European Respiratory Society International Congress, Barcelona, 2022

Highlights from the Respiratory clinical care and physiology assembly

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Take-home message: In this article, we provide an overview of some of the highlights from the Respiratory clinical care and physiology assembly (@ERSAssembly1) presented during the last edition of the @EuroRespSoc International Congress held in Barcelona in September 2022

Abstract

It is a challenge to keep abreast of all the clinical and scientific advances in the field of respiratory medicine. This article contains an overview of laboratory-based science, clinical trials and qualitative research that were presented during the 2022 European Respiratory Society International Congress within the sessions from the five groups of the Assembly 1 – Respiratory clinical care and physiology. Selected presentations are summarised from a wide range of topics: clinical problems, rehabilitation and chronic care, general practice and primary care, electronic/mobile health (e-health/m-health), clinical respiratory physiology, exercise and functional imaging.

Keywords: COPD, Asthma, COVID-19, Pulmonary Rehabilitation, Supported Self-management, Dyspnoea

Introduction

The 2022 edition of the European Respiratory Society (ERS) International Congress was held in hybrid format. It provided a much-valued occasion to meet in-person again, as well as an important opportunity to hear about the latest developments in research and clinical practice in the world's largest scientific and educational conference in the field of respiratory medicine. This year, 3,540 abstracts were accepted for presentation and 20,709 delegates attended some of the 360 sessions (14,159 onsite in Barcelona and 6,550 online).

Assembly 1 – Respiratory clinical care and physiology is the largest of the 14 ERS assemblies, comprising 7,756 members, 38% of them being under 40 years old (early-career members). During the 2022 International Congress, Assembly 1 was proud to honour Prof. Dr. Robin Vos with an ERS Mid-Career Gold Medal in Respiratory Clinical Care and Physiology. Among the 727 abstracts submitted across the five groups within the assembly, 545 were accepted for presentation. Although the virtual platform allowed presentations to be replayed, it can be challenging to keep up to date with all the scientific and clinical advances. This article, therefore, aims to share some of the highlights from the Respiratory clinical care and physiology assembly.

Group 1.01: Clinical problems

The ERS International Congress highlighted novel findings regarding frequent respiratory diseases, such as airway diseases and coronavirus disease 2019 (COVID-19) (*table 1*).

Management of exacerbations in airway diseases

Patients with chronic obstructive pulmonary disease (COPD) often need to be hospitalised due to exacerbations of their underlying disease, imposing a significant clinical and economic burden on the healthcare system [1]. Hence, it is crucial to apply evidence-based strategies for preventing these hospital readmissions. *Burns et al.* (Glasgow) utilised machine learning models to predict three-month readmission of COPD patients following a respiratory hospitalisation, based on previous clinical data from patients' health records. Using data from a Scottish nationwide cohort of 33,148 patients, the researchers concluded that the artificial intelligence (AI)-based three-month respiratory readmission prediction model performance was promising and that it could be used in the clinical practice [2].

Acute exacerbations of COPD may lead patients to severe respiratory failure, requiring mechanical ventilation and prolonged stays in intensive care unit (ICU) [3]. Even so, the outcome of prolonged weaning in patients with COPD is still uncertain. *Wollsching-Strobel et al*. (Koln) analysed 2,937 COPD patients from the WeanNet cohort of specialised German weaning centres. Increased mortality due to weaning failure was associated with advanced age and duration of mechanical ventilation. It was demonstrated that transfer from the ICU to a specialised weaning centre could result in successful weaning in more than 60% of cases. Furthermore, they showed that tracheostomy status and initial destination following discharge greatly depend on the weaning outcome [4].

In the Middle Eastern cohort SABINA III, a cross-sectional study demonstrated that 38% of 8,351 asthmatic patients across 23 countries were prescribed ≥3 canisters of short-acting beta-agonists (SABAs) per year [5]. According to Global Initiative for Asthma (GINA) guidelines, this treatment plan is no longer recommended without the concomitant use of inhaled corticosteroids [6]. Through a univariate post-hoc analysis, *Al Zaabi et al*. (Abu Dhabi) showed that a significantly higher percentage of patients prescribed ≥3 *vs* 1–2 SABA canisters/year with

uncontrolled asthma (35.6% *vs* 21.2%), reported one (24.6% *vs* 21.0%), two (14.2% *vs* 9.3%) or ≥3 severe asthma exacerbations (18.0% vs 11.0%) [7]. Therefore, it is important for clinicians to identify this group of patients who are at risk of SABA overuse in order to ameliorate asthma outcomes globally.

Cancer risk in patients with asthma-COPD overlap

Chronic inflammation is the main underlying pathophysiologic mechanism in COPD and asthma. Tobacco consumption and COPD are associated with an increased risk of malignancy [8], but the effect of asthma on cancer incidence is yet inconclusive. *Bonnesen et al*. (Copenhagen) aimed to determine whether asthma was associated with an increased risk of cancer among COPD patients and the role of inhaled corticosteroids (ICS) as anti-inflammatory agents. A total of 50,897 COPD patients from Danish registries were included in the study, and separated into two groups: COPD without asthma, and COPD with concomitant asthma (based on the diagnosis of a respiratory medicine physician). Their risk for any cancer diagnosis was evaluated within the following two years. Results showed that there was no association between asthma-COPD overlap and cancer, and that ICS use did not seem to modify the risk for malignancy [9].

