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USE OF ALGORITHMS FOR EARLY DIAGNOSIS OF ALZHEIMER'S, PARKINSON'S AND MULTIPLE SCLEROSIS

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ABSTRACT
The application of artificial intelligence (AI) algorithms in the early diagnosis of neurodegenerative diseases, such as Alzheimer's, Parkinson's, and multiple sclerosis, has made significant advances. This integrative review analyzed 22 studies published between 2013 and 2023, using databases such as PubMed, IEEE Xplore, and Scopus. The results highlight the use of Convolutional Neural Networks (CNNs) in neuroimaging, such as magnetic resonance imaging and PET scans, with an accuracy of over 90% in diagnosing Alzheimer's. Multimodal approaches that integrate clinical and genetic data have demonstrated increasing efficacy. For Parkinson's, algorithms that analyze vocal signals and tremors have a sensitivity between 85% and 92%, while deep learning tools allow the detection of minimal motor changes. In the case of multiple sclerosis, models that combine magnetic resonance imaging and immunological profiles show high accuracy in the early detection of brain lesions. Despite the advances, challenges persist, including the standardization of databases, large-scale validation, and interpretation of results by health professionals. The limitations of this study include the lack of methodological uniformity in the articles analyzed and the scarcity of data from large clinical studies. It is proposed that future research invest in the integration of different data sources, expansion of population samples, and development of more transparent algorithms, facilitating its clinical adoption. It is concluded that AI has great potential to transform early diagnosis, allowing more effective and personalized interventions, but it requires refinement to consolidate its practical applicability.

Keywords: Artificial Intelligence. Early Diagnosis. Alzheimer's. Parkinson's. Multiple Sclerosis.

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INTRODUCTION

Early diagnosis of neurodegenerative diseases such as Alzheimer's, Parkinson's, and multiple sclerosis is a priority in modern medicine, given the significant impact of these conditions on patients' quality of life and healthcare systems. These diseases often have nonspecific initial symptoms, which can delay the initiation of treatments that could improve clinical progression and prognosis.

In recent years, the advancement of artificial intelligence (AI) has revolutionized the healthcare field, offering tools that allow faster, more accurate, and more sensitive analysis of complex data. Machine learning and deep learning algorithms have shown great potential in identifying hidden patterns in neuroimaging, biomarkers, and clinical data, often surpassing the accuracy of traditional methods (MEHTA et al., 2023). This could pave the way for faster diagnoses and personalized treatments, reducing the burden of neurodegenerative diseases on society.

The progression of neurodegenerative diseases is a growing challenge due to the global aging population. Early diagnosis is essential to implement therapeutic interventions that can slow the progression of conditions, preserve the patient's functionality, and improve their quality of life. However, traditional diagnostic methods often have limitations in terms of sensitivity and specificity, especially in the early stages of diseases.

The application of AI-based algorithms represents an innovative approach, with the potential to transform clinical practice. These algorithms are able to process large volumes of data efficiently, providing clinical insights that would otherwise be difficult to identify manually. Despite the growing number of studies on the topic, there is still a need to consolidate the available evidence to fully understand the impact, limitations, and future prospects of these technologies.

This work aimed to review the available evidence on the use of artificial intelligence algorithms in the early diagnosis of Alzheimer's, Parkinson's, and multiple sclerosis. The analysis seeks to identify the main contributions, technological advances, and limitations of these methods, in addition to discussing their role in the future of diagnostic medicine.

THEORETICAL FRAMEWORK

The use of deep learning (DL) and machine learning (ML) algorithms has revolutionized the field of medicine, especially in the diagnosis of neurodegenerative diseases such as Alzheimer's, Parkinson's, and multiple sclerosis. These technologies allow the analysis of large volumes of complex data, identifying subtle patterns that may escape human observation (UFPEL, 2021).

Convolutional Neural Networks (CNNs) excel in neuroimaging analysis. Its ability to recognize patterns in medical images, such as MRIs and CT scans, facilitates the early detection of brain changes associated with neurodegenerative diseases (UFPEL, 2021). In the diagnosis of Alzheimer's disease, CNNs have been used to identify atrophies in specific regions of the brain, allowing for earlier and more accurate detection of the disease.

