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Emerging Diagnostic and Therapeutic Applications of Remote Patient Monitoring in Chronic Obstructive Pulmonary Disease (COPD) Care

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Introduction

Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality, with prevalence projected to rise by nearly 25% between 2020 and 2050 to reach approximately 600 million people worldwide.¹ COPD is characterized by persistent airflow limitation, leading to chronic dyspnea and reduced exercise

capacity. Patients experience exacerbations of COPD (ECOPDs), clinically significant acute episodes characterized by increased airway inflammation and sudden worsening of breathlessness, which contribute substantially to lung function decline and are strongly associated with mortality.² Exacerbations account for the vast majority of COPD-related healthcare use, driving hospital admissions, healthcare costs, long-term

functional decline, and mortality risk.² Despite progress in inhaled and biologic therapies, the management of recurrent exacerbations remains a significant challenge, and in fact, admissions for COPD are uniquely increasing rather than decreasing when compared with other chronic diseases after adjusting for population growth and aging in Canada.³ This highlights two important clinical realities: 1) that the current approach to COPD care is failing, and 2) that for both patients and health systems alike, there is a pressing need for innovative strategies to address and reduce the burden of COPD exacerbation admissions and readmissions.

What is Remote Patient Monitoring?

Remote patient monitoring (RPM) has emerged as a promising method to potentially address many ongoing clinical challenges in COPD care, including key individual (dyspnea, mobility) and logistical (rural/isolated populations, winter seasonal care) accessibility gaps,⁴ as well as the overarching need for prompt and timely prevention-oriented strategies (Figure 1). RPM involves the systematic collection and real-time transmission of health-related data from the comfort of the patient's home environment, allowing for the detection of warning signs,

particularly among COPD sub-populations who experience frequent and/or severe exacerbations and hospitalization/re-hospitalization.⁵

Recent technological advances have led to the development of increasingly compact and sophisticated wearable^{4,5} and portable⁶ devices that are capable of continuous, multi-parameter data collection and transmission. 'Wearables' are available in nearly any format, including wristbands, armbands, vests, upper thorax bands, and rings,⁴ and can enable continuous daytime and nighttime monitoring of relevant physiological parameters including respiratory rate (RR), oxygen saturation (SpO₂), heart rate (HR), physical activity, sleep quality, and autonomic function.⁷ Complementing these technologies, portable handheld devices allow for independent home-based measurement and transmission of lung function and lung mechanical changes.^{6,8} A summary of the principal equipment and strategies used in RPM for COPD is presented in Table 1.

A New Approach to Exacerbation Definition and Classification

Alongside rapid advances in wearable and portable technologies, the current artificial intelligence (AI)/machine learning (ML) 'renaissance' has enabled the processing

