Highlights from the Respiratory Failure and Mechanical Ventilation 2022 Conference

Pedro Viegas 1, Elisa Ageno 2,3, Gabriele Corsi 2,3, Federico Tagariello 2,3, Léa Razakamanantsoa 4, Rudolfs Vilde 5,6, Carla Ribeiro 1, Leo Heunks 7, Maxime Patout 8,9 and Christoph Fisser 10

1Pulmonology Department, Centro Hospitalar de Vila Nova de Gaia/Espinho, Vila Nova de Gaia, Portugal. 2Respiratory and Critical Care Unit, IRCCS Azienda Ospedaliero Universitaria di Bologna, University Hospital Sant’Orsola-Malpighi, Bologna, Italy. 3Department of Clinical, Integrated and Experimental Medicine (DIMES), Alma Mater Studiorum University of Bologna, Bologna, Italy. 4Unité Ambulatoire d’Appareillage Respiratoire de Domicile (UAARD), Service de Pneumologie (Département R3S), AP-HP, Groupe Hospitalier Universitaire APHP-Sorbonne Université, Paris, France. 5Centre of Pulmonology and Thoracic Surgery, Pauls Stradēni Clinical University Hospital, Riga, Latvia. 6Riga Stradiņš University, Riga, Latvia. 7Department of Intensive Care, Erasmus University Medical Center, Rotterdam, The Netherlands. 8Service des Pathologies du Sommeil (Département R3S), AP-HP, Groupe Hospitalier Universitaire APHP-Sorbonne Université, site Pitié-Salpêtrière, Paris, France. 9Sorbonne Université, INSERM, UMR1158 Neurophysiologie Respiratoire Expérimentale et Clinique, Paris, France. 10Department of Internal Medicine II, University Hospital Regensburg, Regensburg, Germany.

Corresponding author: Christoph Fisser (christoph.fisser@ukr.de)

Shareable abstract (@ERSpublications)
@ERSAssembly2 gathered in Berlin to organise the second Respiratory Failure and Mechanical Ventilation Conference in June 2022. A conference summary is presented here. https://bit.ly/3tL5ItM

Cite this article as: Viegas P, Ageno E, Corsi G, et al. Highlights from the Respiratory Failure and Mechanical Ventilation 2022 Conference. ERJ Open Res 2023; 9: 00467-2022 [DOI: 10.1183/23120541.00467-2022].

Abstract
The Respiratory Intensive Care Assembly of the European Respiratory Society gathered in Berlin to organise the second Respiratory Failure and Mechanical Ventilation Conference in June 2022. The conference covered several key points of acute and chronic respiratory failure in adults. During the 3-day conference, ventilatory strategies, patient selection, diagnostic approaches, treatment and health-related quality of life topics were addressed by a panel of international experts. Lectures delivered during the event have been summarised by Early Career Members of the Assembly and take-home messages highlighted.

Introduction
In this summary of the second Respiratory Failure and Mechanical Ventilation Conference, held in Berlin, Germany, in June 2022, the Early Career Members of the Respiratory Intensive Care Assembly present the conference highlights. This report includes sessions on both acute and chronic respiratory failure delivered by international experts in the field. It covers symposia on the essentials of respiratory physiology, telemonitoring of patients with chronic respiratory failure, the role of respiratory muscle dysfunction in weaning failure, weaning from invasive ventilation, health-related quality of life (QoL) in mechanical ventilation, ventilatory management of hypercapnic respiratory failure, transitions in chronic noninvasive ventilation and controversies in acute respiratory failure.

Essentials of respiratory physiology
The introductory session of the Respiratory Failure and Mechanical Ventilation Conference 2022 focused on the importance of respiratory physiology in our clinical practice.

A reflection on the lessons learned from the COVID-19 pandemic was presented by Nicholas Hart. SARS-CoV2 triggers an inflammatory response that leads to systemic changes [1]. This may be associated with an increase in neural respiratory drive and a reduction in muscle capacity, which in combination may be associated with an increased respiratory load [2], that may result in patient self-inflicted lung injury (P-SILI) [3]. Throughout the pandemic, several lessons were learned, like the relevance of awake prone positioning [4, 5] and continuous positive airway pressure for the reduction of intubation rates [6]. Finally, he presented new and important evidence regarding aerosol-generating procedures [7, 8].
In the next session, Lise Piquilloud stressed the importance of respiratory mechanics like plateau pressure, the pressure–volume curve, the airway opening pressure, compliance and driving pressure. The compliance (C) equation:

\[ C = \frac{\Delta V}{\Delta P} \]

(where V is volume and P is pressure) was revisited, alongside its applications in daily practice.

Following this talk, Leo Heunks discussed the respiratory drive [9] and its feedback mechanisms: chemical, cortical and reflex [10]. The clinical impact of respiratory drive was analysed; low drive can lead to muscle atrophy and asynchronies, and high drive can lead to haemodynamic consequences and lung injury [3, 11, 12]. The drive can be modulated [13] chemically, through extracorporeal membrane oxygenation and sedation with propofol, and mechanically, through ventilator adjustments: higher positive end-expiratory pressure (PEEP) leads to lung recruitment, decreased effort and less lung injury [14].

In the final lecture, Marieke Duiverman commented on the importance of patient–ventilator asynchrony and its universal presence. Patient–ventilator asynchrony can appear in the trigger phase (ineffective trigger, double triggering or autotriggering), inspiratory phase (flow asynchrony), cycling phase (delayed or premature cycling) and expiratory phase (figure 1) [16]. Patient–ventilator asynchrony leads to deleterious respiratory mechanics [17] and to sleep disturbances [18]. The measurement of patient–ventilator asynchrony should be undertaken through visual inspection of the ventilator curves, electromyography or polysomnography bands, to mitigate its effects on our patients.