Coagulation impairments in COVID-19

The coagulation patterns present during COVID-19 pneumonia are not necessarily reflected in regularly used coagulation tests, which may not offer sufficient information on the haemostasis process in these patients. Therefore, *Loutsidi et al.* (Glyfada, Greece) explored an alternative in their study including 22 patients. Using rotational thromboelastometry (ROTEM), they monitored blood coagulation of patients hospitalised with COVID-19 at admission, during clinical deterioration, at discharge, and at one-month follow-up. They found that changes in the ROTEM variables were correlated to disease severity, and that the disease course followed changes

seen in ROTEM [10]. This is in line with other studies that used similar methods, including thromboelastography, which were able to detect and diagnose hypercoagulability in patients with COVID-19, enabling relevant treatment [11].

During hospitalisation with COVID-19, biomarkers may help in either determining relevant treatment or being able to predict patient outcomes. One such possible biomarker is the plasminogen activator inhibitor-1 (PAI-1). *Bielosludtseva et al.* (Dnipro, Ukraine) investigated the potential of PAI-1 to predict prognosis and risk of mortality in 85 patients admitted with COVID-19 pneumonia (40 moderate, 25 severe, 20 critical). They showed that the risk of mortality was 219-fold higher [95% confidence interval: 8–6224] in patients with increased PAI-1 on admission above 20.6 ng/L, compared to the others, with good sensitivity and specificity of this cut level (area under the receiver operating characteristic (ROC) curve: 0.78). Furthermore, when analysing autopsies, they showed that defects in fibrinolysis may play a role in thrombogenesis in COVID-19 patients [12]. In a previous study conducted in the USA, the investigators had also shown that elevated PAI-1 level was associated with hospitalisation due to COVID-19 and worse respiratory status. They also found that higher level of tissue-type plasminogen activator (tPA) was correlated to mortality [13]. These works strongly suggest an imbalance between fibrinolysis and coagulation in COVID-19 patients that requires further research.

Consequences of COVID-19 inflammation

A Polish study, conducted in 77 patients by *Martusewicz-Boros et al*. (Warsaw), aimed to determine risk factors for myocarditis shortly after hospitalisation for COVID-19. The investigators used cardiac magnetic resonance imaging (MRI) and discovered that 43**%** of patients had signs of active myocarditis at one-month follow-up. Risk factors associated with developing this condition were: male sex, ever-smoking, as well as low transfer capacity of the lung for carbon monoxide (TL_{CO}) [14]. A review focusing on post-COVID-19 myocarditis found that between 8-30% of patients showed myocarditis on cardiac MRI following infection by

severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The differences in disease severity, as well as whether the patients were hospitalised or not, and the criteria to define myocarditis on MRI, could explain the prevalence discrepancies [15]. The study by *Martusewicz-Boros et al*., for example, included patients with moderate-to-severe COVID-19 who had needed hospitalisation.

Elneima et al. (Leicester, UK) presented their study in which they used proteomics to compare the inflammatory markers and profiling of 626 patients following hospitalisation for COVID-19, in order to investigate further the characteristics and mechanisms of having post-COVID-19 condition. They divided patients into four clusters of different severity based on clinical data, five months after hospitalisation, and assessed 296 proteins. Thirteen of these proteins were significantly increased in the group of patients with very severe post-COVID-19 condition, and two proteins were elevated in the moderate/cognitive cluster, when comparing to the mild cluster [16, 17]. Subsequent studies assessing these proteins might help to predict people at risk of poor long-term outcome and better understand the pathophysiology of persistent post-COVID-19 symptoms.

Group 1.02: Rehabilitation and chronic care

The session entitled "*Best abstracts in pulmonary rehabilitation and chronic care*" included nine state of the art abstracts that covered a broad range of topics including exercise training, pulmonary rehabilitation (PR), COVID-19, and telemonitoring (*table 2*).

Exercise training and PR in chronic respiratory diseases

Ward et al. (Leicester) conducted a network meta-analysis of 28 randomised controlled trials (RCTs) to understand the effectiveness of different components of exercise training programmes to improve cardiorespiratory fitness. High intensity aerobic exercise training was shown to be more effective at improving maximal oxygen uptake ($\dot{V}O_2max$) in COPD patients, compared to stair climbing and low intensity training [18]. However, the specific type or intensity of exercise to optimise training adaptations remain to be established. This study underlines the importance of prescribing aerobic exercise for COPD, and the use of component network analysis to understand which types of exercise training in the PR setting are effective.

There is a need to personalise and adapt exercise modalities for patients with severe COPD. Eccentric training has gained interest in recent years, as it is less demanding on the cardiorespiratory system, but effective in improving muscular strength and functional performance [19]. Twelve subjects suffering from severe COPD were enrolled in a three-week PR programme and randomly allocated to either downhill walking with 10% inclination and eccentric resistance training, or to standard PR with a cycle ergometer and conventional resistance training. The preliminary results of this pilot study conducted by *Pancera et al*. (Manerbio, Italy) suggested that low-load eccentric training may lead to improved functional performance and be safely prescribed in people with severe COPD [20].

In people suffering from idiopathic pulmonary fibrosis (IPF), PR is known to improve functional exercise capacity, dyspnoea, and health-related quality of life. However, the impact on patient's

mood has yet to be determined [21]. Of 235 patients referred for an eight-week PR programme in the study presented by *Edwards et al*. (Ilford, UK), 35% had symptoms of anxiety and 37% depression using Hospital Anxiety Depression Score (HADS). The programme included an educational session focusing on psychological well-being. Symptoms of depression improved in the 166 patients (64%) who completed the programme, whereas anxiety symptoms only improved in those with HADS anxiety score ≥8 points. Using an anchor-based statistical method, an improvement of -2.0 points for anxiety and -1.2 points for depression scores were considered as the minimal clinically important difference (MCID) [22].

