Artificial intelligence and the future of telemonitoring in home mechanical ventilation

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Home mechanical ventilation (HMV) is increasingly used to manage chronic respiratory failure across different conditions such as COPD, obesity–hypoventilation syndrome, neuromuscular diseases, and restrictive thoracic disorders [1]. As the prevalence of these conditions rises, the past decade has witnessed a rapid expansion of remote monitoring systems designed to support remote initiation and follow-up, troubleshooting, and ventilator data review. Contemporary commercial platforms provide information on usage, tidal volume, leak, respiratory rate, triggering, pressure adjustments, and event detection, granting clinicians unprecedented insight into the patient's home ventilation patterns [2]. Studies have shown that the average respiratory rate, the percentage of respiratory cycles triggered by the patient, and the daily level of adherence, all obtained from the ventilator, might predict the onset of a COPD exacerbation. However, the sensitivity and specificity of these parameters in predicting exacerbations was moderate and required several days of measuring [3–5].

The recently published European Respiratory Society (ERS) clinical practice guideline on telemedicine in HMV highlights that telemonitoring is both feasible and acceptable during the initiation and follow-up of long-term ventilation in specific clinical settings [6]. Nevertheless, the guideline also highlights the limited evidence supporting its clinical effectiveness and the striking heterogeneity across systems, countries, and healthcare providers [7]. Moreover, in its current form, telemonitoring systems remain largely descriptive and share several limitations. First, data granularity is relatively low, with most of the platforms delivering only summaries of data rather than breath-by-breath analysis. Second, monitoring tends to be reactive, with clinicians reviewing data retrospectively, typically triggered by scheduled follow-ups or patient-reported symptoms rather than automated early detection of deterioration. Third, interoperability between platforms is minimal with proprietary data formats that inhibit cross-platform research and system integration; this issue is exacerbated by manufacturer-specific acquisition and processing of native signals that prevent reliable extrapolation across devices. Fourth, physiological and clinical insights are limited and ventilator metrics are not routinely integrated with peripheral oxygen saturation, transcutaneous carbon dioxide, or symptom tracking. Fifth, notifications often lack specificity, resulting in unnecessary alerts and inconsistent responses. These aspects may limit the ability of telemonitoring to shift care from detection to prevention.

Meanwhile, artificial intelligence (AI) is rapidly transforming remote patient monitoring across healthcare fields, reshaping fields that depend on high-frequency, multi-dimensional data streams [8]. Thus far, AI and machine learning in respiratory medicine have been applied predominantly to the automated interpretation of thoracic imaging [9], digital lung pathology [10, 11], and physiological datasets such as pulmonary function tests [12, 13]. Insights from intensive care unit-based AI research show that

machine-learning models can accurately detect ineffective efforts, flow limitation, and cycling asynchronies from raw ventilator waveforms, providing continuous, actionable insights that clinicians often miss during routine care [14]. Translating these principles to home ventilation could greatly enhance remote identification of suboptimal settings, patient discomfort, or early decompensation.

The following potential applications of AI in HMV should be interpreted as forward-looking expert perspectives rather than evidence-supported clinical benefits. By analysing variations in respiratory-rate variability, inspiratory and expiratory flow waveforms, inspiration to expiration time ratio, leak behaviour, tidal-volume stability, and nocturnal hypoventilation markers, predictive models may signal exacerbations days before symptoms arise. Automated waveform interpretation can similarly detect complex asynchronies and dynamic hyperinflation, supporting timely optimisation of ventilator settings and improving adherence and comfort. However, during noninvasive ventilation, the simultaneous interaction of leaks, obstructions (which are absent in invasive ventilation) and asynchronies greatly complicates event classification [15], highlighting the need for simpler integrative indices that correlate with patient-reported outcome measures.

AI may also assist with personalised titration and interface optimisation by forecasting comfort, leak dynamics, and adherence trajectories. Finally, integrating ventilator telemetry with multimodal data, such as continuous peripheral oxygen saturation/transcutaneous carbon dioxide, patient effort data (*i.e.* with respiratory electromyography or by detecting chest-wall motion), sleep staging, environmental exposures, home spirometry or oscillometry, and symptom reports could enable a comprehensive physiological risk assessment, moving telemonitoring from a descriptive system to a proactive early-warning platform capable of preventing decompensation and reducing unplanned visits.

However, responsible implementation must be considered. Black-box models may undermine clinician trust. Algorithms such as neural networks may perform well for defined diagnostic tasks, such as automated detection of patient–ventilator asynchronies, where accuracy is paramount. However, their limited interpretability makes them less suitable for prognostic modelling, where understanding the reasoning pathway is essential for safe decision-making. Moreover, ventilator-derived telemetry datasets qualify as true Big Data, requiring secure cloud infrastructures and high-performance computational resources, and dataset bias could further introduce inequities in prediction. Vendor lock-in and proprietary data systems could fragment the field and introduce ethical concerns related to transparency, data ownership, interoperability, and equitable access to innovation. Excessive monitoring risks reducing patients' sense of autonomy and increasing caregiver burden. The European Union's AI Act will introduce strict regulatory requirements [16], ranging from data governance and technical documentation to human oversight that aim to ensure transparency, ethical integrity, safety, and regulatory compliance for both AI systems providers and deployers. Therefore, healthcare organisations must adopt structured operational compliance tools (AI policies) and develop adequate AI literacy among staff to ensure safe and trustworthy deployment.

