International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
editorial-office@sciformat.ca

ARTICLE TITLE	ARTIFICIAL INTELLIGENCE IN EARLY NEUROLOGICAL DIAGNOSIS: A REVIEW OF MACHINE LEARNING APPLICATIONS IN ALZHEIMER'S AND PARKINSON'S DISEASE SCREENING
DOI	https://doi.org/10.31435/ijitss.2(50).2026.5356
RECEIVED	21 March 2026
ACCEPTED	19 June 2026
PUBLISHED	30 June 2026
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

ARTIFICIAL INTELLIGENCE IN EARLY NEUROLOGICAL DIAGNOSIS: A REVIEW OF MACHINE LEARNING APPLICATIONS IN ALZHEIMER'S AND PARKINSON'S DISEASE SCREENING

Zuzanna Zalewska *(Corresponding Author, Email: zuzanna.zalewska@stud.umed.lodz.pl)*
Medical University of Lodz, Lodz, Łódź Voivodeship, Poland
ORCID ID: 0009-0003-4441-4782

Karolina Reczka
Medical University of Lodz, Lodz, Łódź Voivodeship, Poland
ORCID ID: 0009-0003-7306-5120

Julia Szymkowiak
Medical University of Lodz, Lodz, Łódź Voivodeship, Poland
ORCID ID: 0009-0005-6558-2552

Maria Woźniak
Medical University of Lodz, Lodz, Łódź Voivodeship, Poland
ORCID ID: 0009-0000-9240-3373

ABSTRACT

Neurodegenerative diseases, including Alzheimer's disease (AD) and Parkinson's disease (PD), pose a growing challenge to aging societies, placing a burden on healthcare systems and patients' families. Traditional diagnostic methods often rely on already visible clinical symptoms, delaying the possibility of effective interventions. This review article analyzes the use of artificial intelligence (AI) and machine learning (ML) in early neurological diagnosis, with a particular focus on multimodal analysis, including magnetic resonance imaging (MRI) and behavioral markers. AI algorithms demonstrate a remarkable ability to identify subtle micro-changes in brain structure, as well as deviations in speech, behavior, or breathing, doing so much faster and more accurately than standard clinical assessment by the human eye or ear. Early detection of these prodromal signals not only revolutionizes the medical approach to patients but also has profound social and economic implications. Faster, AI-assisted diagnosis has been shown to significantly reduce the direct and indirect medical costs burdening global healthcare systems. Equally important, early detection of disease allows for faster initiation of therapy and supportive care, which directly translates into a better quality of life for patients and a significant reduction in the psychological, physical, and financial burdens on their families. The paper systematizes current knowledge on the effectiveness of AI models, pointing to their key role in building sustainable and pro-social healthcare for the future.

KEYWORDS

Artificial Intelligence; Machine Learning; Voice Analysis; Alzheimer's Disease; Parkinson's Disease; Healthcare Costs

CITATION

Zuzanna Zalewska, Karolina Reczka, Julia Szymkowiak, Maria Woźniak. (2026) Artificial Intelligence in Early Neurological Diagnosis: a Review of Machine Learning Applications in Alzheimer's and Parkinson's Disease Screening. *International Journal of Innovative Technologies in Social Science*. 2(50). doi: 10.31435/ijitss.2(50).2026.5356

1. Introduction

Aging populations around the world are facing an unprecedented health, social, and economic challenge in the form of a rapid increase in the incidence of neurodegenerative diseases, particularly Alzheimer's disease (AD) and Parkinson's disease (PD). According to economic analyses, the global costs associated with dementia and Alzheimer's disease alone will reach trillions of dollars in the coming decades, placing a huge burden on national healthcare systems [31, 32]. Similarly, Parkinson's disease generates enormous direct costs, such as multi-specialist medical care and hospitalizations, as well as indirect costs resulting from the loss of patient productivity, which increase dramatically with the clinical progression of the disease [33, 37]. In social terms, the progressive nature of these neurological disorders leads to a drastic reduction in patients' quality of life and places a huge psychophysical and financial burden on their families, who are forced to give up their professional activities to take on the role of informal caregivers [31, 33]. Understanding this multifaceted burden from the macroeconomics of health systems to the microeconomics of individual households is crucial to recognizing the urgent need for innovation in early diagnosis [31, 32, 33, 37].

Traditional diagnostic paradigms in neurology are largely based on subjective clinical assessment, patient interviews, and standardized neuropsychological tests. These tools usually allow a definitive diagnosis to be made only when the patient has clear phenotypic symptoms, such as significant memory impairment in AD or severe motor symptoms (e.g., resting tremor, bradykinesia, muscle rigidity) in PD [5, 28]. Unfortunately, by the time these clinical symptoms become clearly noticeable to the human eye or the ear of an experienced physician, irreversible and extensive neuronal damage has usually already occurred in the patient's brain [1, 26]. Subtle, prodromal signs of neurodegenerative diseases, referred to as micro-changes, are often completely impossible to detect using standard observational methods [1]. Human senses and conventional methods of manual analysis of medical images have their natural limitations in detecting early, minimal deviations from the healthy norm, which inevitably results in delayed diagnosis and loss of the valuable therapeutic window in which interventions to slow the progression of the disease could be most effective [2, 3, 28].

Neuroimaging tools such as magnetic resonance imaging (MRI)–including structural MRI (T1-weighted) and functional MRI (fMRI)–as well as positron emission tomography (PET) provide detailed information on brain atrophy, pathological protein deposition, and changes in functional connectivity [5, 6, 10, 13]. Despite the undeniable usefulness of these technologies, the manual evaluation of thousands of scans by radiologists and neurologists is a tedious, time-consuming process that is naturally prone to human cognitive errors. This is especially true in the early stages of the disease, when structural changes are marginal and difficult to distinguish from natural brain aging processes with the naked eye [1, 6, 7]. The complexity and multidimensionality of the data generated by modern imaging techniques far exceed the analytical capabilities of a single diagnostician, thus creating a systemic bottleneck and forcing the search for automated clinical decision support systems [3, 8].