**Take-home messages**

- COVID-19 triggers an inflammatory response that increases respiratory drive and decreases muscle capacity, altering respiratory physiology.
- High and low respiratory drive challenge lung and diaphragm protective ventilation, and careful monitoring and modulation are necessary.
- Patient–ventilator asynchrony should be assessed in difficult to ventilate patients.

**Telemonitoring of patients with chronic respiratory failure**

Anda Hazenberg presented how to achieve telemonitoring of home mechanical ventilation in patients with chronic respiratory failure. Telemonitoring systems require many different aspects: a well-organised team, a close interaction among different features (patient, caregiver, nurses, general practitioners and the hospital team), appropriate equipment, a “24/7” help service, and the possibility to collect data and change settings remotely. She showed how home mechanical ventilation can be feasible, safe and cost reducing, and noninferior to in-hospital initiation of home mechanical ventilation [19–21].

Maxime Patout emphasised the necessity of improving telemonitoring for long-term follow-up of chronic respiratory failure, to improve quality of care [22] and reduce hospitalisation [23]. Telemonitoring can be used to identify some targets [24], like arterial partial pressure of carbon dioxide, QoL, sleep quality, adherence to treatment and side-effects. Adherence in home mechanical ventilation is an important target as an adherence \( \geq 4 \text{ h·day}^{-1} \) to noninvasive ventilation (NIV) resulted in a lower mortality in patients with chronic respiratory failure [25]. He also described some essential requirements for successful long-term NIV, like appropriate legislation, funding, dedicated staff, connected devices with reliable data [26, 27] and remote settings [28]. To conclude, the benefits of telemonitoring are promising but the best way to deliver it remains to be established.

Marieke Duiverman talked about the evidence for reduction of exacerbation [23] by telemonitoring during home mechanical ventilation and pointed out that this subject is still controversial [29–31]. Early detection of COPD exacerbation is a prerequisite for timely treatment, which leads to improved outcomes. She also underlined the cruciality of choosing the right patients [32] to make telemonitoring more effective. Even if they are still to be established, some of the most effective data to prevent exacerbations are represented by treatment adherence, leaks, curves, expired tidal volume and breathing frequency [28]. Moreover, to get more reliable information, other parameters should be analysed (like gas exchange, lung mechanics [33] and neural drive [34]).
Take-home messages

- Telemonitoring of home mechanical ventilation is feasible, safe and cost reducing, and noninferior to in-hospital initiation.
- The benefits of telemonitoring are promising but the best way to deliver it remains to be established.
- It is crucial to select the right patients to make telemonitoring more effective.

The role of respiratory muscle dysfunction in weaning failure

Martin Dres gave us an overview of the anatomy and physiology of the respiratory muscles, and how to assess their activity to better understand the role of dysfunction in ventilator weaning failure. The diaphragm is not the only respiratory muscle. Extradiaphragmatic inspiratory muscles (scalene, sternocleidomastoid and external parasternal intercostal muscles) and expiratory muscles (transversus abdominis, internal/external oblique and internal parasternal intercostal muscles) also play an important role in the balance between respiratory load and respiratory capacity. Two-thirds of the patients may have a diaphragm dysfunction at any time during their stay on an intensive care unit [35]. In cases of

FIGURE 1 Examples of patient–ventilator asynchrony (arrows) revealed in pressure and flow waveforms (data from the software ResScan version 5.6.0.9419). a) Ineffective effort; b) double triggering. Reproduced and modified from [15] with permission.
diaphragmatic weakness, patients recruit extradiaphragmatic muscles. Measurement of the thickening fraction [36]:

\[
\frac{\text{t}_{\text{end of inspiration}} - \text{t}_{\text{end of expiration}}}{\text{t}_{\text{end of expiration}}}
\]

as well as electromyography activity or measurement of the gastric pressure are tools to assess the activity of these muscles and may help to predict extubation failure [37].

Annemijn Jonkman showed us techniques to monitor the respiratory muscles and highlights the difference between assessing the activation of the muscles versus contraction. Measurement of the electrical activation of the diaphragm is the most specific invasive technique to assess the respiratory drive but it is difficult to translate to a measurement of force output [38, 39], which is also true for surface electromyography [40] (because of important interindividual variations in the signal amplitude). Magnetic stimulation of the phrenic nerve is the reference standard to measure the diaphragm strength by measuring the pressure generated by the diaphragm. Other invasive techniques can surrogate force output using pressures signals (oesophageal pressure and transpulmonary pressure [41, 42]) or advanced analyses [43]. Noninvasive measurement tools always need to be interpreted according to the clinical context. Occlusion pressures are reasonably reliable for detecting the diaphragmatic effort [44, 45]. Maximal inspiratory and expiratory pressures are global measurements of inspiratory and expiratory muscle strength. Effort of breathing can be identified by means of diaphragm ultrasound. If respiratory muscle dysfunction is suspected as a main cause of weaning failure, applying specific techniques is recommended but still complex.

In the final talk, Daniel Langer reflected on the importance of inspiratory muscle training in difficult to wean patients [46], using the “frequency, intensity, time, type, progression, volume” strategy. By using such a strategy in the design of patients’ inspiratory muscle training, we can enhance their maximal inspiratory pressure, optimising the outcomes. He reviewed the techniques, such as the use of pressure threshold loading, using fixed resistances, and “tapered-flow resistive loading” [47], which applies varying resistances, with greater improvement of volume expansion and flow rates, and greater tolerability by our patients [48]. New respiratory muscle function assessment methods are emerging, such as ultrasound and measurements of muscle oxygenation [49].

**Take-home messages**

- Measurement of the thickening fraction, electromyography or measurement of the gastric pressure are tools to assess the activity of the respiratory muscles and may help us to predict extubation failure.
- Noninvasive measurement tools always need to be interpreted according to the clinical context.
- Respiratory muscle conditioning is feasible and improves respiratory function, even though the optimal training regimen is still to be identified.

**New insights in weaning from invasive ventilation**

Successful weaning is critical for recovery. Timely and successful weaning is a key challenge because of the complications of prolonged mechanical ventilation. Inversely, the need for reintubation is associated with increased mortality [50].

