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PROGNOSIS OF NEURODEGENERATIVE DISEASES: ARTIFICIAL INTELLIGENCE IN THE DIAGNOSIS OF ALZHEIMER'S, PARKINSON'S AND MULTIPLE SCLEROSIS

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ABSTRACT

Introduction: Neurodegenerative diseases, such as Alzheimer's, Parkinson's, and Multiple Sclerosis, cause progressive loss of neurons and cognitive function. Alzheimer's Disease is the most common, primarily affecting the elderly, while Parkinson's causes motor problems and affects all ethnicities. Multiple Sclerosis has a survival rate of up to 30 years, with age being the primary risk factor. Early diagnosis is challenging due to the high cost of tests, but the use of artificial intelligence in neuroimaging can improve diagnosis and prognosis, offering a better quality of life for patients. Objective: Given the increasing number of neurodegenerative diseases, especially Alzheimer's Disease, this study aimed to evaluate

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the impact of using artificial intelligence for the diagnosis and prognosis of future patients. Method: This is a literature review on the use of artificial intelligence in neuroimaging for early diagnosis and improved prognosis. Databases such as PubMed and Arxiv were used, with keywords like Alzheimer's, Parkinson's, Multiple Sclerosis, deep learning, and artificial intelligence, covering the years 2014 to 2024. Results: Based on the analysis of selected studies, it was observed that Alzheimer's Disease is the most prevalent pathology in the current population, and artificial intelligence, combined with neuroimaging, can facilitate a more effective and early diagnosis. Conclusion: It was concluded that, although promising, the use of artificial intelligence in neuroimaging still requires extensive research and advancements in this broad field.

Keywords: Neurodegenerative Diseases. Alzheimer's. Parkinson's. Multiple Sclerosis. Deep learning. AI.

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INTRODUCTION

Neurodegenerative diseases are pathologies resulting from the death and/or progressive dysfunction of neurons in the nervous system, triggered by genetic, environmental, and emotional factors. Consequently, there is a progressive and irreversible loss of cognitive and functional abilities in the organism. In this context, the main diseases identified are Alzheimer's, Parkinson's, and Amyotrophic Lateral Sclerosis (ALS). While the first two tend to affect the elderly population more, the latter impacts individuals during their most productive years (SOUSA, 2022).

Alzheimer's Disease (AD) is currently the most common, accounting for 80% of cases. It occurs due to cognitive impairment in individuals, with difficulties in storing new information and recalling past events (APOLINÁRIO, 2011). It has progressive and insidious characteristics, worsening with aging and interfering with daily life. Its preclinical phase begins around the fourth decade of life, with female gender and age above 65 being significant risk factors (SOUSA, 2022).

Additionally, Parkinson's Disease occurs due to the death of dopaminergic neurons in the substantia nigra, affecting approximately 200 people per 100,000 individuals. This disease can lead to severe disability within 15 years of prognosis (MINISTÉRIO DA SAÚDE, 2017). Unlike AD, its prevalence is universal, affecting all ethnicities equally. Symptoms include bradykinesia, initially unilateral motor impairment, dystonia, resting tremors, hyposmia, among others (COUTO, 2023).

Another degenerative disease is Multiple Sclerosis, which affects the central nervous system, composed of the spinal cord and brain. Most cases are sporadic and autosomal dominant, with a survival rate of up to 30 years. Age is the most prevalent risk factor among individuals (MARQUES, 2023).

In summary, degenerative diseases are rarely diagnosed early, as diagnosis is based on clinical evaluation and high cost imaging tests, resulting in an unfavorable prognosis. Thus, the use of artificial intelligence combined with neuroimaging emerges, aiming to provide early diagnosis of the pathology and, consequently, improve the quality of life for individuals by offering a more detailed and anticipated prognosis for both the patient and their family.

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OBJECTIVE

Given the increasing number of neurodegenerative diseases, especially Alzheimer's Disease, this study aimed to evaluate the impact of using artificial intelligence for the diagnosis and prognosis of future patients.

METHODOLOGY

The research was conducted starting in the second semester of 2024, and the chosen terms were considered relevant by the authors of this literature review on the use of artificial intelligence in imaging tests for the early detection of neurodegenerative diseases and their improved prognosis. The research was based on the PubMed and Arxiv databases, with publication date filters between 2014 and 2024.