The answer to these fundamental challenges lies in the dynamic development of artificial intelligence (AI) and advanced machine learning (ML) techniques, in particular deep learning (DL) algorithms, which are currently revolutionizing early neurological diagnosis [4, 12, 19]. Artificial intelligence architectures, such as convolutional neural networks (CNN), demonstrate an extraordinary ability, from a human perspective, to instantly analyze gigantic data sets, identify hidden nonlinear patterns, and detect micro-changes with a precision that no human being can achieve [2, 12, 15, 24]. These models flawlessly process multimodal data, synthesizing neuroimaging results with body fluid analysis (biomarker) results and demographic data, allowing for the creation of a complete, accurate patient profile and significantly more accurate risk stratification [9, 11, 18, 20].

In the context of medical imaging, artificial intelligence algorithms enable automated and imprecise segmentation of key brain regions, such as the hippocampus in Alzheimer's disease or the substantia nigra and basal ganglia in Parkinson's disease. Computers can detect minimal, pixel-level volumetric and structural changes that are characteristic of the early, asymptomatic stages of neurodegeneration [15, 17]. The use of AI to analyze routine MRI scans allows for the extraction of deep radiomic features that strongly correlate with the progression of pathology and even with the risk of specific non-motor symptoms, such as cognitive impairment or depression during PD [14, 27, 35]. As a result, neural network-based systems can distinguish mild cognitive impairment (MCI) from dementia with great accuracy and predict conversion from the prodromal stage to full-blown Alzheimer's disease [9, 26, 27].

Equally fascinating and revolutionary is the use of artificial intelligence to analyze non-invasive behavioral and physiological biomarkers [25]. Neurodegenerative diseases affect the patient's functioning at a microscopic level, determining how the patient speaks, writes, moves, and even how they breathe during sleep

[21, 29, 34]. While the human ear cannot detect the slightest tremor in the voice during a few minutes of a doctor's visit, machine learning models can analyze dozens of acoustic parameters. Using the extraction of features such as mel-frequency cepstral coefficients (MFCC), jitter, and shimmer, artificial intelligence is able to diagnose the early stages of PD with an accuracy of over 90% based solely on a short speech recording [21]. The algorithms show similar sensitivity when analyzing the dynamics of handwriting (micrographia) [29], identifying episodes of freezing of gait in correlation with functional imaging [16], and diagnosing patients using non-contact assessment of nocturnal breathing patterns recorded by radio signals [34].

However, it should be strongly emphasized that effective and early diagnosis aided by AI is not only an unprecedented triumph of biomedical engineering, but above all an urgent socio-economic necessity. The integration of AI-based medical triage systems brings proven, measurable financial savings for countries, drastically reducing the need for extremely costly reference tests (such as PET) and optimizing the diagnostic process [36]. Shortening the time to make the correct diagnosis means earlier implementation of supportive therapy, which delays the most severe stages of the disease and postpones the need for costly institutional care [33, 36, 37]. From the perspective of patients' families, this gained time means longer independence for their loved ones, a radical reduction in personal financial burdens, and a reduction in caregiver burnout, which directly improves their quality of life [31, 33]. To achieve full success in this implementation, science must also focus on explainable artificial intelligence (XAI), which builds the necessary trust between the doctor, patient, and machine through the transparency of diagnostic decisions [8, 21].

The aim of this review article is to provide an in-depth synthesis of the latest advances in the application of artificial intelligence in the early, prodromal diagnosis of Alzheimer's and Parkinson's diseases. With a particular focus on MRI image analysis and innovative behavioral markers, this work not only demonstrates the technological superiority of algorithms over the senses of a physician, but also strongly emphasizes the socio-economic impact of these solutions. The article demonstrates how the transition to a proactive model of AI-assisted medicine redefines the paradigm of care, bringing relief to overburdened healthcare systems and protecting the well-being of families [4, 8, 23, 30].

2. Methodology

This review article was developed based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which ensure transparency of the research process and minimize the risk of cognitive errors. The aim was to investigate the role of artificial intelligence (AI) and machine learning (ML) in the early diagnosis of Alzheimer's disease (AD) and Parkinson's disease (PD) and to assess the socio-economic impact of these innovations [5, 12, 31].

The literature search process covered the following databases: PubMed/MEDLINE, Embase, Scopus, Web of Science, and IEEE Xplore. Queries combining technological terms (e.g., "Artificial Intelligence," "Deep Learning," "Explainable AI"), clinical terms (e.g., "early diagnosis," "prodromal stage"), and terms related to the modalities and economics under study ("MRI," "voice analysis," "economic burden") [3, 6, 22, 33].

The review included: (1) studies using AI/ML in the detection of early stages of AD and PD; (2) analyses of medical images, mainly MRI and multimodal (e.g., MRI with PET); (3) assessments of behavioral markers (speech analysis, handwriting, breathing patterns); and (4) analyses of the cost-effectiveness and economic burden of diseases. Studies focusing exclusively on advanced stages of dementia, animal model studies, and articles without model performance evaluation were excluded [5, 20, 31, 34].

From the 37 identified publications, data on model architectures (e.g., CNN, SVM), training set sizes, input diagnostic modalities, and validation metrics achieved (Accuracy, Sensitivity, Specificity, AUC) were extracted and standardized, as well as estimates of direct and indirect costs. The quality of the studies in terms of diagnostic accuracy and risk of error (bias) – with particular emphasis on the generalizability of models and the risk of overfitting – was assessed by adapting the QUADAS-2 criteria and assessment standards for cost-of-illness analyses [19, 22, 31, 36].

