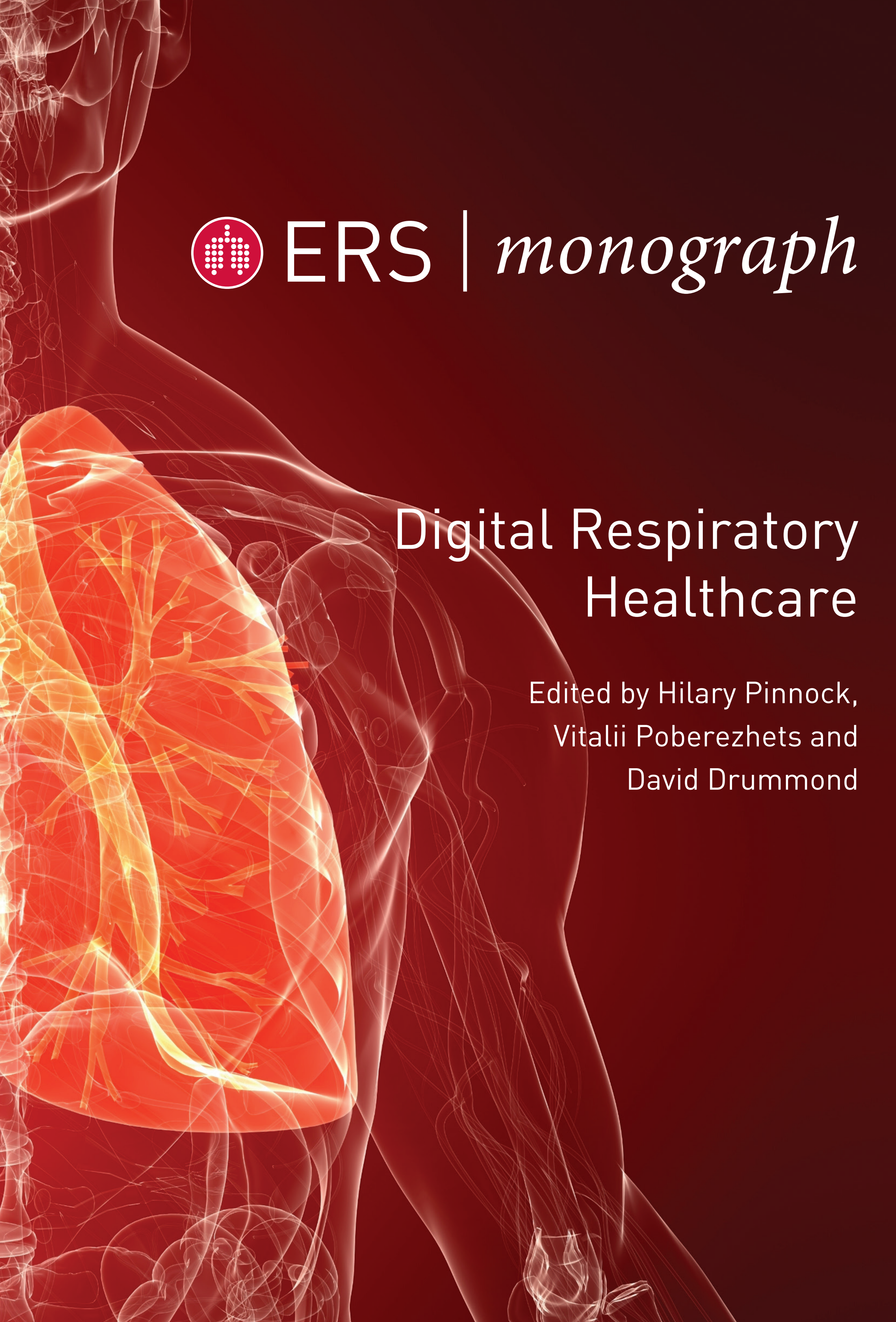

ERS | *monograph*

Digital Respiratory Healthcare

Edited by Hilary Pinnock,
Vitalii Poberezhets and
David Drummond

Digital Respiratory Healthcare

Edited by
Hilary Pinnock, Vitalii Poberezhets
and David Drummond

Editor in Chief
Peter M.A. Calverley

This book is one in a series of *ERS Monographs*. Each individual issue provides a comprehensive overview of one specific clinical area of respiratory health, communicating information about the most advanced techniques and systems required for its investigation. It provides factual and useful scientific detail, drawing on specific case studies and looking into the diagnosis and management of individual patients. Previously published titles in this series are listed at the back of this *Monograph*.