Ventilated patients are grouped based on the difficulty and duration of the weaning process [51]. Up to 80% fall into the simple weaning group. Therefore, daily screening to identify ready-to-wean patients reduces the duration of mechanical ventilation, complication rate and costs [52]. The screening must be followed by a spontaneous breathing trial (SBT) to assess a patient’s ability to breathe with minimal or no respiratory support [53].

John Laffey introduced the yet-to-be-published WEANSAFE study, showing worse outcomes with prolonged weaning. A delayed separation attempt was independently associated with weaning failure.

Alexandre Demoule compared the different SBTs in use. Pressure support ventilation reduces respiratory effort more than the T-piece trial. The T-piece trial reflects the breathing after extubation more accurately [54]. It has, however, been shown that 30-min pressure support ventilation SBT has no higher risk of post-extubation respiratory failure than 2-h T-piece SBT, supporting the use of a shorter, less demanding strategy [55].
The weaning process is not well defined and geographic variations are seen in practices (use of written directives for screening and SBTs, sedation level, etc.) but not in success rate [56]. The severity of the disease, sedation and the presence of a protocol seem to be independent factors associated with success.

American Thoracic Society/European Respiratory Society guidelines suggest using NIV to prevent post-extubation respiratory failure in high-risk patients [57]. Alexandre Demoule summarised that high-flow nasal cannula is not inferior to NIV [58]. Furthermore, high-flow nasal cannula in combination with NIV is more effective in preventing reintubation than high-flow nasal cannula alone [59].

Trials of spontaneous breathing also challenge the circulation [53]. Martin Dres reported on weaning-induced pulmonary oedema, a frequent cause of SBT failure [60, 61]. Increases in extravascular lung water, plasma protein concentration and B-type natriuretic peptide (BNP) are of diagnostic value [62]. Echocardiography and lung ultrasound also allow accurate diagnosis [63, 64]. An increase in haemoglobin level by 5% is diagnostic and convenient to use [62]. Treatment considerations include BNP-driven fluid management and nitroglycerine infusion [65, 66].

Annemijn Jonkman investigated the role of neurally adjusted ventilatory assist (NAVA) mode. It is known that NAVA improves patient–ventilator interaction [67]. NAVA appears to be equally as safe as pressure support ventilation. It is associated with less frequent application of post-extubation NIV [68]. In another study, NAVA decreased the duration of weaning and improved the success of weaning [69]. It seems to achieve a shorter mechanical ventilation duration with no difference in survival [70]. Both studies have several limitations.

**Take-home messages**

- Successful weaning is critical and a weaning protocol may improve weaning outcome.
- Daily screening to identify ready-to-wean patients is advisable. SBTs should be performed in those patients.
- Independent factors for successful weaning are the severity of the disease, the level of sedation and the application of a weaning protocol.
- Post-extubation failure in high-risk patients can be reduced by the application of high-flow nasal cannula and/or NIV.
- NAVA can be used to improve patient–ventilator interactions and possibly clinical outcome.

**Health-related QoL in mechanical ventilation**

Anita Simonds highlighted that QoL questionnaires are multidimensional tools, including but not restricted to assessing physical, psychological and social domains, that attempt to measure how the disease affects a patient’s life. They should be sensitive to changes related to progression of disease or treatment interventions. This can be achieved with generic (such as Short Form-36 or EuroQol-5 Dimension), disease-specific (such as the St George’s Respiratory Questionnaire for COPD) or condition-specific tools (such as the Maugeri Respiratory Failure 28 or Severe Respiratory Insufficiency questionnaires for chronic respiratory failure). They should be obtained directly from the patient as they correlate poorly to physiological measures.

Marieke Duiverman discussed whether NIV affects QoL in COPD patients as results of randomised controlled trials are controversial, highlighting the importance of evaluating whether NIV was successful and setting the right expectations. NIV improves QoL in patients with amyotrophic lateral sclerosis (although the strength of evidence is low) but the disease is rapidly progressive and it will eventually impact QoL [71]. Thus, it is of utmost importance to identify the timing of NIV initiation and the appropriate parameters for NIV success, and to discuss expectations (in some patients, the goal might just be to prevent decay in QoL or delay it) [72].

Sarah Schwarz demonstrated QoL in invasive ventilated patients is quite heterogeneous, and patients’ satisfaction with their degree mobility and communication is the most severely impaired [73, 74]. She presented a study showing that patients’ and caregivers’ perspectives related to satisfaction related to tracheostomy might be very divergent [75]. She defended the need for strategies that identify patients with poor QoL and develop specific strategies for support.

Stefano Nava addressed the problem of “pain of breathing” (dyspnoea) in terminally ill patients and revised the evidence of its management. Guidelines recommend nonpharmacological therapies and opioids to control dyspnoea, whereas supplemental oxygen has failed to prove benefits in nonhypoxic patients [76–78].
NIV can be used, even in patients with otherwise no indication, to palliate symptoms of dyspnoea [79] and to gain time to communicate with relatives, and a trial of NIV can be offered to a willing patient with no contraindications after discussion of its objectives [80].

**Take-home messages**

- QoL questionnaires are multidimensional tools that attempt to measure the impact of the disease and that should be obtained directly from the patient.
- It is of utmost importance to identify the timing of NIV initiation and the appropriate parameters for NIV success, and to discuss expectations.
- There is a need for strategies that identify patients with poor QoL and develop specific strategies for support.
- NIV can be used, even in patients otherwise with no indication, to palliate symptoms such as dyspnoea.

**Ventilatory management of severe acute exacerbation of hypercapnic respiratory failure**

The session started with Paolo Navalesi reviewing the initiation of NIV. Our approach should be guided by arterial blood gas measurement and an effort must be made to determine reversible causes of respiratory failure [57, 81]. NIV should be initiated in all COPD patients if respiratory acidosis is present [82, 83], otherwise oxygen titrated to 88–92% saturation should be the chosen approach [84]. Ventilatory management of these patients can be done safely on a medical ward [85]. NIV should be stopped in cases of success, or early or late failure [81]. There is still no consensus on how to wean from NIV [86, 87].