3.Results

3.1. The advantage of artificial intelligence algorithms in the detection of neurostructural micro-changes in Alzheimer's disease

Early detection of Alzheimer's disease (AD) is one of the greatest challenges in modern clinical neurology, mainly since the first neurodegenerative changes appear in the brain many years before the onset of measurable cognitive symptoms. The results of the analyzed studies clearly indicate that traditional manual evaluation of magnetic resonance imaging (MRI) scans by radiologists is insufficient to detect the early, prodromal stages of the disease. The human eye is unable to identify subtle, pixel-level changes in brain tissue density or minimal volumetric defects. The use of artificial intelligence (AI), and in particular deep learning (DL) models, is revolutionizing this process. Studies based on large data sets, such as the Alzheimer's Disease Neuroimaging Initiative (ADNI) databases, have proven that automated systems can map micro-changes in structures such as the hippocampus, the entorhinal cortex, and the amygdala, which are crucial for memory and the early development of AD [2, 3, 6, 12, 26].

Convolutional neural networks (CNN) have proven to be the main technological tool in neuroimaging analysis, as they can independently extract hierarchical features from three-dimensional T1-weighted MRI scans. Architectures such as ResNet, VGG, and specialized 3D-CNN models achieve highly satisfactory diagnostic parameters. In one study using hybrid neural networks combined with transfer learning, an overall classification accuracy of over 90% was achieved in the task of distinguishing healthy control patients (HC) from patients with mild cognitive impairment (MCI) and full-blown Alzheimer's disease. Such results are impossible to achieve using traditional visual scales for assessing atrophy. Furthermore, the implementation of attention mechanisms allows neural networks to mimic the human decision-making process by assigning higher weights to pixels located in areas with the highest risk of pathology, while ignoring natural noise in the data [3, 5, 7, 12, 26].

In addition to structural imaging, groundbreaking results have been obtained in resting-state functional magnetic resonance imaging (fMRI) analysis. DL networks have proven their value in analyzing complex spatial-temporal dependencies in the functioning of individual brain regions. AI models have demonstrated the ability to identify early dysfunctions in the Default Mode Network (DMN), whose weakened functional connectivity is one of the earliest markers of AD invisible to the naked eye. Complex algorithms, such as autoencoders and recurrent neural networks (RNN), effectively filter out the noise characteristic of fMRI and isolate signals indicative of progressive neurodegeneration, significantly improving the classification of patients who are on the borderline between normality and pathology [5, 11].

An important trend emerging from the review is the superiority of multimodal models over unimodal ones. The highest sensitivity and specificity rates were achieved in studies where machine learning algorithms synthesized data from different diagnostic sources. For example, the fusion of structural MRI data with positron emission tomography (PET) results showing amyloid and tau protein deposits, combined with clinical data and plasma biomarkers, dramatically increases predictive accuracy. Support vector machine (SVM) algorithms and random forest models have been shown to be able to predict the conversion of mild cognitive impairment (MCI) to full-blown AD with very high accuracy (often exceeding 85-90%) over a period of several years. This type of prediction is crucial because it allows for the very early implementation of potential disease-modifying therapies before extensive, irreversible neuron loss occurs [4, 9, 10, 13, 25].

3.2. Radiomics and deep learning in the objectification of Parkinson's disease diagnosis based on MRI images

For many years, routine structural MRI imaging was considered to play a marginal role in the diagnosis of Parkinson's disease (PD), serving mainly to rule out other pathologies such as tumors or strokes. The lack of macroscopic changes visible to radiologists in patients in the early stages of PD forced them to rely on clinical examinations and very expensive isotopic imaging (e.g., DAT-SPECT). This paradigm shift was brought about by the implementation of artificial intelligence, specifically radiomic analysis. Algorithms can extract thousands of so-called radiomic features – objective measures of texture, intensity, shape, and complexity of pixels – from images that appear completely normal and free of any pathology to the human eye [14, 15, 19].

In PD research, artificial intelligence is successfully used for fully automated segmentation and volumetric analysis of subcortical structures, with particular emphasis on the substantia nigra and basal ganglia, including the caudate nucleus, globus pallidus, and putamen. One study used a highly advanced three-dimensional VB-net network, which processed the entire brain in less than a minute, dividing it into over 100

subregions. Using LASSO regression, the artificial intelligence model identified highly specific features associated with the early stages of PD. Based on these features, a classifier (SVM) was constructed, which achieved a remarkable predictive result – an area under the ROC curve (AUC) of 0.976 in the test set, with excellent sensitivity of 87.1% and specificity of 100%. The computer thus proved that standard T1 MRI images contain hidden signals of neurodegeneration that can be precisely described mathematically and used for diagnostic purposes [15, 17, 18, 19].

What is more, artificial intelligence integrated with MRI allows for the analysis of not only motor symptoms, but also non-motor symptoms of PD, which significantly reduces quality of life. Among other things, the impact of structural changes in the brain on the risk of patients experiencing episodes of freezing of gait (FoG) was assessed. By applying machine learning algorithms (e.g., Multilayer Perceptron, Logistic Regression) to parameters obtained from resting-state fMRI, researchers were able to identify connectivity disorders within the sensorimotor network with effectiveness indicators significantly exceeding purely clinical observation. Artificial intelligence allows doctors to "see" preclinical markers of mobility loss before they lead to falls that are dangerous to the patient's health. A similar approach, based on whole brain radiomics, shows promising results in predicting specific subtypes of depression in PD and mild cognitive impairment, which often accompany this condition [16, 20, 27, 35].

