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Artificial Intelligence-enabled Approaches to Early Detection and Diagnosis of Neurodegenerative Diseases

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Abstract

Getting an accurate diagnosis of neurodegenerative diseases is a challenge, especially in primary care settings. Artificial intelligence (AI) could make it easier by using blood-based biomarkers, cognitive tests, and other data to guide clinicians towards an accurate diagnosis based on the clinical information available to them. AI makes essentially complex multi-layered decisions for a clinician available even if the clinician does not have specialty knowledge. The six ways of early Alzheimer's disease detection will first be discussed. It will then be shown that AI tools and systems can detect subtle biological and behavioral changes long before traditional clinical symptoms. Instead of obvious symptoms like severe memory loss, AI focuses on micro-signals, such as neurological, language, and behavioral signals. It will be indicated why early detection matters and what can be done after early detection. It will also be shown how AI is significantly impacting the management of AD by enabling earlier detection, personalizing treatment plans, and accelerating the discovery of new therapies.

Abbreviations

AA: Alzheimer's Association; AD: Alzheimer's disease; AI: Artificial intelligence; BCI: Brain-computer interface; BDD: Breakthrough device design; BDP: (FDA's) Breakthrough Devices Program; CSF: Cerebrospinal fluid; DASH: Dietary Approaches to Stop Hypertension; DE4S: Diet, Exercise, Stress, Sleep, Smoking, Social connections; EHR: Electronic health record; FDA: (U.S.) Food & Drug Administration; MIND: Mediterranean-DASH Intervention for Neurodegenerative Delay; ML: Machine language; MLM: Multiple language model; MRI: Magnetic resonance imaging; MS: Multiple sclerosis; NDD: Neurodegenerative disease; PET: Positron emission tomography; TBI: Traumatic brain injury.

Diseases mentioned: Alzheimer's disease; Brain cancer; Dementia; Depression; Diabetes; Epilepsy; Multiple sclerosis; Parkinson's disease; Traumatic brain injury.

Keywords

Artificial intelligence; Alzheimer's disease; AI-enabled early detection; Neurodegenerative diseases; Precision medicine.

Introduction

Getting an accurate diagnosis of neurodegenerative diseases (NDDs) is a challenge, especially in primary care settings. Artificial intelligence (AI) could make it easier by using blood-based biomarkers, cognitive tests, and other data to guide clinicians towards an accurate diagnosis based on the clinical information available to them. AI makes essentially complex multi-layered decisions for a clinician available even if the clinician does not have specialty knowledge (such as for example about dementia).

The six ways of early Alzheimer's disease detection will first be discussed. It will then be shown that AI tools and systems can detect subtle biological and behavioral changes long before traditional clinical symptoms. Instead of obvious symptoms like severe memory loss, AI focuses on micro-signals, such as neurological, language, and behavioral signals. It will be indicated why early detection matters and what can be done after early detection. It will also be shown how AI is significantly impacting the management of AD by enabling earlier detection, personalizing treatment plans, and accelerating the discovery of new therapies.

Six ways of early AD detection

AI can enable early Alzheimer's disease (AD) detection in the following ways:

Brain changes (20–10 years before symptoms)

AI can analyze MRI and PET scans to detect tiny shrinkage in memory-related regions (like the hippocampus) and early buildup of amyloid plaques. These changes can begin a decade or more before memory loss starts.

Blood biomarkers (15–5 years)

In the case of AD, AI-enhanced blood tests (like PrecivityAD) can detect abnormal amyloid beta ratios and tau protein levels. These signals often appear long before cognitive symptoms.

Speech and language patterns (10–5 years)

AI can pick up subtle communication changes such as increased pauses or hesitations, simpler vocabulary, and trouble finding specific words. These are often too subtle for humans to notice casually but measurable by AI.

Digital behavior (8–3 years)

By analyzing everyday technology use, AI may detect slower typing speed, increased errors, and changes in how someone navigates apps or completes tasks. These patterns reflect early cognitive decline.

Analysis of patients' records with machine language (7-0 years)

Top predictors with machine language (ML) include high cholesterol and osteoporosis, the latter in women only.

Cognitive micro-changes (6–3 years)

AI-driven cognitive tests can detect slight declines in short-term memory, reduced attention or problem-solving speed, and even tiny deviations over time can signal risk.