Annalisa Carlucci focused on high-flow nasal cannula oxygen. To date, there is no indication for this as the first choice of treatment for acute hypercapnic respiratory failure. The latest guidelines suggest a trial of NIV prior to using a high-flow nasal cannula in patients with acute hypercapnic respiratory failure and respiratory acidosis [86, 88].

High-flow nasal cannula might have a complementary role by using it in the breaks from NIV, improving the comfort [89] and dyspnoea [90].

Several physiological effects of high-flow nasal cannula may support its use by reducing work of breathing, mainly counterbalancing intrinsic positive end-expiratory pressure and reducing respiratory rate [86, 91, 92]. However, high-flow nasal cannula does not guarantee support for the respiratory muscles. So far, physiological studies on high-flow nasal cannula are still required.

Christian Karagiannidis presented on extracorporeal carbon dioxide removal (ECCO₂R) in acute hypercapnic respiratory failure. Acute exacerbation of COPD is common. Reducing the arterial partial pressure of carbon dioxide with ECCO₂R can lower the strongest stimulus of the respiratory drive. Moreover, ECCO₂R might improve right heart function by reducing the mean pulmonary arterial pressure. Among the ongoing trials, various ECCO₂R settings have been chosen as well as the pump technology or the inclusion criteria among the exacerbated COPD patients, but they all share the primary outcome of early extubation or avoidance of invasive mechanical ventilation. Technical settings, such as pump blood flow, must be considered to predict the efficacy of carbon dioxide removal [93, 94].

**Take-home messages**

- NIV should be initiated in all COPD with respiratory acidosis and can be safely done on medical wards.
- High-flow nasal cannula has a strong physiological rationale for use in acute hypercapnic respiratory failure, mainly in the breaks from NIV.
- ECCO₂R represents a promising complementary therapy for acute hypercapnic respiratory failure as an adjunctive treatment to NIV to avoid invasive mechanical ventilation or promote early extubation.

**Transitions in chronic NIV**

Alessandro Amaddeo reported the increase in home long-term ventilation in children [95], for which the main indications are neuromuscular diseases [96], cranial-facial abnormalities and obstructive sleep apnoea [97, 98]. Some important differences must be evidenced between ventilated children [99] and adults, like the necessity of life-support ventilators with internal batteries, a low availability of interfaces, and the weight and the growth of the patient [100]. Moreover, as they grow, it should be evaluated whether the child can be weaned [101] or if their needs changes. Indeed, the transition from adolescence to adult care is a challenging process [102, 103] that can lead to a negative impact on the patient’s compliance to

https://doi.org/10.1183/23120541.00467-2022
therapies [104]. The most common issue is a difficult passage from paediatric to adult-centred care [105, 106]. Since all patients require individualised plans of transition, collaboration between these two care sectors should be improved to achieve a smoother transition process [107].

In some ventilated patients, tracheostomy should be considered [105, 108, 109] (especially those with neuromuscular diseases). As explained by Lara Pisani, it is important to identify those who can be decannulated and switched to NIV [110]. Lara Pisani showed the main steps of decannulation [111], like cuff deflation and assessing airway permeability. Weaning from tracheostomy may also require noninvasive support or airway clearance techniques. In conclusion, she emphasised the importance of an appropriate preparation of adult services for these kinds of patients.

For elderly people, Anita Simonds showed a lower mortality in intensive care unit patients treated with NIV. Unlike younger people, the most common indication for NIV is COPD. It is proven that NIV in the elderly has a positive impact on survival and respiratory function [112] but with a high risk of neuropsychological impairment that can lead to a lower compliance [113]. Home long-term ventilation in old people is a difficult topic and there are a lot of controversial data [114, 115]; however, emerging research shows that QoL is influenced by the underlying disease in most patients [114, 116–119]

Take-home messages

- The use of home long-term ventilation is increasing in children and important differences must be adequately managed.
- Transition from adolescence to adult care is a challenging process that can lead to a negative impact on the patient’s compliance.
- In some ventilated patients, tracheostomy should be considered, especially in neuromuscular disease.
- NIV in the elderly has a positive impact on survival and respiratory function.

Controversies in acute respiratory failure

The discussion on whether delayed intubation results in P-SILI opened with Stefano Nava stating that strong efforts are associated with high tidal volumes and lung injury [13]. He concluded that volumes that are harmful in an animal study [120] cannot be translated to proportional tidal volumes in humans.

Severity of the disease, rather than tidal volume >9.5 mL·kg\(^{-1}\), might cause NIV failure [121]. Increased patient effort is not necessarily deleterious, depending on the subphenotype [122] and cause [123] of acute respiratory distress syndrome. NIV can maintain transpulmonary pressure within the range of safety [124]. Oesophageal pressure determines risk of intubation [125]. Paolo Navalesi argues that the animal model [120] strongly links hyperventilation with P-SILI. Lung-protective ventilation can limit progression of P-SILI [3]. Unlike NIV failure, avoiding delayed intubation can reduce mortality [126]. Several studies support tidal volumes >9.5 mL·kg\(^{-1}\) as a predictor of NIV failure [121, 127].

Prone positioning has a strong physiological rationale and is generally accompanied by an improvement in gas exchange due to better ventilation/perfusion matching (figure 2) [129]. The efficacy of prone positioning has been proven in intubated patients [130] but little is known about its efficacy in awake, spontaneously breathing patients. EHRMANN et al. [5] conducted a study demonstrating that awake proning reduces the need for intubation in patients with COVID-19 acute respiratory failure.