1. **First search:** Conducted on PubMed. The keywords used were "neurodegenerative diseases and Alzheimer and artificial intelligence." The filters applied were articles in English, Portuguese, and Spanish, only literature reviews, and a 10-year period between 2014 and 2024. This resulted in a total of 20 articles, of which 8 were excluded for not aligning with the review's theme.
2. **Second search:** Conducted on Arxiv. The keywords used were "multiple sclerosis and deep learning." The filters applied were articles in English, Portuguese, and Spanish, only literature reviews, and a 10-year period between 2014 and 2024. This resulted in a total of 6 articles, of which 2 were excluded for not aligning with the proposed theme.
3. **Third search:** Conducted on Arxiv. The keywords used were "parkinson and deep learning." The filters applied were articles in English, Portuguese, and Spanish, only literature reviews, and a 10-year period between 2014 and 2024. This resulted in a total of 20 articles, of which 14 were excluded for not aligning with the proposed theme.
4. **Fourth search:** Conducted on Arxiv. The keywords used were "multiple sclerosis and MRI." The filters applied were articles in English, Portuguese, and Spanish, only literature reviews, and a 10-year period between 2014 and 2024. This resulted in a total of 15 articles, of which 5 were excluded for not aligning with the proposed theme.

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RESULTS

The results of the four conducted searches are described below. Using the keywords "deep learning," "MRI," "neurodegenerative diseases," and "artificial intelligence," it is possible to observe that, since 2020, studies in this area have grown steadily, becoming an important topic today. It became necessary to use additional filters, such as "Alzheimer's," "Parkinson's," and "multiple sclerosis," as these are the most prevalent pathologies of the central and peripheral nervous systems.

Table 1: Research Results

Author Year / Location	Article Title	Main Findings
Chang C. et al / 2021 / Switzerland	Machine Learning and Novel Biomarkers for the Diagnosis of Alzheimer's Disease	Alzheimer's Disease is marked by progressive memory and cognitive loss, being the most common cause of dementia. New diagnostic methods are being studied, with the combination of AI and neuroimaging being the most promising.
Warren L. Samuel et al / 2023 / Australia	Functional magnetic resonance imaging, deep learning, and Alzheimer's disease: A systematic review	AD is diagnosed with psychological tests and clinical observations, but these methods are not the most adequate and can be updated. A promising example is the use of MRI and AI.
Suppiah Subapriya et al / 2021 / Malaysia	Diagnostic power of resting-state fMRI for detection of network connectivity in Alzheimer's disease and mild cognitive impairment: A systematic review	AD is a neurodegenerative disease characterized by progressive cognitive decline. Resting-state functional MRI (rs-fMRI) is a neuroimaging tool used to study aberrations in the functional activity of different brain networks.
Orellana Paulina et al / 2023 / Chile	Systematic review: fluid biomarkers and machine learning methods to improve the diagnosis from mild cognitive impairment to Alzheimer's disease	Cognitive impairment is considered a precursor stage to dementia. Various psychological and cognitive tests are used, along with neuroimaging and biomarkers, with the goal of integrating artificial intelligence into these methods.
Bahr T et al. / 2024 / United States	Deep learning and machine learning algorithms for retinal image analysis in neurodegenerative disease: Systematic review of datasets and models	Retinal images contain rich information on biomarkers for neurodegenerative diseases. Deep learning models have been used for the automated diagnosis of neurodegenerative diseases and risk prediction, with good results.
Agarwal, D. et al. / 2021 / Switzerland	Transfer Learning for Alzheimer's Disease through Neuroimaging Biomarkers: A Systematic Review	Since 2017, AI and neuroimaging have been integrated and used to detect early signs of dementia and degenerative diseases.
Wang Yi-zhe et al. / 2024 / China	Revolutionizing early Alzheimer's disease and mild cognitive impairment diagnosis: a deep learning MRI meta-analysis	Early diagnosis of Alzheimer's and other dementias remains a challenge for society, mainly due to outdated diagnostic methods. The combination of AI and MRI becomes an essential tool for rapid detection and improved prognosis.