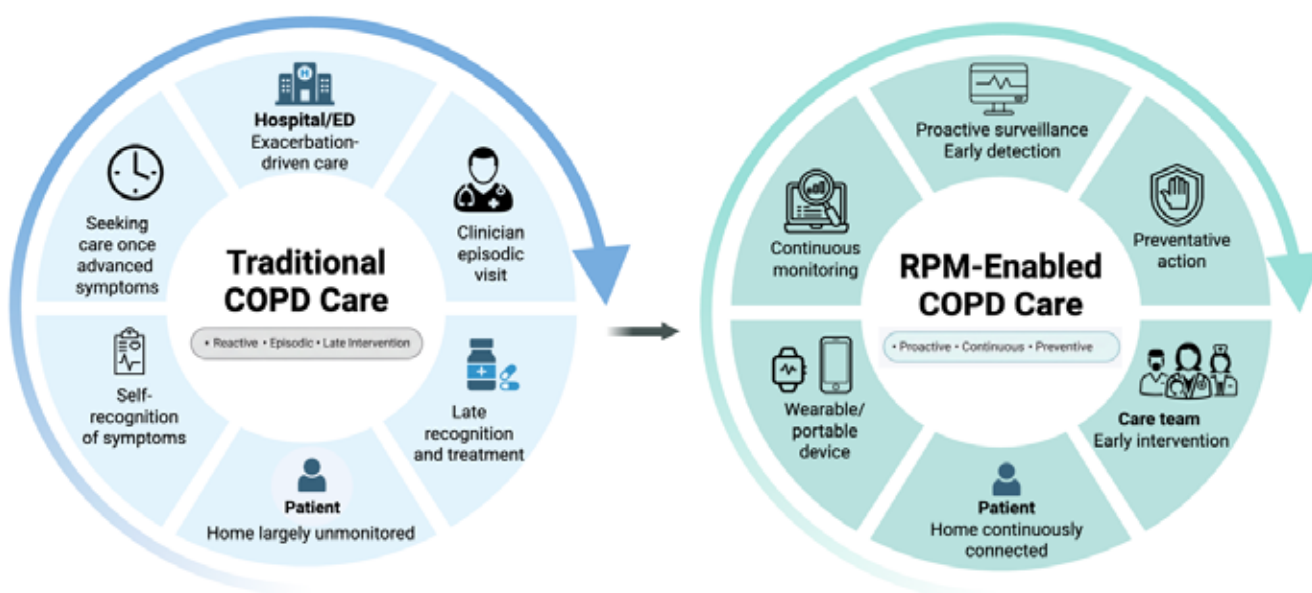


Figure 1. Traditional care model vs remote patient monitoring care model in COPD; courtesy of Felix-Antoine Coutu, BSc, Armita Kalani, Seyedfakhreddin Nabavi, PhD, Bryan A. Ross, MD, FRCPC, MSc, BSCh

Abbreviations: COPD: chronic obstructive pulmonary disease; ED: Emergency Department; RPM: remote patient monitoring

of incredibly large volumes of continuous, multiparametric physiologic data at an unprecedented scale. By leveraging ML to interpret complex physiological signatures, clinicians can improve diagnostic accuracy⁹ while supporting a more personalized approach to care. Historically, COPD exacerbations have been diagnosed based on patient-reported increases in classic symptoms such as dyspnea, sputum production, and cough, with exacerbation severity classified retrospectively, according to treatment decisions and care settings rather than underlying mechanisms or the degree of physiological derangement.^{2,10} These persistent limitations in diagnosis and severity classification have prompted the formulation of a new framework—the Rome Proposal adopted by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) in 2023—whereby severity classification is defined by objective and measurable parameters, including validated dyspnea scores, RR, SpO₂, HR, C-reactive protein, and blood gas values.¹⁰

This framework provides a useful and objective foundation not only for advancing exacerbation research but also for developing and deploying clinical COPD RPM platforms. Reflecting the progress made to date in this field, the 2026 edition of the GOLD Report has, for the first time, included a chapter dedicated to AI and emerging technologies in COPD.²

Diagnostic Applications of Remote Patient Monitoring

Given that COPD exacerbations are characterized by an acute pro-inflammatory burst within the airways,¹⁰ and that emerging evidence identifies the prodromal (pre-symptomatic) period as a key and potentially multi-day window for prompt intervention,¹¹⁻¹³ pre-emptive monitoring strategies in high-risk patients may have a profound impact on health resource use, quality of life, lung function worsening, and mortality.

RPM Domain	Modality	Data Captured	Clinical Application	Strengths	Limitations
Continuous Physiological Monitoring	Wearable sensors	Respiratory, cardiac, activity, sleep, autonomic metrics	Early detection of exacerbations, characterization of exacerbation trajectories	Continuous, passive, home environment, high patient acceptability	Signal variability, possible artefact, requires validation of alert thresholds
Lung Function/ Mechanics	Portable/ handheld oscillometers	Airway resistance, lung mechanical changes	Disease monitoring, risk stratification, complement to wearable data	Effort-independent, autonomous home use	Non-continuous (interval) measurements, limited temporal resolution, technique-dependent
Monitoring of Standard COPD Therapy	Smart inhalers/ device attachments	Inhaler actuation, technique, adherence	Optimization of therapy, early detection of deterioration	Objective adherence data, actionable feedback	Device-specific, cost considerations
Therapeutic Delivery	Virtual pulmonary rehabilitation programs	Activity metrics, exercise adherence, safety monitoring	Maintenance of PR benefits, symptom improvement	Expands access, scalable	Digital literacy requirements

Table 1. Remote Patient Monitoring Domains and Modalities in COPD; *courtesy of Felix-Antoine Coutu, BSc, Armita Kalani, Seyedfakhreddin Nabavi, PhD, Bryan A. Ross, MD, FRCPC, MSc, BScH*

Abbreviations: COPD: chronic obstructive pulmonary disease; RPM: remote patient monitoring; PR: pulmonary rehabilitation.

