Opinion

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Digital Twins in COPD: Simulation Models for Personalized Treatment

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Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory condition characterized by persistent airflow limitation, chronic inflammation, and structural remodeling of the airways and lung parenchyma. It is among the leading causes of morbidity and mortality worldwide, with millions of patients suffering from breathlessness, recurrent exacerbations, and systemic complications that reduce quality of life. Despite decades of research, COPD management remains largely reactive and symptomatic, guided by generalized treatment algorithms that do not adequately capture the heterogeneous nature of the disease. Patients differ significantly in their clinical presentations, underlying pathophysiology, response to therapy, and disease trajectories. Applied to COPD, digital twin technology holds the promise of creating highly individualized simulation models that mirror the physiological, molecular, and behavioral characteristics of patients. These dynamic models enable clinicians and researchers to test treatment strategies in silico before applying them in vivo, paving the way for personalized care, optimized drug regimens, and improved long-term outcomes [1].

Description

The concept of a digital twin originated in engineering and aerospace, where virtual replicas of aircraft engines or industrial machinery were used to predict performance, anticipate failures, and optimize maintenance. In medicine, the digital twin paradigm has been adapted to represent human organs, tissues, or entire physiological systems, integrating multimodal data streams to simulate disease progression and therapeutic response. A COPD digital twin is essentially a computational construct that replicates the respiratory system of an individual patient, incorporating anatomical data from imaging, physiological measurements from spirometry or plethysmography, molecular profiles from omics technologies, and lifestyle factors such as smoking history, environmental exposures, and physical activity [2].

The heterogeneity of COPD makes it an ideal candidate for digital twin applications. COPD encompasses a spectrum of phenotypes, including chronic bronchitis, emphysema-predominant disease, and asthma-COPD overlap, each with distinct pathophysiological underpinnings. Moreover, comorbidities such as cardiovascular disease, diabetes, and depression further complicate management. Traditional clinical tools, such as spirometry, provide only limited snapshots of lung function and fail to capture dynamic changes in airway resistance, ventilation heterogeneity, or systemic inflammation. In contrast, a digital twin can model airflow patterns through bronchial networks, simulate gas exchange at the alveolar level, and incorporate systemic metabolic interactions. For instance, computational fluid dynamics applied to patient-specific CT scans can reveal regions of airflow obstruction or hyperinflation, guiding targeted interventions such as bronchoscopic volume reduction. Machine learning algorithms can integrate longitudinal data to identify patterns predictive of exacerbations, enabling proactive management. In this way, the digital twin transcends conventional diagnostic tools by offering a multidimensional, individualized view of disease biology [3,4].

Beyond pharmacological therapy, digital twins can also model lifestyle interventions and rehabilitation strategies. Pulmonary rehabilitation, encompassing exercise training, nutritional counseling, and behavioral support, is a cornerstone of COPD management but requires customization to maximize benefits. A digital twin can simulate how changes in physical activity, body composition, or dietary intake affect lung function, exercise capacity, and systemic inflammation. By integrating data from wearable devices such as smart inhalers, activity trackers, and home spirometers, the twin can monitor adherence, detect deviations from expected trajectories, and provide real-time feedback to patients and clinicians. This closed-loop system transforms disease management from episodic care to continuous, adaptive support, empowering patients to actively participate in their treatment journey. Digital twins can leverage predictive analytics to identify early warning signals of impending exacerbations by analyzing patterns in physiological data, environmental exposures (such as air pollution levels or seasonal allergens), and behavioral indicators [5].

Conclusion

Digital twin technology represents a paradigm shift in the management of COPD, offering a dynamic, individualized, and predictive approach to treatment. By integrating multimodal data streams and simulating disease progression, digital twins enable clinicians to test interventions in silico, optimize therapies, predict exacerbations, and support continuous patient engagement. Although technical, ethical, and implementation challenges remain, rapid advances in computational modeling and data science are bringing this vision closer to reality. The adoption of digital twins has the potential to transform COPD care from a reactive, one-size-fits-all model to a proactive, personalized, and adaptive system that improves outcomes and quality of life for millions of patients worldwide. As research and innovation continue, digital twins may become indispensable tools not only in COPD but across the spectrum of chronic diseases, heralding a new era of precision respiratory medicine.

Acknowledgment

None.

Conflict of Interest

None.

REFERENCES

1. Globenko AA, Kuzin GV, Rydlovskaya AV, Isaeva EI, Vetrova EN, et al. (2023). Curtailing virus-induced inflammation in respiratory infections: Emerging strategies for therapeutic interventions. Front Pharmacol 14: 1087850.
2. Fan R, Wen B, Liu W, Zhang J, Liu C, et al. (2018). Altered regulatory cytokine profiles in cases of pediatric respiratory syncytial virus infection. Cytokine 103: 57-62.
3. Pompe E, Kwee AK, Tejwani V, Siddharthan T, Hoesein FAM (2023). Imaging-derived biomarkers in asthma: Current status and future perspectives. Respir Med 208: 107130.
4. Phillips KM, Lavere PF, Hanania NA, Adrish M (2025). The emerging biomarkers in chronic obstructive pulmonary disease: A narrative review. Diagnostics 15: 1245.
5. Thwaites RS, Coates M, Ito K, Ghazaly M, Feather C, et al. (2018). Reduced nasal viral load and IFN responses in infants with respiratory syncytial virus bronchiolitis and respiratory failure. Am J Respir Crit Care Med 198: 1074-1084.