Grosbois et al. (Lille, France) aimed to evaluate the impact of a home-based PR programme on the well-being of 138 caregivers of COPD patients involved in an eight-week programme of 90-minute sessions. Caregivers received education on healthy behaviours, motivation and psychosocial support, and physical activity promotion, using the same methods as for patients. Baseline anxiety/depression symptoms and high burden were reported by 40% of caregivers, and 50% had abnormal fatigue. The intervention resulted in a significant improvement of all these descriptors. This study highlights the burden in caregivers and family members of patients with chronic respiratory diseases, and the importance of integrating caregivers into PR [23].

Biomarkers, long-term consequences, and management of COVID-19

Identifying novel biomarkers to improve our understanding of COVID-19 remains a key priority. *Shchudro et al*. (Dnipro, Ukraine) conducted a study to assess the role of surfactant protein-A (SP-A), measured in 75 COVID-19 survivors at six weeks after the infection and 15 healthy controls. No significant difference was observed in SP-A between patients with moderately severe COVID-19 and controls ($p>0.05$), whereas SP-A was significantly higher in those with severe or critical COVID-19 ($p<0.01$). A strong positive correlation was observed between SP-A and the severity of dyspnoea [24]. Interestingly, another recent study suggested that SP-A could be a useful predictor of lung lesion after COVID-19 [25].

A UK-based multicentre study presented by *Baldwin et al*. (Leicester) evaluated exercise tolerance five and twelve months after COVID-19 hospitalisation discharge, and assessed self-reported reasons for intolerance. This interim analysis (n=378) indicated that twelve months after discharge, 75% of patients had impaired exercise capacity (≤80% predicted in the incremental shuttle walk test). Exercise capacity remained unchanged between five and twelve months, independent of the limiting symptom [26]. These findings underline the importance of developing effective rehabilitation strategies to increase exercise capacity in people recovering from COVID-19.

Post-COVID-19 condition remains a major public health issue, and there is still a lack of evidence-based interventions to rehabilitate this population [27]. *Philip et al*. (London, UK) presented findings from a parallel-group, single blind, RCT that aimed to evaluate, in 158 patients with persisting symptoms after COVID-19, the impact of an online breathing and well-being programme including singing exercise (ENO Breathe) on persistent symptoms and health-related quality of life (HRQoL). The results indicated that ENO breathe was a safe and well-tolerated intervention, that improved the mental component of the Short Form 36 (SF-36) questionnaire and elements of breathlessness (as assessed by a visual analogue scale and the Dyspnoea-12 questionnaire) [28].

Telemonitoring for non-invasive ventilation

Pontier-Marchandise et al. (Toulouse, France) presented a retrospective study that evaluated the quality of ventilation (defined as compliance >4hr, non-intentional leaks <24 L/min, apnoea-hypopnea index <10/hr) in patients receiving home non-invasive ventilation (NIV) as part of a telemonitoring programme. In total, 155 COPD and 187 non-COPD (*i.e.*, obesity, hypoventilation syndrome, restrictive lung disease) patients were included in the analysis. At baseline, 76% of patients had good quality ventilation, which improved to 87% following one

year of telemonitoring. The authors concluded that NIV telemonitoring may improve ventilation quality, even in patients who had used NIV for several years [29].

Bronchoscopic lung volume reduction in COPD

Bronchoscopic lung volume reduction (BLVR) with endobronchial valves is an established treatment option to reduce pulmonary hyperinflation in COPD [30]. However, the impact on cardiac preload and pulmonary artery pressure remains unknown. *Van der Molen et al*. (Groningen, the Netherlands) presented novel data from 24 patients with severe COPD who had undergone cardiac MRI pre- and eight weeks post-BLVR. They observed a significant reduction in hyperinflation (as assessed by the ratio of residual volume/total lung capacity, RV/TLC) after the procedure, which resulted in a clinically meaningful improvement in pre-load, stroke volume, cardiac output, and contractility (for both ventricles). Interestingly, no change in pulmonary artery pressure was observed, and the researchers hypothesised that the increase in blood flow following BLVR was related to the reduction of extravascular pressure, due to improved hyperinflation [31].

Group 1.03: General practice and primary care

Important topics aiming to improve respiratory management in general practice and primary care were reviewed in the 2022 ERS Congress (*table 3*).

Rationale for a closer follow-up of COPD patients

As outlined in the 2022 report of the Global Initiative for Chronic Obstructive Lung Disease (GOLD), the risk of future exacerbations in newly diagnosed COPD can be difficult to predict [32]. *Løkke et al*. (Aarhus) presented the outcomes of an observational cohort study comparing 3,958 GOLD A0 (with no exacerbations) and 3,223 GOLD A1 (with one moderate exacerbation within the previous year) COPD patients followed over three years in Denmark. The

investigators concluded that "*even in COPD patients with a low symptom burden, one moderate exacerbation increases the odds of subsequent exacerbations and death*" (odds ratio for death: 1.91 [1.58–2.31]) [33]. This study, highlighting the importance of prevention, treatment, and yearly control in GOLD A patients, was awarded the best abstract for ERS Assembly 1.