ERS Monographs are available online at books.ersjournals.com and print copies are available from www.ersbookshop.com

Editorial Board: Christian B. Laursen (Deputy Chief Editor; Odense, Denmark), Francesco Bonella (Essen, Germany), Daniela Gompelmann (Vienna, Austria), David S. Hui (Hong Kong), and Maria Molina Molina (Catalunya, Spain).

Managing Editor: Rachel Gozzard
European Respiratory Society, 442 Glossop Road, Sheffield, S10 2PX, UK
Tel: 44 114 2672860 | E-mail: monograph@ersnet.org

Production and editing: Caroline Ashford-Bentley, Alice Bartlett, Clarissa Charles, Jonathan Hansen, Claire Marchant, Catherine Pumphrey and Kay Sharpe

Published by European Respiratory Society ©2023
December 2023
Print ISBN: 978-1-84984-172-6
Online ISBN: 978-1-84984-173-3
EPUB ISBN: 978-1-84984-174-0
Print ISSN: 2312-508X
Online ISSN: 2312-5098

Typesetting by Nova Techset Private Limited
Printed by Charlesworth Press, Wakefield, UK

All material is copyright to European Respiratory Society. It may not be reproduced in any way including electronic means without the express permission of the company.

Statements in the volume reflect the views of the authors, and not necessarily those of the European Respiratory Society, editors or publishers.

Member since 2009
JM04643

STM Member 2023

THOMSON REUTERS BOOK CITATION INDEX INDEXED

ERS | *monograph*

Contents

Digital Respiratory Healthcare

Number 102
December 2023

Preface

Peter M.A. Calverley

We live in a digital age. For some of us, this is still something of a shock, given the speed and scope of change in the last 20 years. We carry powerful computers called smartphones in our pockets, ask smartspeakers about the weather and bank online rather than queuing up in person. It is not surprising that these changes have affected respiratory medical practice. We no longer carry bundles of heavy X-ray films with us or write prescriptions by hand on a paper chart. It is now possible to consult remotely with our patients, deliver care at a distance and electronically encourage treatment adherence. Yet each of these promising developments carries the risk of disenfranchising some of our most disadvantaged patients and diminishing the human interactions that have such therapeutic power in medicine.

What we need is an authoritative, up-to-date and balanced account of how the new field of digital respiratory health is developing. This is exactly what Hilary Pinnock, Vitalii Poberezhets and David Drummond have given us in this superb new issue of our *Monograph*. By combining reviews of general principles with specific examples, their contributors show us both the potential and the challenges of this exciting field. Digital medicine is moving from being a technology in search of a problem, to providing novel solutions to the challenges of expanding healthcare need. This issue is an essential guide to this new world, and it will repay your careful study.

Disclosures: P.M.A. Calverley reports receiving grants, personal fees and non-financial support from pharmaceutical companies that make medicines to treat respiratory disease. This includes reimbursement for educational activities and advisory work, and support to attend meetings.

Copyright ©ERS 2023. Print ISBN: 978-1-84984-172-6. Online ISBN: 978-1-84984-173-3. Print ISSN: 2312-508X. Online ISSN: 2312-5098.

https://doi.org/10.1183/2312508X.10017023

Guest Editors

Hilary Pinnock

Hilary Pinnock is Professor of Primary Care Respiratory Medicine at the University of Edinburgh (Edinburgh, UK). She leads programmes of work in the Asthma UK Centre for Applied Research and the RESPIRE Global Health Research Unit funded by the National Institute for Health and Care Research. She is co-Lead of the European Respiratory Society (ERS) Clinical Research Collaboration CONNECT, which focuses on implementation of digital respiratory care.

