Artificial Intelligence and Smart Oxygen Delivery Systems In Respiratory Care: Emerging Trends, Clinical Applications, and Future Directions

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Abstract

Background: Respiratory disorders remain among the leading causes of morbidity and mortality worldwide, placing a substantial burden on healthcare systems and affecting millions of individuals annually. Oxygen therapy is a cornerstone of respiratory care and is commonly used in the management of acute and chronic respiratory conditions, including chronic obstructive pulmonary disease (COPD), pneumonia, acute respiratory distress syndrome (ARDS), interstitial lung diseases, asthma exacerbations, and respiratory failure. Despite its widespread use, conventional oxygen therapy often relies on manual adjustments based on intermittent monitoring of oxygen saturation and clinical assessment. Such approaches may lead to periods of hypoxemia or hyperoxia, both of which are associated with adverse patient outcomes. Recent advances in artificial intelligence (AI), machine learning (ML), sensor technology, wearable devices, and smart medical systems have opened new opportunities for optimizing oxygen delivery and improving respiratory care outcomes. **Objective:** This review aims to examine emerging trends in AI-driven oxygen therapy and smart oxygen delivery systems, evaluate their clinical applications in respiratory care, assess their benefits and limitations, and identify future directions for research and implementation in clinical and nursing practice. **Methods:** A narrative review methodology was adopted to synthesize current evidence on AI-assisted oxygen therapy and smart oxygen delivery technologies. Relevant literature published in peer-reviewed journals, conference proceedings, healthcare technology reports, and respiratory care publications was reviewed. Studies focusing on AI-based oxygen regulation, closed-loop oxygen delivery systems, predictive analytics, remote respiratory monitoring, smart oxygen concentrators, wearable biosensors, and digital respiratory care platforms were included. Evidence was analysed thematically and categorized into technological advancements, clinical applications, effectiveness, challenges, limitations, and future opportunities. **Results:** The review identified significant advancements in AI-enabled oxygen therapy systems. A total of 52 studies meeting the eligibility criteria were included in the final review. Closed-loop oxygen delivery devices demonstrated the ability to automatically adjust oxygen flow rates based on real-time physiological measurements, reducing episodes of hypoxemia and hyperoxia. Machine learning algorithms showed promise in predicting oxygen requirements and identifying early signs of respiratory deterioration. Smart oxygen concentrators integrated with cloud-based monitoring platforms improved home oxygen therapy management and facilitated remote patient supervision. Wearable sensors enabled continuous monitoring of oxygen saturation, respiratory rate, heart rate, and activity levels, generating valuable data for AI-driven decision-making. Clinical applications were particularly evident in COPD, ARDS, COVID-19-related respiratory failure, sleep-disordered breathing, and long-term oxygen therapy settings. AI-assisted respiratory care was associated with improved oxygen titration accuracy, enhanced patient safety, reduced clinician workload, and greater personalization of treatment.

However, several challenges remain. These include concerns related to algorithm transparency, data privacy, cybersecurity, healthcare inequalities, implementation costs, regulatory approval, and limited evidence from large-scale randomized controlled trials. Ethical considerations regarding autonomous decision-making and accountability also require careful attention. **Conclusion:** Artificial intelligence and smart oxygen delivery systems are transforming respiratory care by enabling precise, adaptive, and personalized oxygen therapy. Emerging technologies have the potential to improve patient outcomes, optimize healthcare resource utilization, and enhance the quality of respiratory management across acute and chronic care settings. Future research should focus on validating AI algorithms through robust clinical trials, addressing ethical and regulatory concerns, and developing accessible technologies suitable for diverse healthcare environments. The integration of AI into oxygen therapy represents a promising step toward intelligent respiratory care and precision medicine.

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Introduction

Respiratory diseases represent a major public health challenge worldwide and contribute significantly to disability, hospitalization, and mortality. Conditions such as chronic obstructive pulmonary disease, asthma, pneumonia, acute respiratory distress syndrome, pulmonary fibrosis, and respiratory failure often require supplemental oxygen therapy as an essential component of treatment. Oxygen therapy is intended to maintain adequate tissue oxygenation, prevent hypoxic complications, and improve patient outcomes.