Ultimately, AI must augment rather than replace clinical expertise and shared decision-making, and its safe advancement will require the respiratory community to lead in defining common data standards, reference signal libraries, and robust validation frameworks that ensure generalisability across devices, interfaces, and patient profiles. Open waveform standards and interoperability across manufacturers are essential and could be greatly enhanced by adopting homogeneous formats (*e.g.* EDF, CSV, TXT) and harmonising key acquisition parameters such as sampling rates, filtering strategies, and storage resolution. Algorithms must be transparent, explainable, and externally validated. Robust clinical trials should focus on improvements in clinically meaningful endpoints, including exacerbations, gas exchange, hospitalisation rates, health-related quality of life and patient-reported outcome measures. Patients must be active partners in defining acceptable monitoring intensity, privacy boundaries, and communication pathways. Importantly, the clinical benefits of AI-enabled telemonitoring in HMV must be formally evaluated; given the dynamic nature of AI-based medical devices, this may require methodological approaches beyond traditional randomised trials, in line with emerging regulatory guidance from the European Medicines Agency and the US Food and Drug Agency [17]. Opportunities, challenges and implications for research and implementation of AI in telemedicine for HMV are summarised in table 1.

The ERS Clinical Research Collaboration (CRC) IMPORTANCE (Implications of Positive Airway Pressure and Home Mechanical Ventilation: TowArds optimal patient CarE) is uniquely positioned to accelerate this transition responsibly [18]. CRC IMPORTANCE is primarily funded by the ERS and operates under ERS governance. In addition, selected research activities within the CRC are supported through competitive public funding, including Horizon Europe-associated programmes such as the European Partnership on Transforming Health and Care Systems. Industry partners may contribute in a transparent and non-promotional manner, for example, by providing technical expertise or infrastructure

TABLE 1 Opportunities and challenges of artificial intelligence (AI)-driven telemonitoring in home mechanical ventilation

Opportunities	Challenges	Implications for research and implementation
Earlier detection of deterioration AI may identify subtle physiological trends that precede clinical worsening.	**Data equity, quality and comparability** High-fidelity waveform and annotated clinical datasets remain scarce; inconsistent formats hinder model development. Data derived from ventilators might be internally calculated, limiting comparability. The lack of standardised metrics, secure cloud storage, and adequate computational resources further constrains progress.	Prospective validation of predictive models using clinically meaningful endpoints and predefined alert thresholds.
Improved adherence and comfort Personalised AI-driven feedback can enhance tolerance, synchrony, and long-term use.	**Interoperability and proprietary systems** Lack of open APIs and vendor-neutral standards restricts cross-platform integration and scalability.	Research on personalised feedback tools aligned with patient-reported outcomes and long-term adherence.
Reduced hospitalisations and unscheduled visits Predictive monitoring may enable timely intervention and reduce exacerbation-related healthcare use.	**Explainability and clinical trust** Black-box models undermine clinician confidence and limit adoption in clinical decision–making. While they may be acceptable for focused tasks such as automated asynchrony detection, their lack of explainability hinders wider clinical use.	Pragmatic or adaptive trial designs to assess real-world clinical impact, as well as structured evaluation beyond initial clinical implementation.
Standardised monitoring across centres AI can harmonise definitions, thresholds, and reporting, supporting benchmarking and quality improvement.	**Ethical, regulatory and equity concerns** AI systems must ensure fairness, transparency, data provenance, privacy protection, and avoid reinforcing disparities.	Harmonisation of monitoring parameters and development of shared definitions.
Patient empowerment Interpretable outputs and personalised insights support engagement and shared decision-making.	**Over-surveillance and loss of autonomy** Monitoring must complement, not replace, self-management and safeguard trust and privacy in the home environment.	Co-design approaches involving patients and caregivers to define acceptable monitoring intensity.

support, in accordance with ERS policies [19]. By uniting international experts, integrating industry stakeholders and patient and caregiver perspectives and collecting harmonised real-world data, and defining research priorities, IMPORTANCE aims also to advance evidence-based, equitable, and scalable telemonitoring pathways and may serve as a large dataset for future high-quality studies integrating AI tools for HMV, as a true partner in delivering safer, more personalised, and equitable long-term mechanical ventilation across health systems.

AI can shift telemonitoring from a descriptive, retrospective system to a proactive, personalised and physiologically informed model of care. The future of care for patients on HMV should not be merely digital; it must evolve into an intelligent, collaborative, and clinically integrated system where technology enhances clinical judgment while remaining centred on patient wellbeing.

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