The above approaches are summarized in Table 1:

Time frame before symptoms	Features	Approach(es)	Features
20-10 years	Brain changes	Analyses of MRI, PET scans	o Tiny shrinkage in hippocampus o Early build-up of amyloid plaques
15-5 years	Blood biomarkers	PrecivityAD	o Abnormal amyloid beta ratios o Abnormal tau protein levels
10-5 years	Abnormal speech patterns	Subtle communication changes	o Increased pauses or hesitations o Simpler vocabulary o Trouble finding specific words
8-3 years	Everyday technology use	o Slower typing speed o Increased errors o Changes in how someone navigates apps or completes tasks.	Early cognitive decline
7-0 years	Patient's EHR with ML	o Cholesterol. o Osteoporosis (for women only)	
6-3 years	AI-driven cognitive tests	Cognitive micro-changes	o Slight declines in short-term memory o Reduced attention or problem-solving speed o Tiny deviations over time

Abbreviations: AI: Artificial intelligence; EHR: Electronic health record; ML = Machine language; MRI: Magnetic resonance imaging; PET: Positron emission tomography.

Table 1: AI-enabled ways of early AD detection

Earlier and more accurate AD diagnosis

AI tools and systems can detect subtle biological and behavioral changes long before traditional clinical symptoms. They are increasingly used for:

- Alzheimer's prediction;
- Parkinson's monitoring;
- Epilepsy detection;
- Brain cancer detection; and
- Depression treatment.

Predictive risk assessment

AI models can predict AD up to seven years before symptoms manifest by analyzing electronic health records (EHRs) for risk factors like high cholesterol or osteoporosis.

Advanced imaging analysis

FDA-approved tools like BrainSee (see Sidebar 1) use AI to analyze brain scans and predict the likelihood of disease progression within five years.

Speech-decoding BCIs

AI algorithms analyze speech patterns, such as vocabulary diversity and pause frequency, to identify early signs of cognitive decline with high accuracy.

Speech-decoding brain-computer interfaces (BCIs) represent one of the most exciting areas in restoring communication for paralyzed patients. Recent BCIs can:

- Decode imagined speech;
- Reconstruct words from neural activity; and
- Enable cursor or typing control.

Companies and laboratories pushing this field include: Precision Neuroscience; Synchron; and Neuralink. Precision Neuroscience recently demonstrated high-resolution neural decoding using minimally invasive cortical interfaces.

Pattern recognition

The Mayo Clinic's State Viewer can identify brain activity with much higher accuracy than standard clinical workflows.

What signs is AI looking for?

Instead of obvious symptoms like severe memory loss, AI focuses on micro-signals, such as:

Neurological signals
Brain volume loss (fractions of a percent) and early protein buildup patterns.

Language signals
Examples include less descriptive storytelling, repeating ideas, and reduced sentence complexity.

Behavioural signals
Examples are inconsistent routines, small drops in task efficiency, and subtle decision-making changes.

Why early detection matters?

Catching Alzheimer's early can: enable lifestyle changes (exercise, diet, mental activity); help patients plan; improve chances of benefiting from new treatments; and allow earlier entry into clinical trials.

However, early detection does not always mean that the person will develop dementia or that symptoms will appear soon. Further, Alzheimer's progression varies widely (some people can remain stable for years) and is mainly useful for risk awareness and intervention.

What can be done after early detection?

The approach follows this author's acronym: DE4S, where D stands for Diet, E for Exercise, S for Stress, Sleep, Smoking, and Social connections:

Follow a brain-healthy diet

The most studied approach is the MIND (Mediterranean-DASH Intervention for Neurodegenerative Delay) It combines elements of the Mediterranean DASH diets. The DASH (Dietary Approaches to Stop Hypertension) diet was developed to help lower high blood pressure, but it is also recognized as a healthy eating pattern for reducing the risk of heart disease, stroke, and type 2 diabetes. The MIND diet is an eating pattern designed to support brain health and help reduce the risk of cognitive decline and dementia. Its focus is on foods that are naturally rich in nutrients such as potassium, calcium, magnesium, fiber, and protein, while limiting sodium, saturated fat, and added sugars including leafy greens (spinach, kale), berries, whole grains, and fish and olive oil while limiting red meat, sugar, and processed foods.

Exercise (most powerful intervention)

Strong evidence shows exercise can slow cognitive decline. Regular physical activity improves blood flow to the brain and supports neuron health. The aim is 150 minutes/week (walking, swimming, cycling, strength training 2×/week).

Reduce stress

Chronic stress damages memory-related brain regions. Reducing it includes meditation or mindfulness, light yoga, time spent outdoors, etc.

Protect sleep
Deep sleep helps clear amyloid proteins from the brain while poor sleep is strongly linked to Alzheimer's risk. The aim is 7–9 hours per night and keeping a consistent sleep schedule. If sleep conditions like sleep apnea exist, they should be promptly remedied.