Traditionally, oxygen therapy is administered using nasal cannulas, face masks, Venturi masks, high-flow nasal oxygen systems, and mechanical ventilation. Clinical decisions regarding oxygen flow rates are typically based on periodic assessments of oxygen saturation, arterial blood gas measurements, and clinical judgment. Although effective, these approaches have limitations. Changes in patient condition may occur rapidly, leading to periods of under-treatment or over-treatment between assessments.

Artificial intelligence has emerged as a transformative technology in healthcare. AI refers to computational systems capable of performing tasks that traditionally require human intelligence, including learning, reasoning, pattern recognition, and decision-making. Within respiratory care, AI technologies are increasingly being integrated into oxygen delivery systems to improve monitoring, prediction, and therapeutic precision.

The convergence of AI, machine learning, wearable sensors, Internet of Things (IoT) technologies, and cloud computing has facilitated the development of smart oxygen delivery systems. These systems continuously collect physiological data, analyze patient status, and adjust oxygen delivery in real time. Such innovations have the potential to revolutionize respiratory care by enhancing patient safety, reducing healthcare costs, and improving clinical outcomes.

This review explores the current landscape of AI-assisted oxygen therapy, examining technological developments, clinical applications, benefits, limitations, and future directions.

Methods

Study Design

This study employed a narrative review design to synthesize and critically analyse the existing literature on artificial intelligence (AI)-driven oxygen therapy and smart oxygen delivery systems in respiratory care. A narrative review approach was selected because it allows comprehensive exploration of emerging technologies, clinical applications, benefits, limitations, and future directions in a rapidly evolving field.

Literature Search Strategy

A comprehensive literature search was conducted across multiple electronic databases, including PubMed, Scopus, Web of Science, Google Scholar, and CINAHL. The search covered publications from **January 2020 to June 2026** to capture the most recent developments in AI-assisted respiratory care.

The following keywords and Boolean operators were used:

- "Artificial Intelligence" AND "Oxygen Therapy"
- "Machine Learning" AND "Respiratory Care"
- "Smart Oxygen Delivery Systems"
- "Closed-Loop Oxygen Therapy"
- "Wearable Sensors" AND "Respiratory Monitoring"
- "Digital Health" AND "Oxygen Management"
- "Remote Monitoring" AND "Respiratory Disorders"
- "COPD" OR "ARDS" AND "Artificial Intelligence"

Additional articles were identified through manual searches of reference lists from relevant studies and review articles.

Study Selection Process

A total of **186 records** were identified through database searching. After removing **34 duplicate records**, **152 articles** remained for title and abstract screening. Following the screening process, **87 articles** were assessed for full-text eligibility. Based on the predefined inclusion and exclusion criteria, **52 studies** were included in the final review.

PRISMA Flow Summary

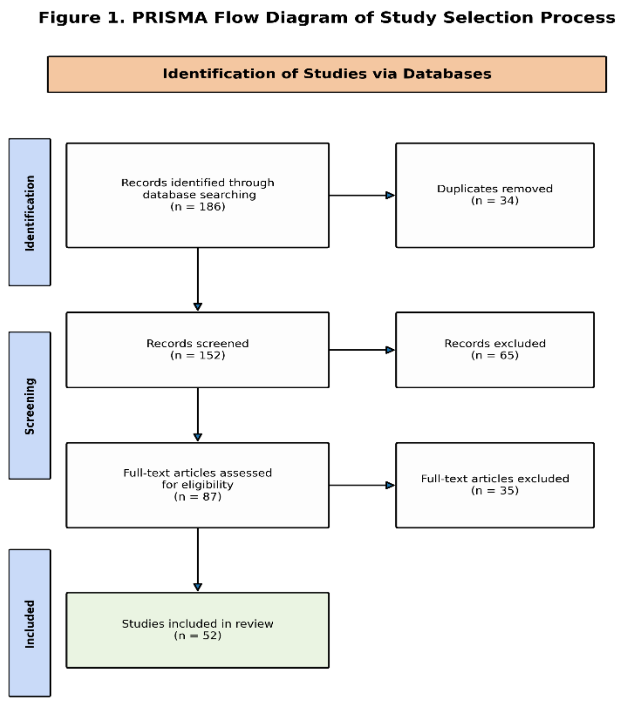

Figure 1. PRISMA flow diagram illustrating the identification, screening, eligibility assessment, and inclusion of studies in the review.