3.3. Algorithms for detecting behavioral and voice patterns as a breakthrough in non-invasive Parkinson's diagnosis

While volumetric imaging concerns neuroanatomy, the study of disease manifestations in behavior opens up a whole new chapter in early neurological diagnosis, characterized by unprecedented non-invasiveness. Artificial intelligence shows incredible sensitivity to micro-changes in the patient's communication and fine motor skills, phenomena more widely known as behavioral markers. Speech disorders often appear up to 5 years before the classic, visually noticeable resting tremor or stiffness (bradykinesia) – unfortunately, at such an early stage, they are inaudible to a doctor conducting a routine clinical interview. In this context, the implementation of AI is an undeniable milestone [21, 23, 28].

The experiments described in the analyzed literature are based on advanced acoustic extraction of speech parameters using machine learning. In one detailed study conducted on a cohort of 81 people, a multi-layered hybrid vocal analysis model was implemented (integrating, among other things, convolutional neural networks with Multiple Kernel Learning architecture). This algorithm analyzed microdeviations in sound pitch, band energy distribution, and respiratory disturbances (parameters such as local jitter, shimmer, HNR, and MFCC coefficients). The results were sensational from a clinical point of view: the hybrid classifier distinguished the voices of people with prodromal Parkinson's from those of completely healthy people with an overall classification accuracy of 91.11%, a sensitivity of 92.50%, and an area under the ROC curve of 0.9125. To emphasize the technological advantage, it is worth adding that routine physical neurological examination achieves a historical effectiveness of only about 80% in the early stages. Using the SHAP (SHapley Additive exPlanations) technique, which is part of the field of XAI (explainable artificial intelligence), researchers were able to directly determine exactly which changes in the voice determined the result. This system increases trust and transparency between the doctor, algorithm, and patient [8, 21, 22].

In addition to voice analysis, outstanding achievements include the detection of changes in micromotor skills that are invisible to the eye, such as handwriting analysis. Micrographia, or the gradual reduction in letter size during writing, studied using sensitive tablets and neural networks that analyze pressure dynamics and the time between strokes, is an extremely sensitive and inexpensive biomarker to implement. In addition, the latest innovations point to the enormous potential of using radio devices operating on the principle of contactless radar in the patient's bedroom. Groundbreaking DL models are able to reconstruct the nighttime breathing rhythm in a completely non-invasive manner from radio waves reflected from the patient's chest, thus detecting the early stages of Parkinson's disease and monitoring the progression of the condition without any interference with the patient's privacy. The sensitivity of this solution reaches an AUC close to 0.90 in independent, external validation cohorts [24, 29, 30, 34].

3.4. Socio-economic impact of AI-based diagnostics: Reducing the burden on the system and benefits for families

The last, but equally important conclusion from a systematic review of the literature is the social and macroeconomic dimension of implementing artificial intelligence in diagnostics. The economic burden associated with caring for patients suffering from neurodegenerative diseases–from diagnosis to the terminal stages of dementia–is enormous and is growing exponentially as the global population ages. As demonstrated in studies on the social costs (Cost of Illness), the indirect costs associated with Alzheimer's disease alone (including lost productivity and the costs of premature withdrawal from the labor market) are a colossal problem. In the case of Parkinson's disease, the average total cost of care per patient per year in developed countries exceeds €20,000, approaching as much as €100,000 for patients in the most severe stages of the disease. These costs include numerous hospitalizations, rehabilitation, and the enormous burden of informal care provided by family members, which directly devastates their financial and mental stability (caregiver burden) [31, 32, 33, 37].

Artificial intelligence appears here as a strategic tool for relieving the burden on healthcare systems. Rapid and mass pre-selection of patients (triage) performed by precise neural networks on inexpensive, routine tests (e.g., scanning for "swallowtail" symptoms on MRI images or voice analysis from a smartphone) reduces the number of expensive, unnecessary referral tests (such as PET). Cost-benefit analyses (CBA) conducted on models in South Korea and the United States have clearly proven that the implementation of intelligent MRI-based triage for suspected PD results in short-term savings of tens of millions of dollars for the state budget, with a rate of return (B/C ratio) significantly higher than the break-even point. In the long term, estimated until 2050, the savings for the healthcare system in Korea alone, due to the lack of redundant scans and the faster implementation of cheaper therapies to slow down the progression of the disease, have been estimated at nearly $2.5 billion [31, 36, 37].

However, the social benefits of faster diagnosis are not limited to a balanced budget for health ministries. Earlier, accurate, objective diagnosis of the disease through the detection of micro-changes by mathematical models gives the patient valuable time. This means that therapies that modify the course of the disease, lifestyle changes, and pharmacotherapy can be implemented at a time when the brain structures have not yet undergone profound, irreversible damage. As a result, the time at which the patient becomes completely dependent and requires placement in an institutional care facility is postponed by years. Families enjoy the active presence of their loved ones for longer, with minimal loss of their own professional productivity, which, according to the literature, is the most measurable improvement in the quality of life of entire households. According to researchers, the integration of automated diagnoses and human care is the foundation of highly empathetic, pro-social, personalized medicine of the 21st century [4, 8, 23, 30, 31, 32].

4. Discussion

A systematic review of the literature conclusively proves that artificial intelligence (AI) and machine learning (ML) techniques represent a fundamental breakthrough in the early, prodromal diagnosis of neurodegenerative diseases such as Alzheimer's disease (AD) and Parkinson's disease (PD). The results of the analyzed studies converge in a common conclusion: automated algorithms, in particular deep learning (DL) networks, have the ability to identify subtle, preclinical micro-changes in brain structure (through volumetric and radiomic MRI analysis) and deviations in behavioral markers (speech, writing, nocturnal breathing) with an efficiency and speed that no human diagnostician can achieve. However, this transformation is not limited to the technological or medical sphere. As has been demonstrated, shifting the moment of diagnosis from the symptomatic phase to the preclinical phase has powerful systemic implications for health economics and the quality of life of entire societies. Despite these promising prospects, the full integration of predictive models into standard clinical practice faces a number of methodological, ethical, and social challenges that require in-depth analysis [4, 12, 19, 23, 31].

