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Artificial intelligence for dementia diagnostics and treatment: a systematic literature review

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Искусственный интеллект в диагностике и лечении деменции: систематический обзор литературы

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Abstract

This systematic literature review examines the use of artificial intelligence (AI) and machine learning (ML) in dementia diagnosis, prediction, monitoring and treatment support. The application of Artificial Intelligence enhances detection and diagnosis of dementia, and also includes the

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neuroimaging and multimodal data integration. This has catalysed a growing body of research exploring the applications of Artificial Intelligence in the early detection, differential diagnosis and management of dementia. The transformative potential of multimodal AI driven methods in the diagnosis of dementia have greatly helped in the precision diagnosis by integrating neuroimaging modalities. Studies published from 2015 to 2025 were screened using a PRISMA-oriented procedure; 80 studies were included. The review covers neuroimaging, quantitative EEG (qEEG), clinical variables, speech, gait and behavioral data, as well as multimodal combinations. Imaging-based deep learning frequently produced the highest reported diagnostic performance, while multimodal systems showed promise for complex prediction. However, small samples, heterogeneous datasets, limited external validation, demographic bias and limited interpretability remain major barriers to clinical implementation.

Аннотация

Данный систематический обзор литературы посвящен применению искусственного интеллекта (ИИ) и методов машинного обучения (МО) в диагностике деменции, прогнозировании, мониторинге и поддержке лечения.

Применение искусственного интеллекта повышает эффективность выявления и диагностики деменции, включая использование методов нейровизуализации и интеграции мультимодальных данных. Это способствовало активному развитию исследований, посвящённых применению искусственного интеллекта для раннего выявления, дифференциальной диагностики и лечения деменции. Трансформационный потенциал мультимодальных методов, основанных на искусственном интеллекте, значительно расширил возможности точной диагностики деменции за счёт интеграции различных методов нейровизуализации. Были проанализированы исследования, опубликованные с 2015 по 2025 год, с использованием процедуры, ориентированной на PRISMA; в обзор включено 80 исследований. Рассмотрены нейровизуализация, количественная ЭЭГ, клинические переменные, речь, походка и поведенческие данные, а также мультимодальные комбинации. Методы глубокого обучения на основе визуализации часто демонстрировали наивысшие показатели диагностической точности, тогда как мультимодальные системы показали перспективность при сложном прогнозировании. Однако небольшие размеры выборок, гетерогенные наборы данных, ограниченная внешняя валидация, демографическая предвзятость и ограниченная интерпретируемость остаются основными барьерами для клинической реализации.

Keywords: artificial intelligence, machine learning, dementia, Alzheimer's disease, EEG, MRI, multimodal data.

Ключевые слова: искусственный интеллект, машинное обучение, деменция, болезнь Альцгеймера, ЭЭГ, МРТ, мультимодальные данные.

Introduction

Dementia is a major public-health problem characterized by progressive cognitive decline. Early and differential diagnosis remain difficult because of heterogeneous causes, overlapping symptoms and limitations of early biomarkers. AI provides tools for pattern recognition, neuroimaging analysis, digital biomarkers and integration of clinical information. Recent studies increasingly combine imaging, clinical, genetic and behavioral data. Wearables and smart environments also allow continuous assessment of activity, gait, sleep and behavioral symptoms, supporting a shift toward proactive care.

The potential benefits must be distinguished from clinical effectiveness. Many AI studies use selected datasets or small samples, and models developed mainly in high-income settings may not generalize to other populations. Data quality, labeling, acquisition protocols, privacy, bias and interpretability therefore remain central concerns.

Materials and Methods

The review asked how data modality affects the predictive performance of AI-based dementia diagnostics and which AI/ML methods are most frequently used. Searches for “artificial intelligence” and “dementia,” including dementia subtypes, were conducted in ScienceDirect, PubMed Central, Wiley Online Library and JMIR Publications. English-language studies published between 2015 and 2025 were eligible when they used AI, ML or deep learning with neuroimaging, clinical or speech/voice data. Non-peer-reviewed publications, book chapters and studies outside the defined scope were excluded. From 1,300 records initially identified, 80 studies were included.

The studies were grouped into five clusters: clinical diagnosis and management; ML/AI for dementia prediction; technology-assisted digital monitoring; rehabilitation and caregiving interventions; and systematic reviews or meta-analyses. The synthesis emphasized modality, algorithm type and reported diagnostic performance.

Results and discussion

Neuroimaging was the principal source of high-performing models. MRI, PET and image-like qEEG data were commonly analyzed with convolutional neural networks (CNNs), ResNet and support vector machines (SVMs). Selected studies reported about 99 % accuracy for MRI-based AD-versus-control classification, 99.99 % for early MCI versus AD using fine-tuned ResNet-18, and near-100 % performance in some binary PET/MRI tasks. These peak results are task-specific and require external validation.

qEEG/EEG is a comparatively accessible modality for diagnosis and monitoring. A qEEG feature-image ResNet approach reported 97.4 % accuracy, with 100 % sensitivity and 96.8 % specificity. Combining qEEG with handwriting dynamics produced 93.7 % accuracy for MCI versus healthy controls. Clinical-variable models also showed strong results, including 98.66 % for binary dementia detection and approximately 92 % for progression prediction in selected studies.

Speech and behavioral modalities provide potentially scalable alternatives. Voice and language models generally reported approximately 90–95 % accuracy, while gait, facial expression, drawing and wearable-sensor methods supported severity estimation and remote monitoring. These methods can capture changes in everyday functioning that may be missed by episodic clinical assessments.

A major trend is multimodal integration. Combining neuroimaging with clinical variables, biomarkers, speech or behavioral measures generally produced stronger results than isolated modalities. One hybrid model integrating temporal, spatial, spectral, audio and text information reported 94.5 % accuracy for AD progression. Nevertheless, multimodal superiority should be tested in independent, real-world populations.

The evidence demonstrates rapid technical progress, but research remains concentrated on diagnosis. Imaging and deep learning often produce the strongest benchmark results, whereas qEEG, speech, gait and other digital biomarkers broaden opportunities for accessible and continuous assessment. Multimodal approaches are attractive because dementia is biologically and clinically heterogeneous.

Translation into practice is constrained by generalizability, small samples, data heterogeneity and limited external validation. Performance can change when scanners, recording protocols, languages, disease prevalence or demographic characteristics differ. Complex models may also be difficult to interpret, creating a “black box” problem. Ethical issues include privacy, consent, algorithmic bias and unequal access.

Future research should prioritize prospective multicenter and longitudinal studies, representative samples, external validation and transparent reporting. Federated learning, explainable AI, bias audits and human-in-the-loop systems may improve accountability. AI may also support treatment-response monitoring and drug discovery, although evidence for clinical benefit is less mature than evidence for diagnostic classification.

Conclusion

The review of 80 studies demonstrates substantial progress in AI-supported dementia diagnosis, prediction and monitoring. Imaging-based deep learning frequently achieves the highest reported performance, while qEEG, clinical, speech and behavioral biomarkers provide complementary information. Multimodal strategies are particularly promising. However, accuracy alone is insufficient for clinical adoption: generalizability, data quality, bias, interpretability and real-world validation remain decisive. AI should augment, rather than replace, professional clinical judgment.

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