Reduce/discontinue smoking
If applicable

Stay socially connected
This includes engaging in regular conversations, participating in group activities or volunteering, and maintaining close relationships. Isolation increases cognitive decline risk.

Also:

Manage heart & metabolic health

"What's good for your heart is good for your brain". For this purpose, one should control blood pressure, cholesterol, blood sugar (especially to prevent type 2 diabetes). And

Consider medical options

Doctors may recommend monitoring with cognitive tests, medications (in some early cases), and participation in clinical trials. Organizations like the Alzheimer's Association (AA) can help find trials and support programs.

Studies suggest that combining these habits can lower risk by 30–50% or more and delay onset by years, even decades. Consistency matters more than perfection, and one should not rely on so-called "brain supplements" with little scientific backing, quick fixes or miracle cures, or extreme diets.

The bottom line is that early AI detection gives something incredibly valuable (time) and the best response may not be a single treatment—it is a lifestyle strategy that supports brain health from multiple angles.

Precision medicine approach to disease management & care

AI is significantly impacting the management of AD by enabling earlier detection (see above), personalizing treatment plans, and accelerating the discovery of new therapies (see Table 2 below).

Personalized treatment and care

AI helps transition AD care from a "one-size-fits-all" approach to precision (or personalized) medicine.

Tailored therapies

Multiple language models (MLMs) can predict how an individual will respond to specific medications based on their genetic and biomarker profile.

Daily monitoring

AI-powered wearables and home sensors track sleep patterns, physical activity, and walking speed to detect health declines or fall risks in real-time.

Cognitive training

Adaptive AI apps provide personalized brain training exercises that adjust in difficulty based on the user's performance, helping to maintain cognitive function.

Application	How it helps?	Example tools/sources
Early detection	Predicts disease years before symptoms appear	UCSF prediction model
Imaging	Spots subtle brain atrophy or protein buildup	BrainSee
Speech	Detects language changes as a biomarker	NIA speech analysis
Daily support	Monitors falls and assists with self-care	AI-powered wearables
Drug research	Screens existing drugs for new uses	DRIAD platform

Abbreviations: DRIAD: Drug repurposing in AD; NIA: (U.S.) National Institute on Aging; UCSF: University of California, San Francisco

Reference: Fymat (1926)

Table 2: Comparison of AI applications in AD care

Conclusions and take-aways

- AI is becoming a powerful new tool in improving how AD is detected, especially in its early stages when traditional diagnosis can be difficult. It is shifting the diagnosis from late-stage confirmation to early-stage prediction and detection, which is crucial for slowing progression and improving quality of life.

- AI intervenes in six stages: biomarker analysis; cognitive and behavioral analysis; early detection from brain scans; clinical decision support; predictive modeling; and drug development and clinical trials.

- Remaining limitations include AI does not replace the clinician; models need large and diverse data sets to avoid bias; privacy and data security should be ongoing concerns; and regulatory approval is still evolving in healthcare AI.

- AI can detect Alzheimer's in several ways: Brain changes (20‒10 years before symptoms); blood biomarkers (15‒5 years; speech and language patterns (10‒5 years); digital behavior (8‒3 years); analysis of patients' records (up to 7 years); and cognitive micro-changes (6–3 years).

- AI tools and systems can detect subtle biological and behavioral changes long before traditional clinical symptoms appear through predictive risk assessment, advanced imaging analysis, speech and language monitoring; and pattern recognition.

- AI looks for neurological, language, and behavioural signals.

- Early detection matters because it can enable lifestyle changes (exercise, diet, mental activity); help patients plan; improve chances of benefiting from new treatments; and allow earlier entry into clinical trials. However, early detection does not always mean that the person will develop dementia or that symptoms will appear soon.

- After early detection, this author's DE4S approach is recommended, where: D stands for a brain-healthy diet such as the MIND diet; E for exercise, which is the most powerful intervention; S for stress reduction as chronic stress damages memory-related brain regions; S for sleep protection as deep sleep helps clear amyloid proteins from the brain; S for smoking which should be reduced or preferably discontinued; and S for social connections that should be nurtured. In addition, heart and metabolic health should be cared for and existing medical conditions attended to. Combining these habits can lower risk by 30–50% or more and delay onset by years, even decades.

- AI is significantly impacting the management of AD by enabling earlier detection, personalizing treatment and care, cognitive training, and accelerating the discovery of new therapies.

- AI is not replacing doctors but is making Alzheimer's diagnosis earlier, cheaper, and more accurate. In the future, AI models will use simple voice recordings for early screening, routine blood tests will replace expensive scans, and continuous monitoring will be performed via smartphones and wearables.

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