The main barrier to the implementation of artificial intelligence in neurology departments remains the so-called "black box" problem. Classic, highly effective deep learning architectures, such as multilayer convolutional neural networks (CNN), process tens of thousands of hidden features (e.g., voxel values from fMRI images or MFCC coefficients from voice recordings) in a non-linear manner that is completely opaque to the human mind. From the perspective of the attending physician, who bears ultimate legal and moral responsibility for the diagnosis, blind trust in a binary result generated by a machine is unacceptable. Therefore, the literature on the subject clearly points to the growing need to implement Explainable Artificial Intelligence (XAI). Tools such as SHAP (SHapley Additive exPlanations) and Layer-Wise Relevance Propagation (LRP)

algorithms are becoming an indispensable bridge between engineering and medicine. They allow the generation of visualizations that are intuitive for the physician, such as heatmaps (heatmaps) superimposed on MRI scans, which precisely indicate that the diagnosis of early AD was determined by atrophy in a specific square millimeter of the hippocampus, or that the prodromal stage of PD was determined by a specific break in the amplitude curve in the patient's voice recording. This transparency not only builds the trust of clinicians but is also required by upcoming legal regulations on medical algorithms [8, 11, 21, 24, 25].

Another extremely important research issue raised in the discussion on AI systems is the problem of model generalizability and the risk of data bias. Most of the impressive results achieved by neural networks (often exceeding 90% accuracy) have been obtained under controlled experimental conditions, using highly homogeneous databases such as ADNI (Alzheimer's Disease Neuroimaging Initiative) or PPMI (Parkinson's Progression Marker Initiative). These collections, while invaluable to science, largely represent white patients from developed countries with high socioeconomic status and access to top-of-the-line MRI scanners. If an algorithm is trained on such data, its performance may drop dramatically when applied to a diverse population in a rural clinic or in developing countries, where the quality of radiological equipment and patient demographics are different. The researchers emphasize that in order to avoid creating technologies that exacerbate health inequalities, it is necessary to train models on multi-center and demographically diverse data. This requires advanced data harmonization techniques (such as the ComBat method) to bridge equipment differences between hospitals, as well as wider use of federated learning, which allows models to be trained on local hospital servers without centralizing sensitive patient medical data [11, 19, 22, 27].

Moving on to the discussion of socio-economic aspects, it should be strongly emphasized that innovations in early diagnosis are the only real response to the impending collapse of healthcare systems. As cost of illness reviews show, the economic burden generated by progressive dementia and motor syndromes is asymmetrical—it skyrockets in the advanced stages of the disease, when patients require round-the-clock, specialized, and highly expensive institutional care. The use of algorithms for early detection of micro-changes in people with mild cognitive impairment (MCI) is changing this dramatic trajectory. AI allows for the implementation of highly effective medical triage mechanisms. Instead of subjecting every suspected patient to invasive lumbar punctures or costly PET scans, systems based on support vector machines (SVM) or CNN networks can analyze inexpensive, routine T1-weighted MRI sequences or cost-free voice recordings from a smartphone. Validation studies from markets such as the US and South Korea have proven that such algorithmic screening rejects false positives, saving hundreds of millions of dollars annually on a macro scale. Resource allocation optimized in this way allows the savings to be directed towards the development of modern disease-modifying therapies and improving care conditions for those who actually need it [31, 32, 33, 36, 37].

However, the social dimension of these innovations is most strongly felt at the level of individual households. Conventional diagnosis, which is only made when neurological deficits visible to the human eye occur, condemns patients' families to a sudden, dramatic redefinition of their lives. The indirect costs of diseases such as AD and PD are predominantly the costs of lost productivity (absenteeism and presenteeism) and the non-monetary burden on informal caregivers (caregiver burden). Family members are often forced to leave the labor market prematurely, which drives households into poverty and leads to extreme physical exhaustion and depressive disorders in the caregivers themselves. Accelerating diagnosis by several years, made possible by the detection of early behavioral biomarkers (such as micrographia or sleep-related breathing disorders), gives patients and their families invaluable time. This time can be used for early implementation of conservative treatment, adaptation of the place of residence, securing legal and financial issues, and participation in support groups. By preserving the patient's physical and intellectual independence for longer, artificial intelligence becomes a deeply empathetic tool that directly protects the social structure and psychophysical well-being of entire families [28, 29, 31, 32, 33].

Future directions paint a picture of highly personalized, proactive, and continuous medicine. The studies analyzed indicate a shift away from stressful, one-off visits to the clinic for elderly patients in favor of continuous ecological momentary assessment. The use of multimodal, non-invasive artificial intelligence sensors–such as bedroom radar devices that analyze breathing patterns without compromising privacy, smartphone apps that analyze voice tremors in real time, or sensitive matrices that assess handwriting dynamics–will enable the creation of digital patient phenotypes. These technologies, coupled with large language models (LLMs) powering reporting systems, will create automated diagnostic frameworks that alert primary care physicians when a patient's health trajectory deviates from the norm. However, for this vision to become a common standard, further rigorous prospective clinical trials involving algorithms (e.g., reported in accordance with TRIPOD+AI guidelines) and close, interdisciplinary collaboration between developers, neurologists, bioethicists, and health policy makers are necessary [19, 21, 24, 34].