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Author Year / Location	Article Title	Main Findings
Moreno Sylvain et al. / 2023 / Canada	Neuroimaging and machine learning for studying the pathways from mild cognitive impairment to alzheimer's disease: a systematic review	AD may begin up to 20 years before reaching its peak. The combination of AI and MRI should be further studied before being implemented in medical practice for diagnosis.
Viejo-Sobera Raquel et al. / 2021 / Spain	Machine learning methods for predicting progression from mild cognitive impairment to Alzheimer's disease dementia: a systematic review	The use of AI and MRI allows for the early visualization of structures affected by the disease, enabling medicine to slow the progression of cognitive loss.
Mei Jie et al. / 2021 / Germany	Machine Learning for the Diagnosis of Parkinson's Disease: A Review of Literature	Parkinson's Disease is primarily diagnosed through clinical parameters, but the combination of AI with biomarkers, such as neuroimaging, may allow for early diagnosis.
Arya Akhilesh et al. / 2023 / India	A systematic review on machine learning and deep learning techniques in the effective diagnosis of Alzheimer's disease	AI recognizes compromised structures more effectively, allowing for a more accurate analysis of the patient's prognosis.
Rezaei Mitra et al. / 2021 / Iran	Applications of deep learning techniques for automated multiple sclerosis detection using magnetic resonance imaging: A review	Multiple Sclerosis is a brain disease that causes visual, sensory, and motor problems, with a detrimental effect on nervous system function.
Tourdias Thomas et al. / 2021 / France	DEEP LESION BRAIN: TOWARDS A BROADER DEEP-LEARNING GENERALIZATION FOR MULTIPLE SCLEROSIS LESION SEGMENTATION	Image processing methods based on deep learning have shown remarkable performance in many tasks, including the segmentation of Multiple Sclerosis lesions.
Gessert Nils et al. / 2021 / Germany	4D Deep Learning for Multiple Sclerosis Lesion Activity Segmentation	Multiple Sclerosis is a chronic disease of the central nervous system that progressively causes disability. AI and neuroimaging have been studied to improve quality of life.
Patel Sb et al. / England	Multi-Cohort Development and Validation of 2D and 3D Deep Learning Models for MRI-based Parkinson's Disease Classification: A Comparative Analysis of Convolutional Kolmogorov-Arnold Networks, Convolutional Neural Networks, and Graph Convolutional Networks	Parkinson's Disease is one of the most common neurodegenerative diseases today, characterized by motor symptoms. AI and neuroimaging are being studied to obtain a rapid diagnosis.
Frasca Maria et al./ 2024 / Italy	Predicting Parkinson's disease evolution using deep learning	Parkinson's Disease currently affects 1% of the global population, with manifestations of motor symptoms. Diagnosis through neuroimaging and AI may be more efficient.
Huseyn Elcin / Azerbaijan	Deep Learning Based Early Diagnostics of Parkinson's Disease	Parkinson's Disease presents symptoms such as tremors, caused by the gradual loss of dopaminergic neurons in the substantia nigra. AI is an essential tool for diagnosis.

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Author Year / Location	Article Title	Main Findings
Wingate James et al. / 2015 / Greece	A Unified Deep Learning Approach for Prediction of Parkinson's Disease	The research studies the use of AI and neuroimaging for the early diagnosis of Parkinson's.
Wang Jueqi et al. / 2019 / Canada	Temporally Adjustable Longitudinal Fluid-Attenuated Inversion Recovery MRI Estimation / Synthesis for Multiple Sclerosis	Multiple Sclerosis is a chronic disease caused by lesions in the brain's white matter. The study seeks to understand the use of AI and neuroimaging.
Durso-Finley Joshua et al. / 2022 / Canada	Personalized Prediction of Future Lesion Activity and Treatment Effect in Multiple Sclerosis from Baseline MRI	Multiple Sclerosis requires early diagnosis for the stabilization of the best treatment. AI and neuroimaging are essential.
La Rosa Francesco et al / 2020 / Switzerland	Automated Detection of Cortical Lesions in Multiple Sclerosis Patients with 7T MRI	Multiple Sclerosis is a demyelinating disease that affects the central nervous system. The study analyzes the use of cortical lesion detection in neuroimaging.
Vincent Olivier et al. / 2020 / Canada	Automatic segmentation of spinal multiple sclerosis lesions: How to generalize across MRI contrasts?	Multiple Sclerosis is an autoimmune disease that causes cortical lesions. Linear implementation in neuroimaging was studied to expand diagnosis.
Aslani Shahab et al. / 2019 / Italy	Scanner Invariant Multiple Sclerosis Lesion Segmentation from MRI	The study analyzes the use of AI and neuroimaging for the diagnosis of neurodegenerative diseases.
Eitel Fabian et al. / 2019 / Germany	Uncovering convolutional neural network decisions for diagnosing multiple sclerosis on conventional MRI using layer-wise relevance propagation	Multiple Sclerosis is the most common autoimmune disease among young adults. The study aims to use AI and neuroimaging for earlier diagnoses.
Salem Mostafa et al./ 2019 / Spain	Multiple Sclerosis Lesion Synthesis in MRI using an encoder-decoder U-NET	The study aims to generate synthetic Multiple Sclerosis lesions in neuroimaging to enhance AI for lesion detection.
Feng Yushan et al. / United States	A SELF-ADAPTIVE NETWORK FOR MULTIPLE SCLEROSIS LESION SEGMENTATION FROM MULTI-CONTRAST MRI WITH VARIOUS IMAGING PROTOCOLS	AI and neuroimaging are promising in terms of diagnosis and prognosis, but further refinement of this tool is necessary.
Wei Wen et al. / 2018 / France	Learning Myelin Content in Multiple Sclerosis from Multimodal MRI through Adversarial Training	The study analyzes the use of neuroimaging and its enhancement through AI in terms of diagnosis.
Roy Snehashis et al. / 2018 / United States	Multiple Sclerosis Lesion Segmentation from Brain MRI via Fully Convolutional Neural Networks	Multiple Sclerosis is an autoimmune disease that affects the brain's white matter, causing lesions. AI facilitates early diagnosis.