John Laffey pointed out that, even though prone positioning of awake patients is feasible and associated with a significant benefit in gas exchange [131], to date, no trial has demonstrated its effect on important clinical outcomes in non-COVID-19 patients. Regarding the COVID-19 population, a reduced intubation rate was found only in a specific subgroup of patients: those receiving advanced respiratory support (high-flow nasal cannula or NIV) in the intensive care unit but not in those receiving conventional oxygen therapy or in nonintensive care unit settings [132].

The role of corticosteroids in treating severe infections has been an enduring controversy and the pandemic has been a potent stimulus for clinical research [133]. Charlotte Summers summarised the data favouring the use of corticosteroids; its administration is associated with lower mortality in critically ill patients with COVID-19, in patients with moderate-to-severe acute respiratory distress syndrome without COVID and in patients with severe community-acquired pneumonia [133–135].

Antonio Artigas pointed out the possible side-effects related to the use of corticosteroids, also underlining the heterogeneity of the studies considered and their treatment protocols (doses, duration and choice of
glucocorticoid). In some cases, the use of corticosteroids is associated with significantly higher mortality [136] and side-effects, such as hyperglycaemia, gastrointestinal bleeding and increased risk of ventilator-associated pneumonia, must be considered [137].

**Take-home messages**

- Avoiding delayed intubation can reduce mortality.
- The efficacy of prone positioning has been proved in intubated patients but little is known about its efficacy in awake, spontaneously breathing patients.
- The role of corticosteroids in treating severe infections has been an enduring controversy. They can be associated with lower mortality in critically ill patients but side-effects may occur.

Provenance: Commissioned article, peer reviewed.

Conflict of interest: P. Viegas reports receiving support for meetings and/or travel from Linde Saúde, outside the submitted work. C. Ribeiro reports receiving speaking fees from Vitalaire, and support for attending meetings and/or travel from Vitalaire and Nippon Gases; and is Coordinator of the Home Mechanical Ventilation Assembly of the Portuguese Respiratory Society (unpaid position); all disclosures made outside the submitted work. L. Heunks reports receiving grants or contracts from Liberate Medical and Fisher and Paykel, and speaker and travel fees from Getinge Sweden; all disclosures made outside the submitted work. M. Patout reports receiving grants or contracts from Fisher & Paykel, Resmed and Asten Santé; consulting fees from Philips Respironics, Resmed, Asten Santé and GSK; payment or honoraria for lectures, presentations, speakers’ bureaux, manuscript writing or educational events from Philips Respironics, Asten Santé, Resmed, Air Liquide Medical, SOS Oxygène, Antadir, Chiesi and Jazz Pharmaceutical; support for attending meetings and/or travel from Asten Santé; participation on a data safety or advisory board for Resmed, Philips Respironics and Asten Santé; stock or stock options in Kernel Biomedical; and receipt of equipment, materials, drugs, medical writing, gifts or other services from Philips Respironics, Resmed and Fisher & Paykel; all disclosures made outside the submitted work. The remaining authors have nothing to disclose.

**References**

1. Marta Monguí-Tortajada, Bayes-Genis A, Rosell A, *et al.* Are mesenchymal stem cells and derived extracellular vesicles valuable to halt the COVID-19 inflammatory cascade? Current evidence and future perspectives. *Thorax* 2021; 76: 196–200.

2.Gattinoni L, Chiurullo D, Caironi P, *et al.* COVID-19 pneumonia: different respiratory treatments for different phenotypes? *Intensive Care Med* 2020; 46: 1099–1102.

3. Brochard L, Slutsky A, Pesenti A. Mechanical ventilation to minimize progression of lung injury in acute respiratory failure. *Am J Respir Crit Care Med* 2017; 195: 438–442.

4. Kelly NL, Curtis A, Douthwaite S, *et al.* Effect of awake prone positioning in hypoxaemic adult patients with COVID-19. *J Intensive Care Soc* 2020; in press [https://doi.org/10.1177/1751143720961244].

https://doi.org/10.1183/23120541.00467-2022
Ehrmann S, Li J, Ibarra-Estrada M, et al. Awake prone positioning for COVID-19 acute hypoxaemic respiratory failure: a randomised, controlled, multinational, open-label meta-trial. Lancet Respir Med 2021; 9: 1387–1395.

Perkins GD, Ji C, Connolly BA, et al. Effect of noninvasive respiratory strategies on intubation or mortality among patients with acute hypoxic respiratory failure and COVID-19: the recovery-RS randomized clinical trial. JAMA 2022; 327: 546–558.

Hamilton FW, Gregson FKA, Arnold DT, et al. Aerosol emission from the respiratory tract: an analysis of aerosol generation from oxygen delivery systems. Thorax 2022; 77: 276–282.

Winslow RL, Zhou J, Windle EF, et al. SARS-CoV-2 environmental contamination from hospitalised patients with COVID-19 receiving aerosol-generating procedures. Thorax 2022; 77: 259–267.

Del Negro CA, Funk GD, Feldman JL. Breathing matters. Nat Rev Neurosci 2018; 19: 351–367.

Jonkman AH, de Vries HJ, Heunks LMA. Physiology of the respiratory drive in ICU patients: implications for diagnosis and treatment. Crit Care 2020; 24: 104.

Heunks L, Ottenheijm C. Diaphragm-protective mechanical ventilation to improve outcomes in ICU patients? Am J Respir Crit Care Med 2018; 197: 150–152.

Yoshida T, Uchiyama A, Matsuura N, et al. The comparison of spontaneous breathing and muscle paralysis in two different severities of experimental lung injury. Crit Care Med 2013; 41: 536–545.

Goligher EC, Jonkman AH, Dianti J, et al. Clinical strategies for implementing lung and diaphragm-protective ventilation: avoiding insufficient and excessive effort. Intensive Care Med 2020; 46: 2314–2326.

Morais CCA, Koyama Y, Yoshida T, et al. High positive end-expiratory pressure renders spontaneous noninvasive ventilation noninjurious. Am J Respir Crit Care Med 2018; 197: 1285–1296.

Ergan B, Nasilowski J, Winck JC. How should we monitor patients with acute respiratory failure treated with noninvasive ventilation? Eur Respir Rev 2018; 27: 170101.