5. Conclusion

This review article clearly demonstrates that the integration of artificial intelligence (AI) and advanced machine learning (ML) algorithms with early neurological diagnosis represents a fundamental paradigm shift in modern medicine. The transition from the traditional, reactive model of diagnosis–based on the identification of advanced visual and audible clinical symptoms–to a proactive model based on the detection of micro-changes and prodromal biomarkers is already a fait accompli in the research space. Deep learning architectures, such as convolutional neural networks (CNN) and models based on attention mechanisms, have proven their undeniable superiority over the limitations of human senses. Where the eye of an experienced radiologist sees an image corresponding to the natural aging process, computer algorithms can identify early, pixel-level structural and volumetric abnormalities within the hippocampus or basal ganglia. Moreover, the ability of artificial intelligence to synthesize multimodal data, combining structural and functional MRI imaging with the results of body fluid or genetic testing, creates unprecedentedly precise tools for risk stratification and predicting the trajectory of neurodegenerative diseases many years before their full manifestation [1, 2, 4, 12, 18].

In the context of Parkinson's disease (PD), the spectacular development of non-invasive behavioral diagnostics deserves special attention. Studies confirm that artificial intelligence analyzes non-motor markers and early fine motor disorders with remarkable precision, far exceeding the capabilities of the human ear or eye. The extraction of complex acoustic features from short recordings of a patient's speech (such as MFCC coefficients, jitter, or shimmer) allows algorithms to identify micro-changes in vocal control with an accuracy exceeding 90%. Equally promising results are achieved by digital analysis of handwriting dynamics (micrographia) and non-contact monitoring of nocturnal breathing patterns using radio waves. These tools not only objectify the diagnostic process, removing the burden of subjective assessment by the physician, but also pave the way for the implementation of continuous, remote monitoring of patients in their natural home environment, which is a huge step towards personalized medicine [21, 24, 28, 29, 34].

In turn, in the field of Alzheimer's disease (AD) and mild cognitive impairment (MCI) diagnostics, advanced radiomic analysis of MRI images has proven to be the key to capturing the critical therapeutic window. Predictive models based on support vector machines (SVM) or random forest algorithms allow us to predict with high probability which MCI patients will convert to full-blown dementia in the coming years. Detecting these preclinical signs of neural network degeneration (e.g., based on functional connectivity analysis in fMRI) allows for the identification of patients eligible for innovative disease-modifying therapies before massive, irreversible cell death and cognitive decline in the brain. Explainable artificial intelligence (XAI) becomes an essential catalyst for trust here, visualizing the exact decision paths of algorithms for clinicians and protecting against the so-called black box error [6, 8, 9, 13, 26].

From the perspective of social sciences and health economics, which are key points of reference for this review, the mass implementation of the algorithms discussed is a necessity dictated by concern for the sustainable development of aging societies. The cumulative economic burden resulting from late diagnosis of neurodegenerative diseases threatens to completely overwhelm public healthcare systems. It has been proven that artificial intelligence systems, used as early triage tools, generate dramatic direct savings by eliminating the need for routine, highly expensive isotope testing (PET or SPECT) in low-risk patients. Shortening the so-called diagnostic odyssey optimizes the allocation of limited human and financial resources in hospitals, as demonstrated by the multimillion-dollar savings modeled for healthcare systems in the United States and South Korea. Automated screening is an opportunity to democratize access to early, elite diagnostics, preventing health exclusion in regions with lower specialist saturation [31, 33, 36, 37].

In summary, the most important beneficiaries of the AI technological revolution are not the healthcare system itself, but patients and their families. Earlier diagnosis translates into years of gained independence, a radical reduction in indirect costs, such as lost professional productivity, and the prevention of extreme psychophysical burnout in informal caregivers. However, in order to fully exploit this potential, the scientific community and decision-makers must focus in the coming years on rigorous clinical validation of models in multicenter studies (to avoid data bias), improving XAI technology, and creating a clear legal and ethical framework. Artificial intelligence cannot replace the empathy and clinical judgment of a neurologist, but it equips them with tools of superhuman sensitivity, laying out the foundation for a more humane, proactive, and cost-effective medicine of the future [19, 23, 27, 30, 32].

Author Contributions:
Conceptualization: Zuzanna Zalewska
Methodology: Zuzanna Zalewska, Karolina Reczka
Software: Zuzanna Zalewska, Maria Woźniak
Check: Zuzanna Zalewska, Julia Szymkowiak
Validation / Check: Zuzanna Zalewska, Karolina Reczka, Julia Szymkowiak, Maria Woźniak
Formal Analysis: Zuzanna Zalewska, Karolina Reczka
Investigation: Zuzanna Zalewska, Karolina Reczka
Resources: Zuzanna Zalewska, Julia Szymkowiak
Data curation: Zuzanna Zalewska, Julia Szymkowiak, Julia Szymkowiak
Writing – rough preparation: Zuzanna Zalewska, Maria Woźniak
Writing – Review and Editing: Zuzanna Zalewska, Karolina Reczka
Supervision / Project Administration: Zuzanna Zalewska, Karolina Reczka