Building on a career as a family physician, her research focusses on delivery of care. Specific examples include the IMP^{2}ART (IMPlementing IMProved Asthma self-management as RouTine) programme of work, which developed and evaluated implementation strategies that facilitate supported asthma self-management in routine care, and the Telescot programme, which tested and implemented digital health for respiratory and other noncommunicable diseases. With the RESPIRE team in Bangladesh, India and Malaysia, she is leading a programme of work delivering pulmonary rehabilitation (both home-based and centre-based) in low-resource settings, which will be evaluated in the PuRe trial (funded by the Medical Research Council). Previous projects include exploring supportive care for people with severe COPD and the potential of general practitioners with special clinical interests to enhance healthcare delivery. Building research capacity is embedded in this work and all the programmes have attached PhD students, incorporate Masters and undergraduate projects, and support the professional development of early career researchers.

Hilary is Chair of the Education Council of the ERS and has been actively involved with the International Primary Care Respiratory Group (IPCRG). She is a member of the British Thoracic Society (BTS)/Scottish Intercollegiate Guidelines Network (SIGN) British Asthma Guideline Development Group, and is an Associate Editor of *npj Primary Care Respiratory Medicine*.

Copyright ©ERS 2023. Print ISBN: 978-1-84984-172-6. Online ISBN: 978-1-84984-173-3. Print ISSN: 2312-508X. Online ISSN: 2312-5098.

https://doi.org/10.1183/2312508X.10017123

Vitalii Poberezhets

Vitalii Poberezhets is an Assistant Professor of the Department of Propedeutics of Internal Medicine at the National Pirogov Memorial Medical University (Vinnytsya, Ukraine). He is an adult pulmonologist and clinical researcher with a particular interest in airway diseases. From 2018 to 2022, he was a PhD student in internal medicine at the National Pirogov Memorial Medical University.

Vitalii is an active member of the European Respiratory Society (ERS), with expertise in m-health/e-health technologies in particular. He is Chair of the m-Health/e-health Group of the ERS, and is author and compiler of the monthly literature update on telemedicine of clinically relevant English-language articles for members of the group. Vitalii has participated in numerous activities as a speaker, highlighting various aspects of digital technology use in respiratory medicine, as follows: at the ERS Congresses of 2020, 2021, 2022 and 2023; at the ERS Presidential Summit in 2021, "Digital respiratory medicine – realism *vs* futurism"; in an ERS webinar entitle "Evidence-based eHealth for COPD"; and at a joint meeting organised by the World Health Organization (WHO) and the ERS entitled "Digital innovations, TB and implementation research".

Vitalii is a current and GOLD Assembly member (Ukraine national delegate). He was a member of the World Health Organization (WHO) Digital Health Roster of Experts (2020–2022). Vitalii is co-chair of the American Thoracic Society (ATS) project for home-based monitoring using spirometry and pulse oximetry in adults with chronic lung disease. He is a current member of the Ukrainian working group on the development of a national standard for the management and treatment of COPD.

https://doi.org/10.1183/2312508X.10017123

David Drummond

David Drummond is a paediatric pulmonologist at the University Hospital Necker-Enfants Malades (Paris, France) and Associate Professor at the Université de Paris Cité (Paris). His research focuses on digital health for children with respiratory diseases, and in particular on how continuous home monitoring of these children can lead to timely and personalised care.

David is the principal investigator of several studies using connected inhalers (ClinicalTrials.gov NCT04810169) or social robots (ClinicalTrials.gov NCT04942639), and was elected in January 2022 as secretary of the m-Health/e-health Group of the European Respiratory Society (ERS).