Vignaux L, Vargas F, Roeseler J, et al. Patient-ventilator asynchrony during non-invasive ventilation for acute respiratory failure: a multicenter study. Intensive Care Med 2009; 35: 840–846.

Nilsestuen JO, Hargett KD. Using ventilator graphics to identify patient-ventilator asynchrony. Respir Care 2005; 50: 202–234.

Fanfulla F, Delmastro M, Berardini A, et al. Effects of different ventilator settings on sleep and inspiratory effort in patients with neuromuscular disease. Am J Respir Crit Care Med 2005; 172: 619–624.

Hazenberg A, Kerstjens HAM, Prins SCL, et al. Initiation of home mechanical ventilation at home: a randomised controlled trial of efficacy, feasibility and costs. Respir Med 2014; 108: 1387–1395.

van den Biggelaar RJM, Hazenberg A, Cobben NAM, et al. A randomized trial of initiation of chronic noninvasive mechanical ventilation at home vs in-hospital in patients with neuromuscular disease and thoracic cage disorder. Chest 2020; 158: 2493–2501.

Duijverman ML, Vonk JM, Bladder G, et al. Home initiation of chronic non-invasive ventilation in COPD patients with chronic hypercapnic respiratory failure: a randomised controlled trial. Thorax 2020; 75: 244–252.

Pinto A, Almeida JP, Pinto S, et al. Home telemonitoring of non-invasive ventilation decreases healthcare utilisation in a prospective controlled trial of patients with amyotrophic lateral sclerosis. J Neural Neurosurg Psychiatry 2010; 81: 1238–1242.

Vitacca M, Bianchi L, Guerra A, et al. Tele-assistance in chronic respiratory failure patients: a randomised clinical trial. Eur Respir J 2008; 33: 411–418.

Jolly G, Razakamanantsoa L, Fresnel E, et al. Defining successful non-invasive ventilation initiation: data from a real-life cohort. Respirology 2021; 26: 1067–1075.

Patout M, Lhuillier E, Kaltsakas G, et al. Long-term survival following initiation of home non-invasive ventilation: a European study. Thorax 2020; 75: 965–973.

Contal O, Vignaux L, Combescure C, et al. Monitoring of noninvasive ventilation by built-in software of home bilevel ventilators. Chest 2012; 141: 469–476.

Georges M, Adler D, Contal O, et al. Reliability of apnea–hypopnea index measured by a home bi-level pressure support ventilator versus a polysomnographic assessment. Respir Care 2015; 60: 1051–1056.

Borel J-C, Pelletier J, Taleux N, et al. Parameters recorded by software of non-invasive ventilators predict COPD exacerbation: a proof-of-concept study. Thorax 2015; 70: 284–285.

Jang S, Kim Y, Cho W-K. A systematic review and meta-analysis of telemonitoring interventions on severe COPD exacerbations. Int J Environ Res Public Health 2021; 18: 6757.

Konstantinidis A, Kyriakopoulos C, Ntritsos G, et al. The role of digital tools in the timely diagnosis and prevention of acute exacerbations of COPD: a comprehensive review of the literature. Diagnostics 2022; 12: 269.

Chatwin M, Hawkins G, Paniccia L, et al. Randomised crossover trial of telemonitoring in chronic respiratory patients (TeleCRAFT trial). Thorax 2016; 71: 305–311.

Masefield S, Vitacca M, Dreher M, et al. Attitudes and preferences of home mechanical ventilation users from four European countries: an ERS/ELF survey. ERJ Open Res 2017; 3: 00015-2017.
Stevenson NJ, Walker PP, Costello RW, et al. Lung mechanics and dyspnea during exacerbations of chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2005; 172: 1510–1516.

Suh E-S, Mandal S, Harding R, et al. Neural respiratory drive predicts clinical deterioration and safe discharge in exacerbations of COPD. *Thorax* 2015; 70: 1123–1130.

Dres M, Goligher EC, Heunks LMA, et al. Critical illness-associated diaphragm weakness. *Intensive Care Med* 2017; 43: 1441–1452.

Dres M, Dubé B-P, Goligher E, et al. Usefulness of parasternal intercostal muscle ultrasound during weaning from mechanical ventilation. *Anesthesiology* 2020; 132: 1114–1125.

Dres M, Similowski T, Goligher EC, et al. Dyspnoea and respiratory muscle ultrasound to predict extubation failure. *Eur Respir J* 2021; 58: 2100002.

Bellani G, Mauri T, Coppadaro A, et al. Estimation of patient’s inspiratory effort from the electrical activity of the diaphragm. *Crit Care Med* 2013; 41: 1483–1491.

Jansen D, Jonkman AH, Roesthuis L, et al. Estimation of the diaphragm neuromuscular efficiency index in mechanically ventilated critically ill patients. *Crit Care* 2018; 22: 238.

Grafhoff J, Petersen E, Farquharson F, et al. Surface EMG-based quantification of inspiratory effort: a quantitative comparison with $P_{aw}$. *Crit Care* 2021; 25: 441.

Akoumianaki E, Maggiore SM, Valenza F, et al. The application of esophageal pressure measurement in patients with respiratory failure. *Am J Respir Crit Care Med* 2014; 189: 520–531.

Mauri T, Yoshida T, Bellani G, et al. Esophageal and transpulmonary pressure in the clinical setting: meaning, usefulness and perspectives. *Intensive Care Med* 2016; 42: 1360–1373.

de Vries H, Jonkman A, Shi Z-H, et al. Assessing breathing effort in mechanical ventilation: physiology and clinical implications. *Ann Transl Med* 2018; 6: 387–387.

Telias I, Junhasavadikul D, Rittayamai N, et al. Airway occlusion pressure as an estimate of respiratory drive and inspiratory effort during assisted ventilation. *Am J Respir Crit Care Med* 2020; 201: 1086–1098.