In addition to CNNs, algorithms such as logistic regression and random forests are widely applied in biomarker analysis. For Researchgate (2021), these statistical and machine learning methods allow the integration of various clinical and laboratory data, helping to build predictive models for the diagnosis of neurodegenerative diseases. The combination of neuroimaging data with specific biomarkers, analyzed through ML algorithms, has shown efficacy in distinguishing between different types of dementia.

Recent studies indicate that multimodal approaches, which combine different types of data, offer greater accuracy in the early diagnosis of neurodegenerative diseases. According to Torres et al. (2024), the integration of neuroimaging data, biomarkers, and clinical information through AI algorithms allows for a more comprehensive and accurate analysis. For example, in Parkinson's disease, the combination of brain imaging with clinical and genetic data, analyzed by ML algorithms, has improved diagnostic accuracy.

In the context of multiple sclerosis, AI has also shown significant potential. ML algorithms have been used to analyze magnetic resonance images, identifying lesions characteristic of the disease and assisting in the monitoring of progression. In addition, the analysis of clinical and laboratory data through ML has contributed to the prediction of relapses and response to treatment in patients with multiple sclerosis (CNCB MED, 2023). Recent studies show that multimodal approaches, which combine different types of data, offer greater accuracy in the early diagnosis of Alzheimer's (RUIZ et al., 2022) and Parkinson's (ZHANG et al., 2021).

In summary, the application of DL and ML algorithms in the diagnosis of neurodegenerative diseases represents a significant advance in modern medicine. The ability of these technologies to integrate and analyze multiple data sources provides earlier and more accurate diagnoses, enabling more effective therapeutic interventions and improving patients' quality of life.

METHODOLOGY

This integrative review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, aiming to ensure the transparency and replicability of the research process. Literature searches were conducted in the main scientific databases PubMed, IEEE Xplore, and Scopus, covering the period from 2013 to 2023, to ensure that the selected studies reflected the latest innovations in the use of artificial intelligence (AI) algorithms in the early diagnosis of neurodegenerative diseases, such as Alzheimer's, Parkinson's, and multiple sclerosis.

The following descriptors were used in the searches: "Artificial Intelligence," "Early Diagnosis," "Alzheimer's Disease," "Parkinson's Disease," and "Multiple Sclerosis." The selection of studies was guided by strict inclusion and exclusion criteria. Only original articles that applied AI algorithms to the early diagnosis of these diseases were included, with clinical or experimental validation of the results. In addition, only studies published in English, Portuguese, or Spanish were considered, aiming at a more comprehensive and inclusive analysis of the available scientific literature. Studies that did not address the use of AI algorithms or that focused primarily on treatments rather than early diagnosis were excluded from the review.

The search strategy was carried out in two stages: the first consisted of analyzing the titles and abstracts of the articles found, in order to filter those that met the inclusion criteria. In the second stage, the selected articles were analyzed in full to confirm their relevance to the objective of the review. Throughout the process, strict quality control was maintained to ensure the validity and reliability of the included sources.

The analysis of the selected studies was conducted qualitatively, highlighting the methods and algorithms used, the types of data analyzed (such as neuroimaging, biomarkers, and clinical data), as well as the results and limitations presented. In addition, a critical evaluation of multimodal approaches, which combine different types of data, and their effectiveness in the early diagnosis of the neurodegenerative diseases in question was carried out.

Finally, the data were organized and presented in a systematic way, with an emphasis on comparing the different AI algorithms applied to each of the diseases, in order to provide a comprehensive and up-to-date view of the use of artificial intelligence in the early diagnosis of these conditions.

RESULTS AND DISCUSSIONS

The integrative review revealed important advances in the application of artificial intelligence (AI) algorithms for the early diagnosis of neurodegenerative diseases, such as Alzheimer's, Parkinson's, and multiple sclerosis. These advances indicate a growing potential to improve accuracy and agility in diagnosing these diseases, which are challenging due to the complexity of the initial symptoms and the lack of clear biomarkers.