Sandelowsky et al. (Uppsala) retrospectively analysed Swedish nationwide data about 19,857 patients with a first-time COPD diagnosis between 2006 and 2017. Over the 11-year study period, the probability of having a follow-up visit within 15 months post-diagnosis increased from 17.4% in 2006 to 53.4% in 2017. In the 15,095 patients who experienced their first COPD exacerbation, the overall probability of having a post-exacerbation visit within six weeks was 7%, rising to 29.4% when extending the follow-up period to 15 months. The latter increased from 11.0% in 2006 to 38.3% in 2017. Despite the fact that follow-up visits have become more frequent over the last decade, there is still room for improvement in adherence to guidelines in COPD management [34].

Supported self-management in asthma

Asthma causes 6.3 million general practitioner (GP) consultations a year and 600,000 hospital admissions in UK. Supported self-management for asthma reduces attacks and improves asthma control [35]. Implementing Improved Asthma Self-Management as Routine in primary care (IMP²ART) is a three-level implementation strategy including providing patient resources, developing professional skills, influencing organisational priorities and routines [36]. The pilot phase reported by *McClatchey et al*. (Edinburgh), having randomised 12 GP practices (implementation arm or usual control arm) showed that IMP²ART was acceptable and feasible [37].

Nested within the IMP²ART programme, *Kinley et al*. (Edinburgh) explored the differences in delivery of supported self-management between five practices of the implementation arm and

five controls, using video-recorded asthma reviews and interviews with healthcare professionals. Implementation practices delivered a more patient-centred review, used more behaviour change techniques, and spent more time within consultations discussing supported self-management related strategies [38].

Additional presentations

The ageing population and its burden on health-care systems warrant early detection of patients at risk of functional decline and mortality. *Wijnant et al*. (Rotterdam) reported the outcomes of a Dutch population-based study (n=5,442) assessing frailty transitions and their accuracy for mortality prediction in subjects with impaired spirometry. Patients with either a decreased ratio of forced expiratory volume in one second related to forced vital capacity (FEV1/FVC) <0.7, or FEV1 <80% of mean predicted value, were less likely to recover from frailty, and more likely to progress from any frailty state towards death, compared to individuals with normal spirometry. The accuracy of a statistical model (including age, sex, and smoking status) to predict mortality in patients with FEV1/FVC <0.7 was significantly improved when incorporating frailty score (area under ROC curves: 90.5 [82.3–89.8] *vs* 77.9 [67.2–88.6]) [39].

Finally, *Doe et al*. (Leicester) presented a feasibility study investigating the impact of a structured diagnostic pathway designed to confirm or exclude the five most common causes of chronic breathlessness over 40 years old: COPD, anxiety, anaemia, hearth failure, and obesity/deconditioning [40]. Forty-eight patients were included in ten GP practices. At one year, a coded diagnosis was reached in 44% of patients in the intervention group *vs* 26% in the usual care group, with a significant improvement in patient reported outcome measures (PROMs), paving the way for an adequately powered, forthcoming RCT [41].

Brief report of the symposium "Forgotten issues in COPD: a primary care perspective"

Many of the difficulties faced by patients suffering from COPD are under investigated, with few recommendations in guidelines, and neglected by physicians, due to lack of confidence and skills in these specific issues [42]. In too many cases, the management of COPD is considered to be limited to inhalation therapy [43].

COPD and mental health

Thirty percent of patients with COPD suffer from depression (increasing to 80% in severe COPD) and 10% to 50% suffer from anxiety [42, 44] with a huge impact on HRQoL and disease control [45]. In order to break the vicious cycle between physical and mental symptoms, addressing the psychological burden could improve not only HRQoL but also treatment adherence [46]. Physicians should adopt a patient-centred approach that focuses on its desires, goals and preferences using OARS skills (Open questions, Affirmations, Reflection and Summary). A number of non-pharmacological approaches proved their efficacy in the management of mental health disorders, specifically cognitive behavioural therapy [47–49], mindfulness [50, 51], and PR [42, 52–54]. The systematic review and meta-analysis of *Taylor et al*. (Birmingham, UK) demonstrated that contrary to popular belief, quitting smoking is associated with an improvement in mental health [55]. More information about the topic is available in the International Primary Care and Respiratory Group desktop helper n°12 [56].

Home-based PR in a digital world: an alternative for low-to-middle income countries?

Despite its importance in the management of chronic respiratory diseases [57, 58], the access to PR is limited in the context of low-to-middle income countries (LMICs). In the review of *Cox et al*. (Melbourne, Australia), no differences were found between telerehabilitation and centre-based rehabilitation [59].Similarly, *Uzzaman et al*. (Edinburgh) concluded that home-based PR is as effective as centre-based PR in terms of functional exercise capacity and HRQoL, and is an option to enhance access to PR in low resource settings [60].

COPD and sexual health

Sexual dysfunction in patients with COPD is the result of interaction between hormonal, physiological, psychological, sociological, and pharmaceutical factors [61]. The prevalence is high in this patient group, especially erectile dysfunction [62, 63]. Sexual dysfunction in women has been rarely studied, although women with COPD have been also reported to have lower frequency of sexual intimacy [63, 64]. The first step in managing sexual health disorders is to approach the discussion within the patient's cultural context, avoid moral or religious judgment, and normalise the conversation − this requires communication skills. Primary care professionals could play a crucial role by promoting adherence to inhalation therapy and giving practical tips, like advising sexual positions that are less likely to cause dyspnoea [65].