Bertoni M, Telias I, Urmey W, et al. A novel non-invasive method to detect excessively high respiratory effort and dynamic transpulmonary driving pressure during mechanical ventilation. *Crit Care* 2019; 23: 2346.

Elkins M, Dentice R. Inspiratory muscle training facilitates weaning from mechanical ventilation among patients in the intensive care unit: a systematic review. *J Physiother* 2015; 61: 125–134.

Hoffman M, Van Hollebeke M, Clerckx B, et al. Can inspiratory muscle training improve weaning outcomes in difficult to wean patients? A protocol for a randomised controlled trial (IMweanT study). *BMJ Open* 2018; 8: e021091.

Langer D, Charususin N, Jácome C, et al. Efficacy of a novel method for inspiratory muscle training in people with chronic obstructive pulmonary disease. *Phys Ther* 2015; 95: 1264–1273.

Van Hollebeke M, Poddige B, Clerckx B, et al. High-intensity inspiratory muscle training improves scalene and sternocleidomastoid muscle oxygenation parameters in patients with weaning difficulties: a randomized controlled trial. *Front Physiol* 2022; 13: 786575.

Thille AW, Richard J-CM, Brochard L. The decision to extubate in the intensive care unit. *Am J Respir Crit Care Med* 2013; 187: 1294–1302.

Boles J-M, Bion J, Connors A, et al. Weaning from mechanical ventilation. *Eur Respir J* 2007; 29: 1033–1056.

Ely EW, Baker AM, Dunagan DP, et al. Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. *N Engl J Med* 1996; 335: 1864–1869.

McConville JF, Kress JP. Weaning patients from the ventilator. *Crit Care Med* 1995; 23: 2399–2409.

Sklar MC, Burns K, Rittayamai N, et al. Effort to breathe with various spontaneous breathing trial techniques. *A physiologic meta-analysis*. *Am J Respir Crit Care Med* 2017; 195: 1477–1485.

Subirà C, Hernández G, Vázquez A, et al. Effect of pressure support vs t-piece ventilation strategies during spontaneous breathing trials on successful extubation among patients receiving mechanical ventilation: a randomized clinical trial. *JAMA* 2019; 321: 2175–2182.

Burns KEA, Rizvi L, Cook DJ, et al. Ventilator weaning and discontinuation practices for critically ill patients. *JAMA* 2021; 325: 1173.

Rochwerger B, Brook L, Elliott MW, et al. Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. *Eur Respir J* 2017; 50: 1602426.

Hernández G, Vaquero C, González P, et al. Effect of postextubation high-flow nasal cannula vs conventional oxygen therapy on reintubation in low-risk patients: a randomized clinical trial. *JAMA* 2016; 315: 1354–1361.

Thille AW, Muller G, Gacouin A, et al. Effect of postextubation high-flow nasal oxygen with noninvasive ventilation vs high-flow nasal oxygen alone on reintubation among patients at high risk of extubation failure: a randomized clinical trial. *JAMA* 2019; 322: 1465–1475.

Liu J, Shen F, Teboul J-L, et al. Cardiac dysfunction induced by weaning from mechanical ventilation: incidence, risk factors, and effects of fluid removal. *Crit Care* 2016; 20: 369.

Bedet A, Tomberli F, Prat G, et al. Myocardial ischemia during ventilator weaning: a prospective multicenter cohort study. *Crit Care* 2019; 23: 321.
Oczkowski S, Ergan B, Bos L, Barnes H, McDonald J, Smallwood N, Marchese S, Lo Coco D, Lo Coco A. Outcome and attitudes toward home tracheostomy ventilation of consecutive patients: a 10-year experience. Respir Med 2008; 102: 430–436.

Barnes H, McDonald J, Smallwood N, et al. Opioids for the palliation of refractory breathlessness in adults with advanced disease and terminal illness. Cochrane Database Syst Rev 2016; 3: CD011008.

Pisani L, Hill NS, Pacilli AMG, et al. Management of dyspnea in the terminally ill. Chest 2018; 154: 925–934.

Abernethy AP, McDonald CF, Frith PA, et al. Effect of palliative oxygen versus room air in relief of breathlessness in patients with refractory dyspnea: a double-blind, randomised controlled trial. Lancet 2010; 376: 784–793.

Nava S, Ferrer M, Esquininas A, et al. Palliative use of non-invasive ventilation in end-of-life patients with solid tumours: a randomised feasibility trial. Lancet Oncol 2013; 14: 219–227.

Hui D, Bohlke K, Bao T, et al. Management of dyspnea in advanced cancer: ASCO guideline. J Clin Oncol 2021; 39: 1380–1411.

Davidson AC, Banham S, Elliott M, et al. BTS/ICS guideline for the ventilatory management of acute hypercapnic respiratory failure in adults. Thorax 2016; 71: Suppl. 2, i1–i35.

Nava S, Navalesi P, Conti G. Time of non-invasive ventilation. Intensive Care Med 2006; 32: 361–370.

Lightowler JV. Non-invasive positive pressure ventilation to treat respiratory failure resulting from exacerbations of chronic obstructive pulmonary disease: Cochrane systematic review and meta-analysis. BMJ 2003; 326: 185.

Austin MA, Wills KE, Blizzard L, et al. Effect of high flow oxygen on mortality in chronic obstructive pulmonary disease patients in prehospital setting: randomised controlled trial. BMJ 2010; 341: c5462.

Fiorino S, Bacchi-Reggiani L, Detotto E, et al. Efficacy of non-invasive mechanical ventilation in the general ward in patients with chronic obstructive pulmonary disease admitted for hypercapnic acute respiratory failure and pH <7.35: a feasibility pilot study. Intern Med J 2015; 45: 527–537.

Longhini F, Pisani L, Lungu R, et al. High-flow oxygen therapy after noninvasive ventilation interruption in patients recovering from hypercapnic acute respiratory failure: a physiological crossover trial. Crit Care Med 2019; 47: e506–e511.