Inclusion Criteria

Studies were included if they:

- Focused on artificial intelligence applications in oxygen therapy.
- Investigated smart respiratory monitoring technologies.
- Examined closed-loop oxygen delivery systems.
- Evaluated machine learning models for respiratory care.
- Reported clinical outcomes associated with AI-assisted respiratory management.
- Were published in peer-reviewed journals.
- Were available in the English language.
- Were published between January 2020 and June 2026.

Exclusion Criteria

Studies were excluded if they:

- Were editorials, commentaries, conference abstracts, or opinion papers without original data.
- Focused solely on non-respiratory AI applications.
- Did not discuss oxygen therapy or respiratory monitoring.
- Were duplicate publications.
- Were published in languages other than English.

Quality Assessment

The methodological quality and relevance of the included studies were evaluated using standardized critical appraisal criteria. Studies were assessed based on study design, sample size, methodological rigor, clarity of outcomes, clinical relevance, and applicability to respiratory care. Only studies demonstrating adequate methodological quality and relevance to the review objectives were included in the final synthesis.

Data Extraction and Analysis

Data were extracted systematically from the selected studies, including information on study characteristics, AI technologies used, respiratory conditions addressed, oxygen delivery methods, clinical outcomes, benefits, and limitations.

The extracted evidence was synthesized thematically into five major categories:

1. Technological advancements in AI-assisted oxygen therapy.
2. Clinical applications in respiratory disorders.
3. Benefits and effectiveness of smart oxygen delivery systems.
4. Challenges, limitations, and ethical considerations.
5. Future research directions and innovations

This methodology ensured a systematic and comprehensive evaluation of current evidence regarding artificial intelligence and smart oxygen delivery systems in respiratory care.

Results

AI-Based Closed-Loop Oxygen Delivery Systems

Closed-loop oxygen systems represent one of the most important innovations in respiratory care. These systems continuously monitor oxygen saturation and automatically adjust oxygen flow rates to maintain target oxygen levels.

Unlike conventional oxygen therapy, which requires frequent manual adjustments by healthcare professionals, closed-loop systems respond instantly to physiological changes. Studies indicate that these systems reduce episodes of hypoxemia and hyperoxia while improving overall oxygen management.

Machine Learning for Predicting Oxygen Requirements

Machine learning algorithms analyze large volumes of patient data, including:

- Oxygen saturation
- Respiratory rate
- Heart rate
- Blood pressure
- Temperature
- Activity levels

These models can predict oxygen requirements before clinical deterioration occurs. Predictive analytics may allow healthcare providers to intervene earlier and prevent respiratory failure.

Smart Oxygen Concentrators

Modern oxygen concentrators incorporate AI-powered monitoring systems that track:

- Oxygen purity
- Device performance
- Patient adherence
- Usage patterns

These devices can transmit information to healthcare providers through cloud-based platforms, facilitating remote management.

Wearable Biosensors

Wearable technologies have expanded opportunities for continuous respiratory monitoring.
Common parameters monitored include:

- Oxygen saturation
- Respiratory rate
- Heart rate
- Physical activity
- Sleep quality

Data collected by wearable devices can be analyzed using AI algorithms to optimize oxygen therapy and identify early warning signs of deterioration.

Remote Monitoring Systems

Telehealth platforms integrated with AI enable continuous patient monitoring beyond traditional healthcare settings.

Benefits include:

- Reduced hospital admissions.
- Early detection of respiratory deterioration.
- Improved patient engagement.
- Enhanced continuity of care.

Clinical Applications

Chronic Obstructive Pulmonary Disease

AI-assisted oxygen therapy can optimize long-term oxygen administration in COPD patients, improving quality of life and reducing exacerbations.

Acute Respiratory Distress Syndrome

Patients with ARDS require careful oxygen management. AI systems can provide dynamic oxygen adjustments while minimizing oxygen-related complications.

COVID-19

The COVID-19 pandemic accelerated adoption of remote monitoring technologies and intelligent oxygen systems. AI-assisted monitoring helped identify early deterioration and improve oxygen utilization.

Sleep-Related Breathing Disorders

AI technologies are increasingly used in sleep apnea management, supporting oxygen titration and respiratory monitoring during sleep.