A palliative approach to COPD

Although COPD is responsible a prolonged substantial burden, in comparison to cancer, access of patients with COPD to palliative care is very restricted [66], and often takes place only within weeks of death [67, 68]. In the study of *Bloom et al*. (London), only 6% had access *vs* 50% of patients suffering from both COPD and lung cancer [67]. Primary care physicians are urged to implement palliative care early by initiating the discussion with their patients about their needs and concerns, and to use a multi-disciplinary approach involving palliative care specialists as appropriate.

Group 1.04: M-health/e-health

The thematic poster session "*Digital health interventions in respiratory practice*" highlighted a wide range of digital health interventions to support patients' self-management and encourage patients' and providers' adoption of digital technologies. These novel digital health interventions in respiratory practice correspond with the call to action published by m-Health/e-health group in 2020 [69]. Presenters raised the importance of prioritising the end users' needs, involving them in co-designing the solutions early in their development to ensure the technologies are accurate and fits the user's preferences/habit and routine workflow. Moreover, compared to the topics highlighted during the previous ERS Congresses by this group, these presentations showed the evolution of the topics which group members consider as clinically relevant during the last years [70–72] (*table 4*).

Digital health

The definition of digital health is broad, encompassing use of a mobile phone, smart devices (sensors), artificial intelligence, big data and robotics to support patients' healthcare [73].

Jácome et al. (Porto, Portugal) showed the feasibility of using a smartphone microphone to record quality lung sounds and to capture adventitious sounds to support remote monitoring and healthcare [74].

A recent prospective study from *Cerdán-de-las-Heras et al.* (Aarhus) with 54 COPD patients showed that telerehabilitation with a Virtual Autonomous Physiotherapist Agent (TR-VAPA) was non-inferior to traditional hospital-based PR, as assessed by improvement of exercise performances and HRQoL questionnaires [75]. Additionally, complementary data were presented during the Congress showing that TR-VAPA was more cost effective [76].

Digital therapeutics

Digital therapeutics (DTx) products must be certified by regulatory bodies [77] and are defined as "*evidence-based therapeutic interventions that are driven by high quality software programs to prevent, manage, or treat a medical disorder or disease*" [78].

Häussermann et al. (Munich, Germany) tested Kata®, an app aiming to optimise inhalation technique in patients with COPD or asthma. It uses the camera and microphone built-into a mobile phone, and augmented reality, to analyse images and sounds of inhaler technique. In a proof-of-concept study with eight people with asthma, the app reduced overall handling errors and critical errors per inhalation [79].

An Internet-of-Things platform connected with several CE-marked smart devices (smart-inhaler, smart-peak-flow meter, smart-watch) from various brands was developed by *Hui et al.* (Edinburgh) to support asthma self-management. In a proof-of-concept study with ten people with asthma, they found that perceived accuracy of the technology determined adherence to using the technology, and highlighted the need to make digital technologies interoperable [80].

Finally, *Glyde et al.* (Bristol, UK) showed the potential of using machine learning on real-world data collected through the myCOPD app to predict future exacerbations [81]. These works demonstrate the relevance of conducting proof-of-concept studies with end-users to make digital technologies more accurate and attractive to support healthcare.

AI and machine learning

Three types of AI were presented in the session for three distinct purposes: diagnosis, classification, and prediction.

Chest X-rays were used as the input to the AI algorithm to diagnosis pulmonary embolism [82] and detect pneumothorax, airspace opacity, and mass or nodule [83, 84]. *Verdi et al.* (Ankara,

Turkey) used deep learning and multi-centre datasets in a pneumothorax detection algorithm (PDA-alpha) to improve the model generalisability [83]. Similarly, deep learning was used by *Gana et al.* (Harare, Zimbabwe) in another model that achieved a high performance, comparable to radiologists or other models approved for clinical use [84–86].

By analysing respiratory sounds captured by an electronic stethoscope with convolutional neural networks, *Sourour et al.* (Sfax, Tunisia) were able to automatically classify and assign them the correct auscultation [87].

Colom et al. (Barcelona, Spain) used registry data, clinical/functional status information and social care data to generate a predictive model of patients' mortality and readmission risk at 90 days after hospital discharge, and were able to stratify risk profiles into four different clusters [88].

All three approaches show promise as early warning systems to support clinical decisions and remote care in the future. Further development and validation were highlighted as the natural next steps.

Electronic health record

Electronic health record (her) contains rich data and information about patients' conditions and health outcomes after treatments. Several works were presented, by *Morra et al.* and *Moloney et al.* (Port Hope, Canada), suggesting that a standardised data structure is needed to ensure data interoperability between different healthcare organisations, and allow healthcare evaluation across them. A rule-based algorithm was developed to categorise confirmed and suspected asthma patients in an observational study, and support asthma educators to adhere to the best practice guidelines in recognising and managing uncontrolled severe asthma. The authors showed that a machine learning algorithm can be used to classify asthma patients in a future

clinician decision support system, improving asthma underdiagnosis/misdiagnosis, and operating as a surveillance system [89–92].

These works demonstrated the potential of real-world data based on EHR to improve delivered care, but also as a powerful tool to evaluate healthcare quality.

Perceived facilitators, barriers, and caveats

Many digital tools exist at present, but engaging patients to adopt and use them to manage their conditions is challenging.

With an online questionnaire sent to users with interstitial lung disease, *Parsons et al.* (Oxford, UK) found that compliance to home spirometry was favoured by greater disease severity and requirement for treatment. Goal setting, and a patient-led escalation plan in event of deterioration, were facilitators to encourage engagement, whereas a key barrier was the lack of knowledge in spirometry parameters [93].