Within ERS, David is a member of the core group of the CONNECT clinical research collaboration (Moving multiple digital innovations towards connected respiratory care: addressing the over-arching challenges of whole systems implementation) launched in 2023.

https://doi.org/10.1183/2312508X.10017123

Introduction

Hilary Pinnock [1,2], Vitalii Poberezhets [3] and David Drummond [4]

[1]Usher Institute, University of Edinburgh, Edinburgh, UK. [2]Whitstable Medical Practice, Whitstable, UK. [3]Department of Propedeutics of Internal Medicine, National Pirogov Memorial Medical University, Vinnytsya, Ukraine. [4]Department of Pediatric Pulmonology and Allergology, University Hospital Necker-Enfants Malades, AP-HP; Université Paris Cité; Inserm UMR 1138, HeKA team, Centre de Recherche des Cordeliers, Paris, France.

Corresponding author: Hilary Pinnock (hilary.pinnock@ed.ac.uk)

@ERSpublications
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

Copyright ©ERS 2023. Print ISBN: 978-1-84984-172-6. Online ISBN: 978-1-84984-173-3. Print ISSN: 2312-508X. Online ISSN: 2312-5098.

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

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

https://doi.org/10.1183/2312508X.10016623

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

 https://doi.org/10.1183/2312508X.10016623

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].

We thank Professor Peter M.A. Calverley and the editorial team for their guidance, and the many colleagues who have contributed to the writing of the different chapters and have given willingly of their expertise. We hope their insights will catalyse further interest and enquiry so that implementation of digital healthcare addresses the challenges and mitigates the disadvantages, ultimately realising the benefits for people with respiratory conditions.

References

1 Shaping Europe’s digital future. Luxembourg, Publications Office of the European Union, 2020.
2 Lupiáñez-Villanueva F, Gunderson L, Vitiello S, *et al.* Study on Health Data, Digital Health and Artificial Intelligence in Healthcare. Brussels, European Commission, 2021.
3 Aceto G, Persico V, Pescapé A. The role of information and communication technologies in healthcare: taxonomies, perspectives, and challenges. *J Netw Comput Appl* 2018; 107: 125–154.
4 World Health Organization. Future of Digital Health Systems: Report on the WHO Symposium on the Future of Digital Health Systems in the European Region. Copenhagen, WHO, 2019.