Foundational studies of RPM in COPD used to leverage ‘fixed’ non-wearable home equipment (home oxygen, non-invasive ventilation) to demonstrate that subtle changes in RR could precede acute exacerbations by up to 5 days.^{12,13} Subsequent studies used biometric wearable chest bands to collect daytime ambulatory (non-tethered) parameters for several weeks after an exacerbation. These investigations demonstrated both the feasibility of prolonged monitoring as well as a progressive normalization of RR over time in the recovery period, suggesting a possible application for RPM in ‘high-risk’ patients at discharge and monitoring to prevent re-hospitalizations.¹⁴

More recently, smaller and more comfortable wearables, such as biometric rings and wristbands, have been used to demonstrate the feasibility of non-invasive, continuous recording of parameters in the unperturbed ambulatory home setting during COPD exacerbations over periods of several weeks. These investigations have shown that excellent quality data could be captured and transmitted autonomously by older adults with advanced disease (i.e., the target population most likely to benefit from RPM platforms in real-world clinical practice).⁵ These studies have also demonstrated that the scientific community is starting to leverage wearable devices to better address the fundamental question of ‘what exactly is an exacerbation?’. More recently, wearable devices (biometric rings and wristbands) have been used to characterize the trajectory of exacerbations over 3 consecutive weeks, capturing subtle longitudinal changes in respiratory, cardiac, activity, sleep, and autonomic parameters (*exacerbation characterization*), while also identifying patients who ultimately recover (“recovered” subgroup) from those with persistent symptom worsening (“persistent-worsening” subgroup). This work has delineated distinct pathophysiological patterns (“*clinical subgroup signatures*”).⁷ The former (*exacerbation characterization*) serves as the foundation to construct and validate the sophisticated COPD RPM platforms using prospectively collected data from a large cohort of patients with COPD with a history of frequent exacerbations, such as the ePredictAECOPD trial ([ClinicalTrials.gov NCT06802003](https://clinicaltrials.gov/ct2/show/study/NCT06802003)). These platforms are designed to detect the very early prodromal period of an exacerbation, allowing for prompt trajectory-altering intervention. In parallel, clear and distinct patterns that differentiate clinically recovered

from non-recovered patients (“clinical subgroup signatures”)⁷ are being integrated into RPM alert algorithms to support monitoring of high-risk patients after hospital or emergency department discharge.

Handheld portable devices are increasingly being used and incorporated into RPM platforms for chronic disease monitoring in COPD, due in part to concomitant technological advances that have allowed lighter, more compact, and user-friendly designs. These advancements also address the need to complement wearable-derived vital sign-based metrics with daily lung function-based metrics. Portable oscillometry devices are often preferred over spirometry for home monitoring, as they can be used more reliably and autonomously without the need for a skilled technician or uncomfortable repeated forced respiratory manoeuvres, an advantage that is particularly important when the patient is acutely unwell.¹⁵ The feasibility and practicality of home-based oscillometry was demonstrated in the CHROMED randomized controlled trial, which also reported a reduction in healthcare costs as an exploratory outcome following the incorporation of this lung function monitoring intervention.⁸ Following this trial, smaller handheld portable devices designed for estimating large and small airway resistance have been tested and validated against conventional oscillometry. These devices demonstrated a comparable, and in some cases superior, ability to discriminate disease severity alongside excellent user-reported experience scores among patients with COPD.⁶