All authors have read and agreed to the published version of the manuscript

REFERENCES

1. Soulier, T., Burgos, N., Hassanaly, R., Pitombeira, M., Solal, M., Roy, H., Hamzaoui, M., Yazdan-Panah, A., de Paula Faria, D., Louapre, C., Bodini, B., Bottlaender, M., Ayache, N., Colliot, O., & Stankoff, B. (2025). Artificial intelligence in presymptomatic neurological diseases: Bridging normal variation and prodromal signatures. *Revue Neurologique, 181*, 944–950. https://doi.org/10.1016/j.neurol.2025.07.011
2. Yao, Z., Wang, H., Yan, W., Wang, Z., Zhang, W., Wang, Z., & Zhang, G. (2023). Artificial intelligence-based diagnosis of Alzheimer's disease with brain MRI images. *European Journal of Radiology, 165*, 110934. https://doi.org/10.1016/j.ejrad.2023.110934
3. Shanmugavadivel, K., Sathishkumar, V. E., Cho, J., & Subramanian, M. (2023). Advancements in computer-assisted diagnosis of Alzheimer's disease: A comprehensive survey of neuroimaging methods and AI techniques for early detection. *Ageing Research Reviews, 91*, 102072. https://doi.org/10.1016/j.arr.2023.102072
4. Kale, M., Wankhede, N., Pawar, R., Ballal, S., Kumawat, R., Goswami, M., Khalid, M., Taksande, B., Upaganlawar, A., Umekar, M., Kopalli, S. R., & Koppula, S. (2024). AI-driven innovations in Alzheimer's disease: Integrating early diagnosis, personalized treatment, and prognostic modeling. *Ageing Research Reviews, 101*, 102497. https://doi.org/10.1016/j.arr.2024.102497
5. Warren, S. L., & Moustafa, A. A. (2023). Functional magnetic resonance imaging, deep learning, and Alzheimer's disease: A systematic review. *Journal of Neuroimaging, 33*(1), 5–18. https://doi.org/10.1111/jon.13063
6. Basanta-Torres, S., Rivas-Fernández, M. Á., & Galdo-Alvarez, S. (2025). Artificial intelligence for Alzheimer's disease diagnosis through T1-weighted MRI: A systematic review. *Computers in Biology and Medicine, 197*, 111028. https://doi.org/10.1016/j.compbiomed.2025.111028
7. Bi, X., Liu, W., Liu, H., & Shang, Q. (2021). Artificial intelligence-based MRI images for brain in prediction of Alzheimer's disease. *Journal of Healthcare Engineering, 2021*, 8198552. https://doi.org/10.1155/2021/8198552
8. Borchert, R. J., Azevedo, T., Badhwar, A. P., Betts, M., Bruffaerts, R., Burkhart, M. C., Dewachter, I., Gellersen, H. M., … Veldsman, M. (2023). Artificial intelligence for diagnostic and prognostic neuroimaging in dementia: A systematic review. *Alzheimer's & Dementia*. https://doi.org/10.1002/alz.13412
9. Ai, M., Liu, Y., Liu, D., Yan, C., Wang, X., & Chen, X. (2025). Research progress in predicting the conversion from mild cognitive impairment to Alzheimer's disease via multimodal MRI and artificial intelligence. *Frontiers in Neurology, 16*, 1596632. https://doi.org/10.3389/fneur.2025.1596632
10. Christodoulou, R. C., Woodward, A., Pitsillos, R., Ibrahim, R., & Georgiou, M. F. (2025). Artificial intelligence in Alzheimer's disease diagnosis and prognosis using PET-MRI: A narrative review of high-impact literature post-Tauvid approval. *Journal of Clinical Medicine, 14*(16), 5913. https://doi.org/10.3390/jcm14165913
11. Nature Medicine. (2024). AI-based differential diagnosis of dementia etiologies on multimodal data. *Nature Medicine*. https://doi.org/10.1038/s41591-024-03118-z
12. Mou, F. S., Ahmed, T., Huda, M. N., & Nandi, A. K. (2025). Artificial neural networks fighting real neural decline: A systematic review of AI in Alzheimer's research. *Artificial Intelligence Review*. https://doi.org/10.1007/s10462-025-11484-4
13. Karlsson, L., Vogel, J., Arvidsson, I., Åström, K., Strandberg, O., Seidlitz, J., … Hansson, O. (2025). Machine learning prediction of tau-PET in Alzheimer's disease using plasma, MRI, and clinical data. *Alzheimer's & Dementia*. https://doi.org/10.1002/alz.14600
14. Reddy, S., Giri, D., & Patel, R. (2024). Artificial intelligence diagnosis of Parkinson's disease from MRI scans. *Cureus, 16*(4). https://doi.org/10.7759/cureus.58841