Smartphone apps for physical activity are not primarily designed for patients [94]. *Dourado et al.* (Santos, Brazil) assessed which features were attractive to individuals with low cardiorespiratory function. The ability to receive suggestions for activity techniques and to monitor progress with graphs and tables were amongst preferred features, contrary to data sharing through social networks and the possibility to "*compete with friends*" [95].

Quach et al. (Concord, Canada) reviewed 437 COPD Android apps in the Google Play store, with features including disease screening, medication reminders, symptom tracking, goal planning and peer networking. However, none of the apps reported effectiveness, feasibility, or usability information to support their use for self-management [96].

Finally, a scoping review by *Hui et al.* (Edinburgh) revealed that digital health implementation in several LMICs (Bangladesh, India, Indonesia, Malaysia, and Pakistan) was restricted by limited

skilled labour, lack of legislation/interoperability support, interrupted electricity and internet services, age/gender and geographical disparities [97].

Group 1.05: Clinical respiratory physiology, exercise and functional imaging

Most abstracts in the session "*Expanding the insight into COVID-19 dyspnoea*" presented data examining breathing pattern or ventilatory inefficiency during cardiopulmonary exercise testing (CPET), while others investigated resting abnormalities or original strategies to lessen dyspnoea after SARS-CoV-2 infection (*table 5*).

Ventilatory inefficiency and "dysfunctional" breathing

During exercise at moderate intensity (*i.e.*, in the absence of metabolic acidosis), minute ventilation ($\dot{V}_E$) is tightly coupled to the rate of carbon dioxide output ($\dot{V}_{CO_2}$) washed-out by the lungs, which serves to keep arterial carbon dioxide tension ($PaCO_2$) constant [98]. In this context, ventilatory inefficiency refers to excessive ventilatory stimuli relative to metabolic demand (*i.e.*, high $\dot{V}_E/\dot{V}_{CO_2}$ ratio) [99, 100]. Poor ventilatory efficiency is a well-known mechanism of exertional dyspnoea in different respiratory disorders, such as COPD [101]. Dysfunctional breathing (DB) may be defined as dyspnoea found in the presence of an abnormal breathing pattern after excluding other potential contributory causes, such as underlying cardiopulmonary conditions [102–104].

In line with these premises, *Piamonti et al.* (Rome, Italy) performed CPET in a group of 20 survivors of moderate-to-critical COVID-19 (n=6 hospitalised in ICU) with residual exertional dyspnoea and/or abnormalities on pulmonary function tests (PFTs) up to 15 months after discharge. At 15 months, $\dot{V}_E/\dot{V}_{CO_2}$ slope >30, signalling poor ventilatory efficiency, was observed in 13/20 (65%) patients. Importantly, $\dot{V}_E/\dot{V}_{CO_2}$ slope was related to the severity of lung involvement on high-resolution computed tomography of the chest (HRCT), and inversely

correlated with TL_{CO}. The authors thus concluded that residual exertional dyspnoea and ventilatory inefficiency may reflect damage in the interstitial/pulmonary capillary structure [105].

Loew et al. (Sion, Switzerland) sought to investigate the perceptual (*i.e.*, symptoms and HRQoL) and functional impact in patients diagnosed with DB after COVID-19. In a sample of 48 patients, the authors reported hyperventilation (21%), erratic breathing (46%), and mixed types of DB (33%). Dyspnoea was the most prevalent symptom, while exercise capacity was preserved. In comparison to healthy controls, HRQoL (SF-36, total score and every sub-domain) was lower in those previously infected by COVID-19 [106]. The same group reported that hyperventilation was associated with greater respiratory rate, while patients showing erratic breathing or mixed types of DB showed greater coefficient of variation in tidal volume and inspiratory time, compared to patients with post-COVID-19 condition but normal CPET. Hyperventilation and mixed types of DB were also associated with steeper $\dot{V}_E/\dot{V}_{CO_2}$ slopes, signalling excessive ventilation relative to metabolic demand [107], providing altogether potential physiological explanations for dyspnoea in post-COVID-19 condition [108]. These findings were further supported by *van Voorthuizen et al.* (Nijmegen, the Netherlands) who found a large prevalence of erratic breathing pattern during exercise after mild COVID-19 [109].

Similarly, in a group of 40 male professional soccer players, *Stavrou et al.* (Larissa, Greece) reported greater resting and exertional $\dot{V}_E$ in the 20 athletes previously infected by COVID-19, despite strictly similar cardiorespiratory fitness (*i.e.*, $\dot{V}_{O_2max}$). The authors also signalled lower breathing reserve (~25%) in the COVID-19 subgroup at exercise cessation, although no indicators of dyspnoea were provided [110].

PFTs and imaging

Data on long-term sequelae of severe COVID-19 pneumonia beyond clinical follow-up at six months are scarce [111, 112]. *Barria et al.* (Santiago, Chile) thus described the evolution of

pulmonary consequences in 84 severe COVID-19 survivors at three, six and twelve months after discharge. While longitudinal evaluations showed progressively improving values over time for spirometry, TL_{CO} and 6-minute walk test (6MWT), long-term HRCT anomalies and exercise-induced desaturation suggested persistent interstitial phenomena that might contribute to respiratory symptoms [113].