Therapeutic Applications of Remote Patient Monitoring

The applications of RPM in COPD management extend well beyond diagnosis and monitoring. The COVID-19 pandemic emphasized the relevance of therapeutic RPM-based solutions, as remote modalities became essential for maintaining standard-of-care interventions, such as pulmonary rehabilitation (PR) programs, during periods when in-person care was restricted or even prohibited.¹⁶ This rapid and, initially, forced clinical transition from traditional in-person PR to virtual or hybrid alternatives, adopted during the COVID-19 pandemic and sustained thereafter, has been complemented by research demonstrating these approaches to be both feasible and safe, with similar clinical outcomes comparable to those of in-person programs, including effects on

symptom burden and quality of life.¹⁷ In addition, a recent systematic review and meta-analysis evaluating the addition of wearable-based activity tracking into PR programs reported a significant increase in daily step count compared with usual care, although no clear additional benefits were observed for quality of life or functional capacity. Overall, these findings support the integration of RPM modalities within virtual PR programs.¹⁸

Digital ‘smart’ inhalers and other connected therapeutic devices represent an additional avenue through which RPM can be used as an adjunct to existing standard-of-care COPD therapies. These technologies support the monitoring of objective inhaler-related metrics, and provide direct feedback on inhaler technique, supporting optimized medication delivery and improved adherence to controller therapy. In a recent prospective observational study of 40 patients with COPD, smart inhaler sensors detected reductions in core inhalation characteristics (volume, duration, and peak inspiratory flow) up to 2 weeks before an exacerbation. These findings suggest that smart inhalers have the ability to identify not only issues related to proper technique and adherence, but also may help identify the prodromal/early therapeutic window for acute intervention.¹⁹ Building on this premise, an ongoing prospective clinical trial (ClinicalTrials.gov NCT06614959) is investigating the integration of a ‘smart’ attachment to an oscillatory positive expiratory pressure device. This technology collects parameters related to both the quality of the technique (time of use, number of use, pressure gradient generated) and the quality and technical parameters of use (including frequency and amplitude of pressure oscillations and the sum of oscillations over a predefined threshold). These parameters, transmitted without any “active” participation whatsoever from the patient to the clinical care team, have the potential to remotely identify nonadherence, poor technique, and even early signs of deterioration. Collectively, “smart” inhalers and connective device attachments have the potential to complement, and even enhance, existing COPD therapeutic strategies.

Finally, app-based delivery of educational modules and self-management training for COPD is being developed and implemented. Recent studies have shown that these digital interventions can significantly improve self-management behaviours and quality of life. Motivational and peer-support features embedded within

these applications appear to contribute to their effectiveness,²⁰ and have been shown to improve physical activity, adherence to exercise, and reductions in depression scores.²¹

Barriers to Implementation

The actual implementation of RPM innovations into frontline clinical practice remains limited by both perceived and genuine barriers to health system integration. In contrast to in-person monitoring methods, RPM relies on the patient’s adherence and ability to operate the devices in the home setting, including wearing and using the device, recharging it, and transmitting data.²² Therefore, end-user (patient) ease of use and comfort from prolonged wear become important factors.^{23,24} Moreover, because RPM occurs outside the hospital or clinic, and generates large volumes of continuous, multiparametric data, many platforms rely on third-party cloud-based storage solutions.²⁵ These considerations raise significant concerns about data privacy and confidentiality. Aside from data collection and storage, achieving the primary goal of RPM, which is prompt intervention, requires trained healthcare professionals to triage alerts and notify physicians promptly. Especially during early implementation, ‘false-positive’ alerts may lead to unnecessary use of limited resources. Continuous monitoring also increases the likelihood of detecting unrelated pathological findings, raising questions about medico-legal liability, particularly if an acute event occurs outside of routine care hours. At the same time, patients enrolled in RPM platforms may feel continuously monitored and may inappropriately delay seeking urgent inpatient care. Finally, the transition from small-scale passive data collection for research purposes to large-scale, real-time clinical monitoring will require substantial infrastructure and personnel.