15. Li, C., Hui, D., Wu, F., Xia, Y., Shi, F., Yang, M., Zhang, J., Peng, C., Feng, J., & Li, C. (2024). Automatic diagnosis of Parkinson's disease using artificial intelligence based on routine T1-weighted MRI. *Frontiers in Medicine, 10*, 1303501. https://doi.org/10.3389/fmed.2023.1303501
16. Vicidomini, C., Fontanella, F., D'Alessandro, T., Roviello, G. N., De Stefano, C., De Pandis, M. F., Stocchi, F., & Quarantelli, M. (2025). Resting-state functional MRI metrics to detect freezing of gait in Parkinson's disease: A machine learning approach. *Computers in Biology and Medicine, 192*, 110244. https://doi.org/10.1016/j.compbiomed.2025.110244
17. Sui, H., Mo, Z., Luan, H., Yao, W., Wang, M., & Zhang, L. (2025). AI-assisted MRI segmentation analysis of brain region volume alterations in Parkinson's disease. *Frontiers in Human Neuroscience, 19*, 1666556. https://doi.org/10.3389/fnhum.2025.1666556
18. Lu, S., Gui, S., Wang, C., & Liu, Y. (2025). Combined with multimodal medical imaging and artificial intelligence for early diagnosis of Parkinson's disease. *Frontiers in Neurology, 16*, 1650968. https://doi.org/10.3389/fneur.2025.1650968
19. Ebrahimian Sadabad, F., Honhar, P., Houshi, S., Nejati, S. F., Bagherieh, S., Brackett, A., Yazdanpanah, F., Cayir, S., Hosseini, M., Tagare, H., & Matuskey, D. (2026). Detection of Parkinson's disease with neuroimaging modalities using machine learning and artificial intelligence: A systematic review. *Neurological Sciences, 47*, 160. https://doi.org/10.1007/s10072-025-08768-6
20. Dennis, A.-G. P., & Strafella, A. P. (2024). The identification of cognitive impairment in Parkinson's disease using biofluids, neuroimaging, and artificial intelligence. *Frontiers in Neuroscience, 18*, 1446878. https://doi.org/10.3389/fnins.2024.1446878
21. Shen, M., Mortezaagha, P., & Rahgozar, A. (2025). Explainable artificial intelligence to diagnose early Parkinson's disease via voice analysis. *Scientific Reports, 15*, 11687. https://doi.org/10.1038/s41598-025-96575-6
22. Chou, S. C., Cong, C., Brownson-Smith, R., Milne-Ives, M., & Meinert, E. (2026). Assessment of mental and behavioral non-motor symptoms of Parkinson's disease using artificial intelligence (AI): A systematic review. *Communications Medicine, 6*, 101. https://doi.org/10.1038/s43856-025-01304-9
23. Twala, B. (2025). AI-driven precision diagnosis and treatment in Parkinson's disease: A comprehensive review and experimental analysis. *Frontiers in Aging Neuroscience, 17*, 1638340. https://doi.org/10.3389/fnagi.2025.1638340
24. Priyadharshini, S., Ramkumar, K., Narasimhan, K., Surya Prasath, V. B., & Venkatesh, S. (2025). Web-based AI-driven framework combining multi-modal data with CNN and LLM for Parkinson's disease diagnosis. *Scientific Reports, 15*, 38556. https://doi.org/10.1038/s41598-025-22448-7
25. Vrahatis, A. G., Skolariki, K., Krokidis, M. G., Lazaros, K., Exarchos, T. P., & Vlamos, P. (2023). Revolutionizing the early detection of Alzheimer's disease through non-invasive biomarkers: The role of artificial intelligence and deep learning. *Sensors, 23*(9), 4184. https://doi.org/10.3390/s23094184
26. Mmadumbu, A. C., Saeed, F., Qasem, S. N., & Ghaleb, F. (2025). Early detection of Alzheimer's disease using deep learning methods. *Alzheimer's & Dementia*. https://doi.org/10.1002/alz.70175
27. Moeinafshar, A., Barati, A. R., Tehrani Fateha, S., Pahlevan Fallahya, M. T., & Soltani Khaboushana, A. (2025). Artificial intelligence in diagnosis and prognosis of cognitive impairment in Parkinson's disease. *Dementia and Geriatric Cognitive Disorders*. https://doi.org/10.1159/000547180
28. Yang, N., Liu, J., Sun, D., Ding, J., Sun, L., Qi, X., & Yan, W. (2025). Motor symptoms of Parkinson's disease: Critical markers for early AI-assisted diagnosis. *Frontiers in Aging Neuroscience, 17*, 1602426. https://doi.org/10.3389/fnagi.2025.1602426
29. Marano, G., Rossi, S., Marzo, E. M., Ronsisvalle, A., Artuso, L., Traversi, G., Pallotti, A., Bove, F., Piano, C., Bentivoglio, A. R., Sani, G., & Mazza, M. (2025). Writing the future: Artificial intelligence, handwriting, and early biomarkers for Parkinson's disease diagnosis and monitoring. *Biomedicines, 13*(7), 1764. https://doi.org/10.3390/biomedicines13071764
30. Reddy, A., Reddy, R. P., Roghani, A. K., Garcia, R. I., Khemka, S., Pattoor, V., Jacob, M., Reddy, P. H., & Sehar, U. (2024). Artificial intelligence in Parkinson's disease: Early detection and diagnostic advancements. *Ageing Research Reviews, 99*, 102410. https://doi.org/10.1016/j.compbiomed.2025.110244
31. Tay, L. X., Ong, S. C., Tay, L. J., Ng, T., & Parumasivam, T. (2024). Economic burden of Alzheimer's disease: A systematic review. *Value in Health Regional Issues*. https://doi.org/10.1016/j.vhri.2023.09.008
32. Webster, N. J., Zahodne, L. B., Ajrouch, K. J., & Antonucci, T. C. (2024). Introduction to the costs of Alzheimer's disease and related dementias. *Journal of Aging and Health, 36*(9), 507–509. https://doi.org/10.1177/08982643241265789
33. Wijers, A., Ravi, A., Evers, S. M. A. A., Tissingh, G., & van Mastrigt, G. A. P. G. (2024). Systematic review of the cost of illness of Parkinson's disease from a societal perspective. https://doi.org/10.1002/mds.29995
34. Yang, Y., Yuan, Y., Zhang, G., Wang, H., Chen, Y.-C., Liu, Y., Tarolli, C. G., Crepeau, D., Bukartyk, J., Junna, M. R., Videnovic, A., Ellis, T. D., Lipford, M. C., Dorsey, R., & Katabi, D. (2022). Artificial intelligence-enabled detection and assessment of Parkinson's disease using nocturnal breathing signals. *Nature Medicine, 28*, 2207–2215. https://doi.org/10.1038/s41591-022-01932-x

35. Zhang, Z., Peng, J., Song, Q., Xu, Y., Wei, Y., & Shu, Z. (2024). Identification of depression subtypes in Parkinson's disease patients via structural MRI whole-brain radiomics: An unsupervised machine learning study. *CNS Neuroscience & Therapeutics*. https://doi.org/10.1111/cns.70182
36. Kim, K., Song, S., Kim, S. S., Shin, D. H., & Lee, A.-L. (2025). Economic value of AI-based MRI triage for Parkinson's disease: A cost-benefit study in South Korea and the United States. *Frontiers in Public Health, 13*, 1723829. https://doi.org/10.3389/fpubh.2025.1723829
37. Albarmawi, H., Zhou, S., Shulman, L. M., Gandhi, A. B., Johnson, A., Myers, D. E., Gray, D., Alvir, J., & Onukwugha, E. (2024). The economic burden of Parkinson disease among Medicare beneficiaries. https://doi.org/10.18553/jmcp.2022.28.4.405