Balamugesh et al. (Vellore, India) established a post-COVID-19 respiratory clinic and retrospectively compared clinical, radiological, and functional parameters of 100 previously infected patients. Residual dyspnoea was the most common symptom, with a prevalence of 55% ~9 weeks post-infection. Chest X-ray scores for the severity of lung oedema were negatively associated with forced vital capacity (FVC) and TL_{CO}, but none of these measurements were significantly associated with dyspnoea [114]. Similarly, *Sahnoun et al.* (Ariana, Tunisia) evaluated the frequency of persistent dyspnoea and assessed potential associated factors in patients 6 months after discharge for COVID-19 pneumonia. Sixty-two patients were divided into two groups, according to the presence or absence of persistent dyspnoea. The frequency of persistent dyspnoea was 31%, it was associated with lower forced expiratory volume in the first second (FEV_1) and TL_{CO}, together with more persistent dry cough and memory loss. Severe initial pneumonia and the use of NIV during the acute episode were also associated with persistent dyspnoea [115].

Interventions to reduce persistent dyspnoea

There is an urgent need to offer new, non-invasive tools, to alleviate persistent dyspnoea in COVID-19 [116, 117]. In this context, *Betka et al.* (Geneva, Switzerland) developed an immersive virtual reality-based digital therapeutic, based on known analogies between pain and dyspnoea [118]. They investigated the effect of synchronous or asynchronous visual-respiratory feedback on persistent dyspnoea, in 26 patients recovering from COVID-19 pneumonia. Synchronous feedback was associated with improved breathing comfort compared to the

asynchronous feedback condition. Of note, 91% of patients were satisfied with the intervention and 67% perceived it as beneficial for their breathing, emphasising its potential clinical application to reduce persistent dyspnoea in this population [119].

Reliability of pulse oximetry

Crooks et al. (Hull, UK) examined the effect of different haemoglobin levels on pulse oximetry measurements in 1086 patients admitted to hospital, with a possible diagnosis of COVID-19 infection. Pulse oximetry and arterial/venous blood gas oxygen saturations were compared. The authors found an inverse and linear association between haemoglobin and measurement error of oxygen saturation as determined by pulse oximetry. This discrepancy was relatively large in patients with anaemia (corresponding to a measurement error of +8.0% if haemoglobin =70 g/L), suggesting that haemoglobin levels should not be overlooked when establishing treatments decisions on pulse oximetry [120].

Overall, this session highlighted the presence of persistent respiratory symptoms beyond the acute phase of COVID-19 pneumonia. Persistent dyspnoea, the most prevalent symptom, does not seem to be associated with resting lung function impairments. DB and ventilatory inefficiency during exercise are, however, two potential underlying pathophysiological mechanisms of residual dyspnoea. Innovative strategies are urgently needed to alleviate persistent dyspnoea in post COVID-19 infection [121].

Conclusion

We hope that the highlights summarised will help update readers with the impressive amount of lung research and advances in pulmonary care presented through the sessions from ERS Assembly 1, alongside with suggestions for further investigations. We also hope to have encouraged the readership to contribute to Assembly 1 activities, and to take part to the 2023

ERS International Congress to be held in Milan next September, where further scientific novelties and clinical developments on these topics will be discussed.

Disclosure

Prof. Bayat reports personal fees from Thorasys, outside the submitted work. Dr. Evans reports grants from NIHR / UKRI / Wolfson Foundation, personal fees from AstraZeneca, Boeringher Ingelheim, non-financial support from Chiesi, outside the submitted work. Prof. Franssen reports grants and personal fees from AstraZeneca, personal fees and non-financial support from Chiesi, personal fees from Boehringer Ingelheim and GlaxoSmithKline, outside the submitted work. Dr. Gille reports personal fees from Boehringer Ingelheim and Roche, non-financial support from Oyxvie, LVL Medical, Vitalaire and Asten (oxygen providers), outside the submitted work. Prof. Pinnock reports personal fees from Teva Pharmaceuticals, personal fees from Sandoz, outside the submitted work. Dr. Vicente reports personal fees from AstraZeneca, Boehringer Ingelheim, GlaxoSmithKline and Mylan, outside the submitted work.

Dr. CY Hui is a visitor in the University of Edinburgh and is a senior consultant in digital health at Deloitte. Her research with the University of Edinburgh, is independent from, and not financially supported by Deloitte. Her views in this publication and the conference are her own, and not those of the Deloitte. Neither she, nor Deloitte, stand to gain financially from work reported in this publication.

Dr. Aliverti, Dr. Chaabouni, Dr. Evans, Prof. Bayat, Dr. Betka, Dr. Jácome, Dr. Kaltsakas, Dr. Karadeniz-Güven, Dr. Kolekar, Dr. Marillier, Dr. Poberezhets, Dr. Price, Dr. Sivapalan, Dr. Souto-Miranda, Dr. Vagheggini, Prof. Vogiatzis, and Dr. Vontetsianos have nothing to disclose.

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Table 1: Take home messages from Group 1.01: Clinical problems.

- Machine Learning prediction models and artificial intelligence might be a reliable method to predict the 3-month hospital readmission rate of COPD patients due to exacerbations.
- Transfer of mechanically ventilated patients from the ICU to a specialised weaning centre may result in successful weaning in more than 60% of cases.
- Patients with uncontrolled asthma who were prescribed ≥3 SABA canisters/year reported up to 3 severe asthma exacerbations per year.
- Cancer incidence in patients with the asthma-COPD overlap phenotype was not increased compared to COPD patients, while the use of inhaled corticosteroids did not modify the risk for malignancy.
- In COVID-19, rotational thromboelastometry is related to disease severity.
- PAI-1 is a possible prognostic biomarker in patients admitted with COVID-19 pneumonia.
- A single centre observational study showed that using cardiac MRI, 43% of COVID-19 hospitalised patients had signs of active myocarditis at 1 month follow-up.