5 World Health Organization. Global Diffusion of eHealth: Making Universal Health Coverage Achievable. Report of the Third Global Survey on eHealth. Geneva, WHO, 2019.
6 Health Foundation and Nuffield Trust. The remote care revolution during COVID-19. https://www.nuffieldtrust.org.uk/sites/default/files/2020-12/QWAS/digital-and-remote-care-in-covid-19.html#1 Date last accessed: 17 September 2023.
7 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.
8 Digital Therapeutics Alliance. Understanding DTx. A New Category of Medicine. https://dtxalliance.org/understanding-dtx Date last accessed: 22 September 2023.
9 Uzzaman MN, Agarwal D, Chan SC, *et al.* Effectiveness of home-based pulmonary rehabilitation: systematic review and meta-analysis. *Eur Respir Rev* 2022; 31: 220076.
10 Pinnock H. Connecting professionals and patients: how technology can support asthma self-management. *Respir Drug Del Eur* 2017; 1: 43–52.
11 Pinnock H, Murphie P, Vogiatzis I, *et al.* Telemedicine and virtual respiratory care in the era of COVID-19. *ERJ Open Res* 2022; 8: 00111-2022.
12 James HM, Papoutsi C, Wherton J. 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.
13 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: e6731.
14 Hart JT. The inverse care law. *Lancet* 1971; 297: 405–412.
15 UK Government Digital Service. Data Ethics Framework 2020. www.gov.uk/government/publications/data-ethics-framework Date last accessed: 22 September 2023.
16 European Commission. European Health Data Space 2022. https://health.ec.europa.eu/ehealth-digital-health-and-care/european-health-data-space_en Date last accessed: 22 September 2023.
17 European Respiratory Society. ERS submission to the European Commission's proposal on the European Health Data Space. www.ersnet.org/wp-content/uploads/2022/08/ERS-submission-EHDS.pdf Date last accessed: 22 September 2023.
18 OpenAI. Introducing Chat GPT. https://openai.com/blog/chatgpt Date last accessed: 22 September 2023.
19 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.
20 ERS Presidential summit 2021. Digital respiratory medicine – realism *vs* futurism. www.ersnet.org/events/ers-presidential-summit-2021 Date last accessed: 22 September 2023.
21 Daines L, Buekers J, Abascal-Bolado B, *et al.* ERS International Congress 2020: highlights from the General Pneumology Assembly. *ERJ Open Res* 2021; 7: 00841-2020.
22 Gille T, Sivapalan P, Kaltsakas G, *et al.* European Respiratory Society International Congress 2021: highlights from the Respiratory Clinical Care and Physiology Assembly). *ERJ Open Res* 2022; 8: 00710-2021.
23 Vontetsianos A, Karadeniz Güven D, Betka S, *et al.* European Respiratory Society International Congress 2022: highlights from the Respiratory Clinical Care and Physiology Assembly. *ERJ Open Res* 2023; 9: 00194-2023.
24 Poberezhets V, Pinnock H, Vogiatzis I, *et al.* Implementation of digital health interventions in respiratory medicine: a call to ERS action by the m-health/e-health group. *ERJ Open Res* 2020; 6: 00281-2019.
25 European Lung Foundation. Patient Organisation Networking Day 2021. Digital health: the role of patients and their healthcare teams in the future of healthcare. https://europeanlung.org/en/elf-patient-organisation-networking-day-2021/ Date last accessed: 22 September 2023.
26 Campbell JL, Fletcher E, Britten N, *et al.* Telephone triage for management of same-day consultation requests in general practice (ESTEEM trial): a cluster-randomised controlled trial and cost-consequence analysis. *Lancet* 2014; 384: 1859–1868.
27 Wanat M, Hoste ME, Gobat NH, *et al.* Patients' and clinicians' perspectives on the primary care consultations for acute respiratory infections during the COVID pandemic: an 8-country qualitative study in Europe. *BJGP Open* 2022; 6: BJGPO.2021.0172.
28 Boers SN, Jongsma KR, Lucivero F, *et al.* 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.
29 Orlando JF, Beard M, Kumar S. Systematic review of patient and caregivers' satisfaction with telehealth video-conferencing as a mode of service delivery in managing patients' health. *PloS One* 2019; 14: e0221848.
30 van Boven JFM, Drummond D, Chan AHY, *et al.* ERS "CONNECT" Clinical Research Collaboration – moving multiple digital innovations towards connected respiratory care: addressing the over-arching challenges of whole systems implementation. *Eur Respir J* 2023; 62: 2301680.
31 Shaw SE, Hughes G, Wherton J, *et al.* Achieving spread, scale up and sustainability of video consulting services during the Covid-19 pandemic? A comparative case study of policy implementation in England, Wales, Scotland and NI. *Front Digit Health* 2021; 3: 754319.