The use of AI for analyzing large volumes of data has been a promising tool in detecting subtle patterns and anticipating the onset of these conditions, enabling faster and more personalized interventions. Below, we will discuss the main findings related to each of the diseases and the challenges associated with this technology.

Regarding Alzheimer's disease, one of the most significant findings was the use of Convolutional Neural Networks (CNNs), applied to neuroimaging such as magnetic resonance imaging (MRI) and positron emission tomography (PET scans). Several studies indicate that these neural networks are capable of identifying subtle patterns of brain atrophy, with an accuracy of more than 90%, exceeding the capacity of traditional diagnostic methods (IEEE, 2023). CNNs, by analyzing magnetic resonance images, can detect brain changes that may precede the appearance of evident clinical symptoms, a crucial point for the early diagnosis of the disease.

In addition, the combination of neuroimaging data with clinical and genetic information has shown to be a promising strategy. The integration of variables such as family history, laboratory tests, and clinical data has allowed multimodal approaches not only to increase diagnostic accuracy, but also to improve the ability to predict disease progression. This type of integrative approach is crucial, as Alzheimer's disease has an insidious nature, with symptoms that manifest gradually and often imperceptibly in the early stages. The use of AI, therefore, not only facilitates early detection but also improves prognosis by enabling more timely and personalized interventions. However, the clinical implementation of this approach still faces significant barriers, such as the need for standardization of data collection methods and the adequacy of health professionals to interpret the results (LIU et al., 2023). The training of professionals to interpret the results obtained through AI algorithms is essential for the acceptance and application of these models in clinical routine.

The application of algorithms for the early diagnosis of Parkinson's has also shown remarkable results, especially in the use of vocal cues and tremors. Analysis of vocal signals has been shown to be particularly useful, since Parkinson's disease often affects speech and articulation, even in the early stages of the disease. A study conducted by Zhang et al. (2024) demonstrated that deep learning algorithms can detect minimal motor changes, with sensitivity ranging between 85% and 92%. This level of sensitivity is crucial for an initial diagnosis, when clinical changes are still discrete and can be easily confused with other conditions or ignored by healthcare professionals. Early detection allows patients to begin receiving treatments that slow the progression of the disease and improve their quality of life.

The use of AI for the analysis of tremors and motor signs has also expanded to remote patient monitoring. Tremor sensors, integrated into mobile devices, have shown great potential to perform continuous and more accurate diagnostics. The possibility of real-time monitoring, outside the hospital environment, is a low-cost solution that also allows patient monitoring to be more dynamic and less costly. However, the implementation of these algorithms still faces challenges, especially related to the variability of the data collected, since factors such as the environment, the patient's emotional state, and others can interfere with the measurements. For Tian et al. (2023), the need for large-scale validation is also a central concern, since, although the initial results are promising, they still need to be confirmed in multicenter studies and with larger populations to ensure their clinical applicability.

In the case of multiple sclerosis, AI has shown great potential in the early detection of brain lesions, typical characteristics of this condition. Models that integrate magnetic resonance imaging data with immunological profiles are demonstrating high accuracy in identifying lesions, which allows for a more effective follow-up of the evolution of the disease. According to Ruiz et al. (2024), the combination of clinical, immunological, and neuroimaging data has enabled not only the early detection of lesions, but also a more detailed view of the dynamics of disease progression. This multimodal approach not only improves diagnostic accuracy, but also offers prognostic information that can help clinicians tailor treatments more effectively.

Early detection of brain lesions is especially relevant, as it allows for earlier intervention with immunomodulatory therapies, which are often used in the treatment of multiple sclerosis. This early intervention can prevent or delay permanent damage, significantly improving the quality of life of patients. However, as with other neurodegenerative conditions, the algorithms used to analyze these lesions still need to be refined to address the heterogeneity of clinical data. The variability in MRI images, due to different imaging devices or protocols, poses an additional challenge for the creation of universal and reliable models (RUIZ et al., 2022).

Despite the advances, several challenges remain in the implementation of AI in the early diagnosis of these neurodegenerative diseases. The lack of standardization in the databases used to train the algorithms remains a significant obstacle. The diversity of imaging protocols, the variability between MRI equipment, and the lack of uniformity in data collection methods make it difficult to create robust and generalizable AI models. This limits the ability of algorithms to adapt to different clinical contexts and populations, affecting their universal applicability.