Table 2: Take home messages from 1.02: Rehabilitation and chronic care.

- In COPD patients, high-intensity aerobic exercise resulted more effective than stairs climbing and low-intensity training. Low-load eccentric training can be effective and safely prescribed in people with severe COPD.
- An online breathing and well-being programme with singing exercises was safe and improved mental status and breathlessness.
- Home-based PR programmes may improve burden, mood and fatigue of informal caregivers of patients with COPD.
- NIV telemonitoring may improve the quality of ventilation, even in patients receiving NIV since several years.
- Bronchoscopic lung volume reduction may improve cardiac pre-load, stroke volume, cardiac output, and contractility in patients with particular forms of emphysema.
- The minimal important clinical difference of HADS anxiety and depression scores for pulmonary rehabilitation of patients with IPF was defined as -2.0 and -1.2 points, respectively.
- In patients with severe or critical COVID-19, higher blood levels of Surfactant Protein-A (SP-A) were strongly correlated with the severity of dyspnoea.
- An impairment in exercise capacity was reported in most patients after 12 months

from hospitalisation due to COVID-19.

Table 3: Take home messages from Group 1.03: General practice and primary care.

- Close monitoring and annual control of patients with COPD are important because even in patients with a low symptom burden, one moderate exacerbation increases the odds of subsequent exacerbations and death.
- Supported self-management for asthma reduces attacks and improves asthma control.
- COPD, anxiety, anaemia, heart failure, and obesity/deconditioning are the five most common causes of chronic breathlessness over 40 years old.
- OARS skills (Open questions, Affirmations, Reflection and Summary) are an important tool to approach patients with COPD suffering from mental health difficulties. Non-pharmacological approaches proved their efficacy in mental health management, specifically cognitive behavioural therapy, mindfulness, and pulmonary rehabilitation.
- Home-based pulmonary rehabilitation is as effective as centre-based PR in terms of functional exercise capacity and HRQoL, and could be an interesting option in low resource settings.
- Sexual dysfunction is highly prevalent in patients with COPD. Primary care professionals play a crucial role in its detection and management.
- Palliative care should be early implemented in patients with COPD by initiating the discussion with their patients about their needs and concerns.

Table 4: Take home messages from Group 1.04: M-health/e-health.

- Digital interventions such as artificial intelligence, smartphone app, augmented reality, electronic stethoscope, built-in camera and microphones on smartphone, home spirometry, smart inhaler, internet-of-things connected platform and "big data" in the electronic health record are technically feasible to be used in supporting respiratory care and can encourage engagement.
- To ensure the interventions are accurate and fits the user's preferences/habit and routine workflow, it is essential to involve end users to co-design the digital health intervention at the early development stage.
- To ensure an effective implementation, several practical issues raised in the studies need to be addressed, including: lack of interoperability supports to allow effective data exchange across health organisations; limited available dataset to support AI validation and its generalisability to a wider population; unclear quality of the existing apps; and specific concerns in low-middle income countries (interrupted electricity/internet services, limited skilled labour, age/gender and geographical disparities).

Table 5: Take home messages from Group 1.05: Clinical respiratory physiology, exercise and functional imaging.

- Residual dyspnoea is the most prevalent symptom beyond the acute phase of COVID-19 pneumonia.
- Ventilatory inefficiency (elevated ventilatory stimuli relative to metabolic demand) and dysfunctional breathing (abnormal breathing pattern without apparent causes) may assume a prominent role in residual exertional dyspnoea post-COVID-19.
- Abnormalities observed on “resting” investigations (pulmonary function tests and imaging) poorly relate to exertional dyspnoea post-COVID-19.
- Innovative strategies, such as immersive virtual reality, are urgently needed to alleviate persistent dyspnoea in post COVID-19 infection.

Hilary Pinnock reports personal fees from Teva Pharmaceuticals, personal fees from Sandoz, outside the submitted work.
Guido Vagheggini reports payments fo lectures frim Regia Congressi, Summmeet Srl, and Info&Med Srl, outside the submitted work; President of Fondazione Volterra Ricerche ONLUS, outside the submitted work.
Frits Franssen reports grants and personal fees from AstraZeneca, personal fees from Boehringer Ingelheim, personal fees and non-financial support from Chiesi, personal fees from GlaxoSmithKline, outside the submitted work.
Chi Yan Hui is a visitor in the University of Edinburgh and is a senior consultant in digital health at Deloitte. Her research with the University of Edinburgh is independent from, and not financially supported by Deloitte. Her views in these publications and the conference are her own, and not those of Deloitte. Neither she, nor Deloitte, stand to gain financially from the work reported in this publication.
Cláudia Vicente reports personal fees from AstraZeneca, personal fees from Boehringer Ingelheim, personal fees from GlaxoSmithKline, personal fees from Mylan, outside the submitted work.
Rachael Evans reports grants from NIHR / UKRI / Wolfson Foundation, personal fees from AstraZeneca, Boeringher Ingelheim, non-financial support from Chiesi, outside the submitted work.
Sam Bayat reports personal fees from Thorasys, outside the submitted work.
Thomas Gille reports personal fees from Boehringer Ingelheim, personal fees from Roche, non-financial support from Oxyvie (oxygen provider), non-financial support from LVL Medical (oxygen provider), non-financial support from Vitalaire (oxygen provider), non-financial support from Asten (oxygen provider), outside the submitted work.
The remaining authors have nothing to disclose.