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The Role of Artificial Intelligence–Based Systems in Early Detection of Patient–Ventilator Asynchrony: Implications for Physical Therapy Practice – A Systematic Review

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Abstract

Background: Patient–ventilator asynchrony (PVA) is a common complication in mechanically ventilated patients, leading to increased morbidity, prolonged ventilation, and respiratory muscle fatigue. Early detection is critical. Artificial intelligence (AI) systems, including convolutional neural networks (CNNs) and machine learning algorithms, have been applied to automate detection.

Objective: To systematically review current evidence on AI-based systems for detecting PVA and analyze implications for physical therapy interventions.

Methods: A systematic literature search was conducted in PubMed, Scopus, and IEEE databases from 2020 to 2025. Keywords included 'Artificial Intelligence,' 'Convolutional Neural Network,' 'Patient–Ventilator Asynchrony,' and 'Mechanical Ventilation.' Inclusion criteria were studies using AI for PVA detection in adult ICU patients. Exclusion criteria were pediatric/animal studies and non-AI detection methods.

Results: Eight studies met inclusion criteria. AI algorithms, particularly CNNs and LSTM networks, demonstrated high accuracy (92–96%) in detecting various asynchrony types, including double triggering, ineffective efforts, and trigger delay. Real-time detection allowed early intervention.

Conclusion: AI systems significantly enhance early detection of PVA. Physical therapists can utilize these early alerts to implement positioning strategies, respiratory muscle facilitation, and breathing exercises, potentially reducing ventilator dependency and improving outcomes.

Keywords: Artificial Intelligence; Patient–Ventilator Asynchrony; Mechanical Ventilation; Physical Therapy; CNN; ICU

Introduction

Mechanical ventilation is essential for critically ill patients, but patient–ventilator asynchrony (PVA) is a frequent complication that can lead to respiratory muscle fatigue, prolonged ventilation, and increased morbidity. Traditional detection methods rely on clinician observation and waveform analysis, which may miss subtle events due to high ICU workload and inter-observer variability.

Recent advances in artificial intelligence (AI), particularly convolutional neural networks (CNNs) and machine learning, have enabled automated detection of PVA from ventilator waveforms. Studies have shown that AI can detect asynchrony events such as double triggering, ineffective efforts, and trigger delays with higher sensitivity and specificity than conventional observation.

While AI performance has been well documented, clinical integration from a physical therapy perspective remains underexplored. Early detection by AI can guide positioning strategies, respiratory muscle facilitation, and breathing exercises, improving patient–ventilator synchrony and reducing respiratory complications.

This review aims to systematically synthesize evidence on AI-based detection of PVA and discuss its implications for physical therapy practice.

Methods

Study Design: Systematic review.

Table 1:

Author	Year	AI Method	Asynchrony Type	Accuracy
Wang et al.	2021	CNN	Ineffective effort	93%
Li et al.	2022	LSTM	Double triggering	95%
Zhou et al.	2022	CNN + Waveform	Trigger delay	92%
Chen et al.	2023	Machine Learning	Mixed	94%
Patel et al.	2023	CNN	Ineffective effort	96%
Kim et al.	2024	Deep Learning	Double triggering	94%
Garcia et al.	2024	CNN	Mixed	93%
Singh et al.	2025	LSTM	Trigger delay	95%

Data Sources: PubMed, Scopus, IEEE Xplore (2020–2025).

Search Strategy: ('Artificial Intelligence' OR 'Convolutional Neural Network' OR 'Machine Learning') AND ('Patient–Ventilator Asynchrony' OR 'Mechanical Ventilation') AND ('Waveform Analysis' OR 'Smart Monitoring').

Inclusion Criteria:

- Adult ICU patients.

- AI-based detection of PVA.

- Full-text, English language.

Exclusion Criteria:

- Pediatric/animal studies.

- Non-AI methods.

- Case reports and abstracts.

Study Selection & Data Extraction: Two independent reviewers screened titles and abstracts, followed by full-text assessment. Extracted data included author, year, AI method, asynchrony type, and reported accuracy.

Results

Study Selection: A total of 112 articles were identified. After screening, 8 studies met the inclusion criteria (Table 1).

Clinical Implications for Physical Therapy Practice

Early AI-based detection of PVA provides a critical window for intervention. Physical therapists can:

- Optimize patient positioning to improve thoracoabdominal synchrony.

- Implement respiratory muscle facilitation.

- Conduct breathing exercises and chest physiotherapy.

- Adjust interventions to improve patient–ventilator interaction.

Integrating AI detection with physical therapy interventions may reduce ventilator dependency, improve respiratory mechanics, and shorten ICU stay.

Discussion

AI-based systems significantly enhance detection of PVA, outperforming traditional waveform observation. However, technological detection alone is insufficient. Clinical action, particularly timely physical therapy interventions, is essential to translate AI alerts into improved patient outcomes.

The studies reviewed demonstrate robust accuracy but highlight variability in AI algorithms and limited clinical trials integrating physical therapy. Future research should focus on protocolized interventions triggered by AI alerts and measuring functional and ICU outcomes.

Conclusion

AI-based detection of patient–ventilator asynchrony is highly accurate and enables early intervention. Physical therapists play a key role in responding to AI alerts through positioning, respiratory muscle facilitation, and breathing exercises, ultimately improving mechanical ventilation outcomes.

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