In addition, the lack of a clear interpretation of the results generated by AI algorithms raises ethical and practical questions. AI often works as a "black box", making it difficult to explain the reasoning behind the decisions made. This creates a significant challenge for healthcare providers, who may be hesitant to adopt these technologies without a deeper understanding of how the conclusions are drawn. The physician's confidence in the algorithm's results is crucial for its adoption in the clinical setting, and this will only be possible if the algorithms are able to provide understandable explanations for their recommendations.

Another important challenge is large-scale clinical validation. Although the results of the selected studies are promising, most of them are limited to small samples or limited data. Validating the algorithms in large patient cohorts and in a variety of clinical scenarios is essential to ensure that the models are effective and reliable when applied in real clinical practice. The absence of multicenter studies with diversified samples limits the ability to generalize the results.

CONCLUSION

In summary, the use of artificial intelligence (AI) algorithms for the early diagnosis of neurodegenerative diseases, such as Alzheimer's, Parkinson's, and multiple sclerosis, has shown promise, bringing substantial benefits in terms of accuracy, agility, and personalization of diagnosis. These advances enable earlier detection, which is essential for the initiation of treatments that can alter the course of these diseases. In addition, multimodal approaches, which integrate neuroimaging data, clinical signs, and genetic information, have shown significant results, increasing diagnostic sensitivity and accuracy, and improving the ability to monitor disease progression.

However, despite the progress, there are still technical and clinical hurdles to overcome. Standardizing data is one of the main limitations, as AI models rely on large amounts of high-quality data for training. The heterogeneity of clinical and neuroimaging data, combined with the lack of consistent standards, can compromise the effectiveness and generalizability of models. In addition, the complexity and "black box" of algorithms, which make it difficult to clearly interpret the results, pose a significant challenge. While AI is capable of identifying complex patterns, the lack of explainability can lead to hesitancy among healthcare professionals, who may not fully understand how conclusions are reached.

Another critical point is large-scale validation. Many existing studies are still limited in terms of samples and the diversity of the populations analyzed, which makes it difficult to extrapolate the results to generalized clinical practice. The lack of robust validation in different clinical scenarios can result in uncertainties about the actual applicability of these technologies.

This study has some limitations. First, the inclusion of studies carried out until 2023 may not reflect the most recent innovations in the area of AI applied to the early diagnosis of neurodegenerative diseases. In addition, the analysis was restricted to three main databases, which may have excluded relevant studies published in other sources. Another important aspect is the absence of an in-depth evaluation of the clinical validation methods used in the selected studies, which limits the analysis of the practical applicability of the algorithms.

Given the promising potential of AI, there are several directions for future research in the area. First, studies involving the standardization of databases and the creation of broad and diverse datasets are fundamental for the advancement of AI techniques. The collection of clinical and neuroimaging data from diverse populations will help overcome the problem of lack of generalization of models. In addition, it is crucial to implement explainability techniques in the algorithms in order to provide greater transparency and trust to the healthcare professionals who will use these tools.

Another important area for research is the large-scale validation of AI models in real-world clinical settings. Multicenter clinical trials and longitudinal studies are needed to validate the efficacy of the models at different stages of the disease and in various clinical conditions. The integration of AI with remote monitoring devices, such as wearables for Parkinson's and Alzheimer's, also deserves greater attention, as it can offer continuous, real-time diagnosis, enhancing early detection.

Finally, there is a need for research to focus on developing algorithms that are not only accurate but also accessible and implementable in daily clinical practice. This includes creating AI platforms that easily integrate with existing healthcare systems and empowering healthcare professionals to interpret and use these technologies effectively. Such approaches will ensure that early diagnosis, facilitated by AI, is truly accessible to all patients who need it.

In short, while there are challenges to be faced, the field of artificial intelligence in the diagnosis of neurodegenerative diseases has great potential to transform medicine, providing faster, more accurate, and more personalized diagnoses, and improving long-term patient outcomes.

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