Conclusion

RPM has substantial potential to support a more proactive and sophisticated approach to chronic disease management in patients with COPD. Advances in continuous monitoring technologies, parallel progress in “hardware” (devices) and “software” (ML-based models), and the introduction of more objective diagnostic and severity classification criteria for exacerbations have converged over the same time period. Together, these developments enable a range of

clinical applications, including earlier detection of clinical deterioration, monitoring post-discharge of high-risk patients in the recovery period, creating novel home-based therapeutic interventions, and strengthening the effectiveness of existing standard-of-care COPD therapies. Achieving a broader implementation of RPM in frontline clinical practice will require robust evidence of clinical efficacy beyond current standards of care, as well as seamless integration into an already overburdened, stagnant, and failing “traditional” healthcare system.

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References

1. Boers E, Barrett M, Su JG, Benjafield AV, Sinha S, Kaye L, et al. Global burden of chronic obstructive pulmonary disease through 2050. *JAMA Netw Open*. 2023;6(12):e2346598-e. doi:10.1001/jamanetworkopen.2023.46598
2. Global Initiative for Chronic Obstructive Lung Disease - GOLD. Global strategy for the diagnosis, management, and prevention of COPD: 2026 Gold Report [Internet]. 2026 [cited 2026 March 26]. Available from: https://goldcopd.org/wp-content/uploads/2026/01/GOLD-REPORT-2026-v1.3-8Dec2025_WMV2.pdf
3. Amegadzie JE, Lee TY, Sadatsafavi M, Lynd LD, Sin DD, Johnson KM. Trends in hospital admissions for chronic obstructive pulmonary disease over 16 years in Canada. *CMAJ*. 2023;195(35):E1172-E1179. doi:10.1503/cmaj.221051
4. Coutu FA, Iorio OC, Ross BA. Remote patient monitoring strategies and wearable technology in chronic obstructive pulmonary disease. *Front Med (Lausanne)*. 2023;10:1236598. doi:10.3389/fmed.2023.1236598
5. Iorio OC, Coutu F-A, Malaeb D, Ross BA. Feasibility, functionality, and user experience with wearable technologies for acute exacerbation monitoring in patients with severe COPD. *Front Sig Proc*. 2024;4:1362754. doi:10.3389/frsip.2024.1362754.
6. Coutu FA, Malaeb D, Iorio OC, Nabavi S, McFarland T, Lundblad LKA, et al. Measuring lung mechanics in patients with COPD using the handheld portable rapid expiratory occlusion monitor (REOM): a cross-sectional study. *Physiol Rep*. 2025;13(7):e70307. doi:10.14814/phy2.70307
7. Coutu FA, Iorio OC, Nabavi S, Hadid A, Jensen D, Pamidi S, et al. Continuous characterisation of exacerbation pathophysiology using wearable technologies in free-living outpatients with COPD: a prospective observational cohort study. *EBioMedicine*. 2024;110:105472. doi:10.1016/j.ebiom.2024.105472
8. Walker PP, Pompilio PP, Zanaboni P, Bergmo TS, Prikk K, Malinovski A, et al. Telemonitoring in chronic obstructive pulmonary disease (CHROMED). A randomized clinical trial. *Am J Respir Crit Care Med*. 2018;198(5):620-628. doi:10.1164/rccm.201712-2404OC
9. Glyde HMG, Morgan C, Wilkinson TMA, Nabney IT, Dodd JW. Remote patient monitoring and machine learning in acute exacerbations of chronic obstructive pulmonary disease: dual systematic literature review and narrative synthesis. *J Med Internet Res*. 2024;26:e52143. doi:10.2196/52143
10. Celli BR, Fabbri LM, Aaron SD, Agusti A, Brook R, Criner GJ, et al. An updated definition and severity classification of chronic obstructive pulmonary disease exacerbations: the Rome Proposal. *Am J Respir Crit Care Med*. 2021;204(11):1251-1258. doi:10.1164/rccm.202108-1819PP
11. Al Rajeh AM, Hurst JR. Monitoring of physiological