Sellares J, Ferrer M, Anton A, et al. Discontinuing noninvasive ventilation in severe chronic obstructive pulmonary disease exacerbations: a randomised controlled trial. Eur Respir J 2017; 50: 1601448.

Oczkowski S, Ergan B, Bos L, et al. ERS clinical practice guidelines: high-flow nasal cannula in acute respiratory failure. Eur Respir J 2022; 59: 210154.
Dale CM, King J, Amin R, Chatwin M, Tan H-L, Bush A, Spoletini G, Mega C, Pisani L, MacLusky I, Keilty K. Section 12: Transition from pediatric to adult care.

Wallis C, Paton JY, Beaton S, Hull J, Aniapravan R, Chan E, Onofri A, Broomfield A, Tan H. Transition to adult care in children on long-term ventilation.

Blum RWM, Garell D, Hodgman CH, Mastouri M, Amaddeo A, Griffon L, Steindor M, Wagner CE, Bock C, Mündel T, Feng S, Tatkov S, Appendini L, Patessio A, Zanaboni S, Möller W, C, Gonçalves MR, Bach JR, Ishikawa Y, de Medeiros GC, Sassi FC, Lirani-Silva C, Paulides FM, Plötz FB, Verweij-van den Oudenrijn LP, McDougall CM, Adderley RJ, Wensley DF, et al. The treatment burden of long-term home noninvasive ventilation.

Cantero C, Adler D, Pasquina P, Couturier H, Dupuis J, Ghrsallaoui MZ, et al. Quality of life and outcome of home noninvasive ventilation (NIV) in patients above 80 yrs old. Eur Respir J 2019; 54: Suppl. 63, PA2315.
López-Campos JL, Failde I, Masa JF, et al. Factors related to quality of life in patients receiving home mechanical ventilation. *Respir Med* 2008; 102: 605–612.

Markussen H, Natvig GK, Lehmann S, et al. Health related quality of life in patients treated with long-term mechanical ventilation. *Eur Respir J* 2017; 50: Suppl. 61, PA2147.

Mascheroni D, Kolobow T, Fumagalli R, et al. Acute respiratory failure following pharmacologically induced hyperventilation: an experimental animal study. *Intensive Care Med* 1988; 15: 8–14.

Carteaux G, Millán-Guilarte T, De Prost N, et al. Failure of noninvasive ventilation for de novo acute hypoxic respiratory failure: role of tidal volume. *Crit Care Med* 2016; 44: 282–290.

Calfee CS, Delucchi K, Parsons PE, et al. Subphenotypes in acute respiratory distress syndrome: latent class analysis of data from two randomised controlled trials. *Lancet Respir Med* 2014; 2: 611–620.

Tonelli R, Busani S, Tabbi L, et al. Inspiratory effort and lung mechanics in spontaneously breathing patients with acute respiratory failure due to COVID-19: a matched control study. *Am J Respir Crit Care Med* 2021; 204: 725–728.

Schifino G, Vega ML, Pisani L, et al. Effects of non-invasive respiratory supports on inspiratory effort in moderate-severe COVID-19 patients. A randomized physiological study. *Eur J Intern Med* 2022; 100: 110–118.

Tonelli R, Fantini R, Tabbi L, et al. Early inspiratory effort assessment by esophageal manometry predicts noninvasive ventilation outcome in de novo respiratory failure. A Pilot Study. *Am J Respir Crit Care Med* 2020; 202: 558–567.

Carrillo A, Gonzalez-Diaz G, Ferrer M, et al. Non-invasive ventilation in community-acquired pneumonia and severe acute respiratory failure. *Intensive Care Med* 2012; 38: 458–466.

Frat J-P, Ragot S, Coudroy R, et al. REVA network. Predictors of intubation in patients with acute hypoxic respiratory failure treated with a noninvasive oxygenation strategy. *Crit Care Med* 2018; 46: 208–215.

Touchon F, Trigui Y, Prud’homme E, et al. Awake prone positioning for hypoaemic respiratory failure: past, COVID-19 and perspectives. *Eur Respir Rev* 2021; 30: 210022.

Guérin C, Albert RK, Beitler J, et al. Prone position in ARDS patients: why, when, how and for whom. *Intensive Care Med* 2020; 46: 2385–2396.

Guérin C, Reignier J, Richard J-C, et al. Prone positioning in severe acute respiratory distress syndrome. *N Engl J Med* 2013; 368: 2159–2168.

Scaravilli V, Grasselli G, Castagna L, et al. Prone positioning improves oxygenation in spontaneously breathing nonintubated patients with hypoxic acute respiratory failure: a retrospective study. *J Crit Care* 2015; 30: 1390–1394.

Li J, Luo J, Pavlov I, et al. Awake prone positioning for non-intubated patients with COVID-19-related acute hypoxaemic respiratory failure: a systematic review and meta-analysis. *Lancet Respir Med* 2022; 10: 573–583.

Sterne JAC, Murthy S, Diaz JV, et al. Association between administration of systemic corticosteroids and mortality among critically ill patients with COVID-19: a meta-analysis. *JAMA* 2020; 324: 1330–1341.

Villar J, Ferrando C, Martínez D, et al. Dexamethasone treatment for the acute respiratory distress syndrome: a multicentre, randomised controlled trial. *Lancet Respir Med* 2020; 8: 267–276.

Jiang S, Liu T, Hu Y, et al. Efficacy and safety of glucocorticoids in the treatment of severe community-acquired pneumonia: a meta-analysis. *Medicine (Baltimore)* 2019; 98: e16239.

Antcliff DB, Burnham KL, Al-Beidh F, et al. Transcriptomic signatures in sepsis and a differential response to steroids. From the VANISH Randomized Trial. *Am J Respir Crit Care Med* 2019; 199: 980–986.

Reyes LF, Rodriguez A, Bastidas A, et al. Dexamethasone as risk-factor for ICU-acquired respiratory tract infections in severe COVID-19. *J Crit Care* 2022; 69: 154014.