Source: Prepared by the author, 2024.

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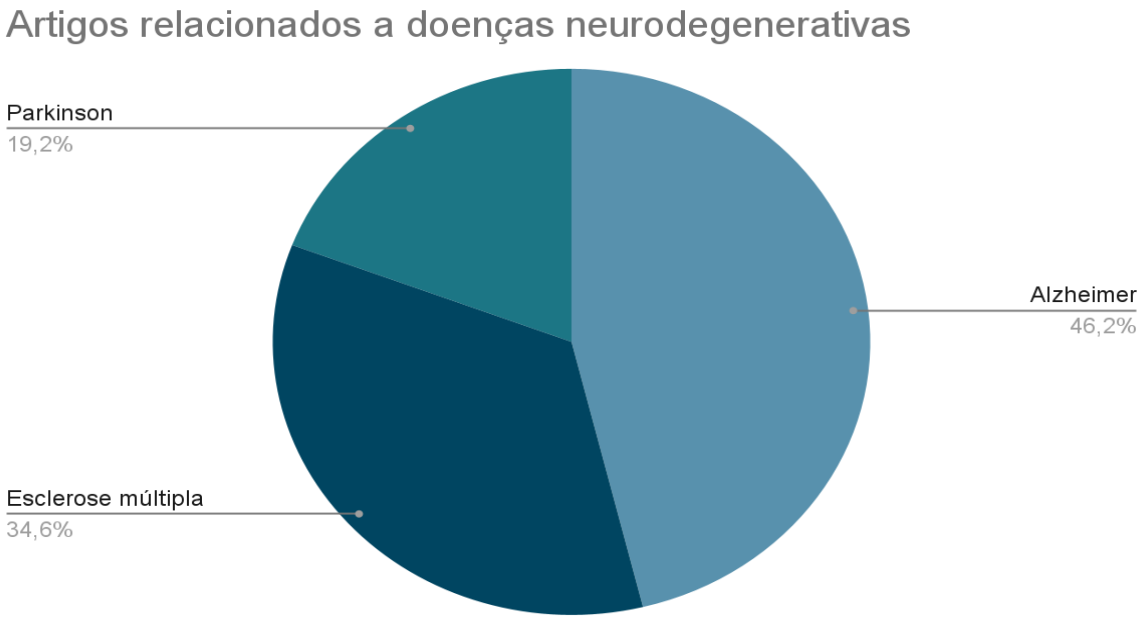

Source: Prepared by the author, 2024.

DISCUSSION

ARTIFICIAL INTELLIGENCE LIMITATION

Given the complexity and variability of neurodegenerative diseases such as Parkinson's Disease and Multiple Sclerosis, there has been growing interest in the application of Artificial Intelligence (AI) to assist in their diagnosis and prognosis. Various AI models, particularly deep learning and machine learning algorithms have been developed to analyze neuroimaging data and provide more accurate and timely diagnoses.