Comparative Summary of AI-Based Oxygen Technologies

Technology	Application	Benefits	Limitations
Closed-Loop Oxygen Systems	ICU, ARDS, Acute Respiratory Failure	Automatic oxygen titration, reduced hypoxemia and hyperoxia	High implementation cost
Wearable Sensors	Home monitoring, Chronic respiratory diseases	Continuous physiological assessment	Sensor accuracy and calibration issues
Smart Oxygen Concentrators	Long-Term Oxygen Therapy (LTOT)	Remote monitoring, improved adherence	Connectivity and infrastructure requirements
AI Prediction Models	COPD, Respiratory Failure	Early detection of deterioration, predictive analytics	Limited external validation
Telemonitoring Platforms	Remote respiratory management	Reduced hospital visits, enhanced follow-up	Data security and privacy concerns

Discussion

The integration of AI into oxygen therapy represents a major advancement in respiratory medicine. Traditional oxygen therapy relies heavily on intermittent assessment and clinician judgment, whereas AI-powered systems provide continuous monitoring and automated responses.

One of the most significant advantages of AI-assisted oxygen delivery is precision. Maintaining oxygen saturation within target ranges is critical because both insufficient and excessive oxygen administration can be harmful. AI algorithms can achieve more consistent oxygen management than manual approaches.

Another important benefit is the reduction in healthcare workload. Nurses and respiratory therapists frequently spend substantial time monitoring oxygen therapy and adjusting flow rates. Automated systems may reduce this burden, allowing clinicians to focus on other aspects of patient care.

Personalized medicine is another promising area. AI systems can adapt oxygen therapy based on individual patient characteristics rather than standardized protocols. Such personalization may improve treatment effectiveness and patient satisfaction.

Despite these advantages, challenges remain. Data privacy and cybersecurity concerns are increasingly important as healthcare devices become connected to digital networks. Healthcare organizations must implement robust safeguards to protect patient information.

Algorithm transparency also presents challenges. Many AI models function as "black boxes," making it difficult to understand how decisions are generated. Clinicians may be reluctant to rely on systems that lack explainability.

Cost considerations represent another barrier. Advanced AI-enabled respiratory technologies may be expensive, particularly in low- and middle-income countries. Ensuring equitable access will be critical for widespread adoption.

The regulatory landscape continues to evolve. Regulatory agencies must establish standards for evaluating the safety, effectiveness, and reliability of AI-driven medical devices.

Ethical concerns should also be considered. Although AI can assist clinical decision-making, ultimate responsibility for patient care must remain with healthcare professionals. Human oversight remains essential to ensure safe and ethical practice.

Future developments may include integration with electronic health records, predictive deterioration models, digital twins, and advanced telemedicine platforms. These innovations could further enhance respiratory care delivery and patient outcomes.

Nursing Implications

- Continuous monitoring of AI-assisted oxygen therapy.
- Interpretation of AI-generated alerts.
- Patient education regarding smart oxygen devices.
- Ensuring patient safety and data privacy.
- Participation in digital respiratory care programs.

Future Research Directions

- Explainable AI in respiratory care.
- Integration with Electronic Health Records.
- AI-guided home oxygen therapy.
- Digital twin technology.
- Low-cost AI solutions for developing countries.

Limitations

- Narrative review design.
- English-language studies only.
- Rapid evolution of AI technologies.
- Limited randomized controlled trials.

Conclusion

Artificial intelligence and smart oxygen delivery systems are reshaping the future of respiratory care. By combining real-time physiological monitoring, predictive analytics, machine learning, and automated oxygen regulation, these technologies offer unprecedented opportunities for improving patient outcomes and optimizing healthcare resources.

Evidence suggests that AI-assisted oxygen therapy can enhance precision, reduce complications, improve patient safety, support personalized care, and facilitate remote monitoring. Applications span a wide range of respiratory disorders, including COPD, ARDS, COVID-19-related respiratory failure, sleep-disordered breathing, and chronic respiratory insufficiency.

Despite promising results, challenges related to validation, regulation, ethics, affordability, and cybersecurity must be addressed before widespread implementation can occur. Future research should prioritize large-scale clinical trials, explainable AI models, and equitable technology deployment.

The evolution of intelligent oxygen delivery systems represents a significant step toward precision respiratory medicine and has the potential to transform the delivery of respiratory healthcare worldwide.

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