- parameters to predict exacerbations of chronic obstructive pulmonary disease (COPD): a systematic review. *J Clin Med*. 2016;5(12):108. doi:10.3390/jcm5120108.
12. Yañez AM, Guerrero D, Pérez de Alejo R, Garcia-Rio F, Alvarez-Sala JL, Calle-Rubio M, et al. Monitoring breathing rate at home allows early identification of COPD exacerbations. *Chest*. 2012;142(6):1524-1529. doi:10.1378/chest.11-2728
 13. Borel JC, Pelletier J, Taleux N, Briault A, Arnol N, Pison C, et al. Parameters recorded by software of non-invasive ventilators predict COPD exacerbation: a proof-of-concept study. *Thorax*. 2015;70(3):284-285. doi:10.1136/thoraxjnl-2014-206569
 14. Rubio N, Parker RA, Drost EM, Pinnock H, Weir CJ, Hanley J, et al. Home monitoring of breathing rate in people with chronic obstructive pulmonary disease: observational study of feasibility, acceptability, and change after exacerbation. *Int J Chron Obstruct Pulmon Dis*. 2017;12:1221-1231. doi:10.2147/COPD.S120706
 15. Stanojevic S, Kaminsky DA, Miller MR, Thompson B, Aliverti A, Barjaktarevic I, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. *Eur Respir J*. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021
 16. Foppiani A, Calcaterra V, Montanari C, Bertoli S, Battezzati A, Zuccotti G. Active home surveillance system (COD19) in managing chronic obstructive pulmonary disease: lessons and future perspectives from the COVID-19 pandemic experience. *Ther Adv Respir Dis*. 2025;19:17534666251346097. doi:10.1177/17534666251346097
 17. Qu M, Yang L, Liu K, Tang T, Sun X, Chen Y, et al. The effectiveness and feasibility of virtual pulmonary rehabilitation in patients with chronic respiratory diseases: a systematic review and meta-analysis. *Respir Med*. 2025;244:108159. doi:10.1016/j.rmed.2025.108159
 18. Oliveira TRA, do Nascimento Sales Figueiredo Fernandes AT, Santino TA, da Silva Menescal FEP, de Miranda Silva Nogueira PA. Effects of wearable devices on physical activity monitoring in pulmonary rehabilitation programs for chronic respiratory diseases: a systematic review and meta-analysis. *Sci Rep*. 2025;15(1):44767. doi:10.1038/s41598-025-28554-w
 19. Drummond MB, Hemphill CC, Hill T, Boe A, Yu D, Ohar JA. Use of a digital inhaler to assess COPD disease variability and identify impending acute COPD exacerbations: a pilot study. *Chronic Obstr Pulm Dis*. 2025;12(3):250-259. doi:10.15326/jcopdf.2024.0555
 20. Wang L, Guo Y, Wang M, Zhao Y. A mobile health application to support self-management in patients with chronic obstructive pulmonary disease: a randomised controlled trial. *Clin Rehabil*. 2021;35(1):90-101. doi:10.1177/0269215520946931
 21. Benzo R, Hault J, McEvoy C, Clark M, Benzo M, Johnson M, et al. Promoting chronic obstructive pulmonary disease wellness through remote monitoring and health coaching: a clinical trial. *Ann Am Thorac Soc*. 2022;19(11):1808-1817. doi:10.1513/AnnalsATS.202203-214OC
 22. Nabavi S, Lundblad LKA, Ross BA. Susceptibility assessment of oscillometry parameters to motion artifact. *Annu Int Conf IEEE Eng Med Biol Soc*. 2024;2024:1-4. doi:10.1109/EMBC53108.2024.10782180
 23. Fan KG, Mandel J, Agnihotri P, Tai-Seale M. Remote patient monitoring technologies for predicting chronic obstructive pulmonary disease exacerbations: review and comparison. *JMIR Mhealth Uhealth*. 2020;8(5):e16147. doi:10.2196/16147
 24. Hawthorne G, Greening N, Eslinger D, Briggs-Price S, Richardson M, Chaplin E, et al. Usability of wearable multiparameter technology to continuously monitor free-living vital signs in people living with chronic obstructive pulmonary disease: prospective observational study. *JMIR Hum Factors*. 2022;9(1):e30091. doi:10.2196/30091
 25. Waleed M, Kamal T, Um TW, Hafeez A, Habib B, Skouby KE. Unlocking insights in IoT-based patient monitoring: methods for encompassing large-data challenges. *Sensors (Basel)*. 2023;23(15):6760. doi:10.3390/s23156760.