AI Model	Diseases Applied	Advantages	Limitations	Estimated Accuracy
Segment Anything Model (SAM)	Parkinson's, Multiple Sclerosis	Precise lesion segmentation, improved early diagnosis	Requires large, high-quality datasets for training	85-90%
Convolutional Neural Networks (CNN)	Alzheimer's, Parkinson's	Excellent for pattern recognition in large volumes	Sensitive to noise and requires high-resolution images	80-85%
Deep Learning for MS Lesions	Multiple Sclerosis	Effective for lesion segmentation in MS brain imaging	Limited by the quality of the MRI images used	87%

Source: Prepared by the author, 2024.

These models have been tailored to handle specific challenges of each disease, including the identification of characteristic lesions in MRI scans and other neuroimaging

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techniques. The integration of AI into clinical practice for neurodegenerative diseases is promising, but still requires refinement and validation across broader datasets.

NEURODEGENERATIVE DISEASES AND THEIR CLINICAL PRESENTATION

Neurodegenerative diseases are pathologies that occur due to neuronal death over the lifetime of the affected individual. These diseases cause atrophy in specific regions of the brain, triggering irreversible and progressive symptoms over time. The number of cases has significantly increased among the global population in recent years, making it necessary to discuss the most common neurodegenerative diseases today.

Parkinson's Disease, for example, currently affects 1% of the global population, with prevalence increasing with age (FRASCA, 2024). It is a slow-progressing and degenerative disease, with primary symptoms being motor-related, such as tremors, rigidity, and bradykinesia, resulting from the gradual loss of dopaminergic neurons in the substantia nigra (PATEL, 2022). Symptoms such as personality changes and depression also occur as the disease progresses. In about one-third of patients, dementia develops in later stages, resulting in the individual's incapacitation within 15 years.

Multiple Sclerosis, on the other hand, is an incurable autoimmune disease that commonly affects younger populations (WANG, 2019). This demyelinating pathology originates in the brain's white matter, causing cortical lesions that eventually affect the gray matter and spinal cord (LA ROSA, 2020). The life expectancy is up to 30 years, as the disease degenerative affects the nervous system, impairing functions such as speech, vision, motor coordination, and other essential human capabilities.

ALZHEIMER'S AND ARTIFICIAL INTELLIGENCE IN NEUROIMAGING

Alzheimer's Disease is the most prevalent neurodegenerative pathology, known as the malady of the 21st century. It is the most common cause of dementia among the elderly population, with the likelihood of development significantly increasing after the age of 65 (MORENO, 2023). The disease results from the progressive and irreversible destruction of neuronal cells, triggering symptoms such as progressive memory and cognitive loss, with an average period of 20 years until the peak of progression.

The diagnosis of Alzheimer's Disease is generally based on the patient's clinical presentation, along with neuroimaging tests and assessments such as the Mini-Mental State Examination, which evaluates neurological function. However, in most cases, it is not

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easy to recognize the characteristics of the pathology in radiology quickly and efficiently, resulting in delayed diagnosis. This delay is critical, as the disease has no cure, and treatment aims only to slow the progression of the pathology and preserve mental functionality (ARYA, 2023).

Considering this, new studies have been conducted over the past 10 years, analyzing the benefits of using artificial intelligence in conjunction with neuroimaging and clinical presentation. AI can more effectively recognize characteristic lesions, facilitating the classification and staging of the disease in which the individual is located (ARYA, 2023). For this, biomarkers, vectors associated with radiology, and patterns of lesions found in tests such as computed tomography and magnetic resonance imaging are necessary.

The creation of a vast database is essential to feed the algorithms of artificial intelligence, allowing it to recognize all necessary imaging patterns (GRUESO, 2021). However, this is a challenge for the scientific community, as, in addition to requiring a large amount of data, it is necessary to prioritize and filter information to enhance AI (WANG, 2024).

CONCLUSION

In summary, artificial intelligence combined with neuroimaging and clinical evaluation may become a significant advantage in terms of diagnosis and prognosis for patients in the future. AI will facilitate the early detection of neurodegenerative diseases, particularly Alzheimer's, providing more time for individuals to prepare for this new phase and improve their quality of life. However, this is a study that requires time and high-quality data for the refinement of this technology.

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COMPETING INTERESTS

The authors declare no competing interests.

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