32 Sunyer-Vidal J-G, Rodes M, Lupiáñez-Villanueva F. Policy context for digital transformation: benefits and challenges of implementing EU digital health regulation. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 132–141.
33 Heads of Medicines Agencies - European Medicines Agency. HMA-EMA Joint Big Data Taskforce. www.ema.europa.eu/en/about-us/how-we-work/big-data Date last accessed: 22 September 2023.
34 Cano I, Lluch-Ariet M, Gomez-Cabrero D, *et al.* Biomedical research in a digital health framework. *J Translat Med* 2014; 12: 1–9.
35 Norman CD, Skinner HA. eHealth literacy: essential skills for consumer health in a networked world. *J Med Internet Res* 2006; 8: e9.
36 Dimitrov DV. Medical internet of things and big data in healthcare. *Healthc Inform Res* 2016; 22: 156–163.
37 Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices, amending Directive 2001/83/EC, Regulation (EC) No 178/2002 and Regulation (EC) No 1223/2009 and repealing Council Directives 90/385/EEC and 93/42/EEC 2017. https://data.europa.eu/eli/reg/2017/745/oj/eng Date last accessed: 17 September 2023.
38 Andrikopoulou E, Scott PJ, Herrera H. Important design features of personal health records to improve medication adherence for patients with long-term conditions: protocol for a systematic literature review. *JMIR Res Protoc* 2018; 7: e159.
39 Angelucci A, Aliverti A. The Medical Internet of Things: applications in respiratory medicine. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 1–15.
40 Licari A, Ferrante G, Malizia V, *et al.* Medical assistive robots. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 16–26.
41 Cano I, Arismendi E, Borrat X. Digital health frameworks. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 27–37.
42 Markus AF, Arinze JT, Verhamme KMC. Big data: challenges and opportunities within respiratory care. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 38–50.
43 Exarchos K, Kostikas K. Artificial intelligence. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 51–62.
44 Gilbert S. European regulation of digital respiratory healthcare. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 63–78.
45 Kayser L, Phanareth K. Leave no one behind: the role of digital health literacy. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 79–94.
46 Hansen C, Ringel M, Evans L, *et al.* Leave no community behind: the digital divide. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 95–106.
47 Andrikopoulou E, Thwaites T, De Vos R. Rapport and ethics in a digital world: impact on individuals. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 107–121.
48 Drummond D, Gonsard A, Robinson PD. Digital respiratory medicine for children and young people. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 122–131.
49 Lokmic-Tomkins Z, Davies S, Bhandari D, *et al.* Interconnectedness of digital health, climate change and respiratory care: navigating an environmentally sustainable path forward. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 142–159.
50 Mittelstadt B. The impact of artificial intelligence on the doctor-patient relationship. Strasbourg, Council of Europe, 2021.
51 Royal College of General Practitioners. Relationship-based care. www.rcgp.org.uk/representing-you/policy-areas/relationship-based-care Date last accessed: 17 September 2023.
52 Drummond D, Coulet A. Technical, ethical, legal, and societal challenges with digital twin systems for the management of chronic diseases in children and young people. *J Med Internet Res* 2022; 24: e39698.
53 Sijm-Eeken ME, Arkenaar W, Jaspers MW, *et al.* Medical informatics and climate change: a framework for modeling green healthcare solutions. *J Am Med Inform Assoc* 2022; 29: 2083–2088.
54 Poberezhets V, Kasteleyn MJ, Aardoom JJ. The use of digital health solutions for COVID-19: pandemic surveillance, remote monitoring and big data. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 160–169.
55 Fielding KL, Subbaraman R, Khan A, *et al.* The use of digital technologies in adherence to anti-tuberculosis treatment. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 170–184.

56 Chan AHY, van Boven JFM. Digital adherence interventions for asthma. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 185–198.
57 Pinnock H, McClatchey K, Hui CY. Supported self-management in asthma. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 199–215.
58 Disler R, Ly L, Carter D, *et al.* Telehealth in COPD. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 216–228.
59 Meijer E, Mansour MBL. Digital approaches to smoking cessation. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 230–236.
60 Fauroux B, Bonsignore MR, Verbraecken J. Remote consultations in sleep disorders. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 236–249.
61 Bui S, Galodé F, Macey J, *et al.* Remote monitoring in children and adults with cystic fibrosis. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 250–260.
62 Hume E, Megaritis D, Vogiatzis I. Telerehabilitation in chronic respiratory disease. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 261–275.
63 Chassagnon G, Marini R, Canniff E, *et al.* Artificial intelligence for interstitial lung disease assessment on chest CT. *In*: Pinnock H, Poberezhets V, Drummond D, eds. Digital Respiratory Healthcare (ERS Monograph). Sheffield, European Respiratory Society, 2023; pp. 276–286.

Disclosures: H. Pinnock is a principal investigator on research grants in supported self-management and the implementation of digital respiratory health. She does not stand to gain financially from this chapter. V. Poberezhets has nothing to disclose. D. Drummond is the Secretary of the m-Health/e-health Group at the European Respiratory Society (ERS). He is the principal investigator of several ongoing studies involving electronic monitoring devices (NCT04810169) and social robots (NCT04942639), the latter being funded by the company Ludocare.

https://doi.org/10.1183/2312508X.10016623