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Advances in neurology: The impact of artificial intelligence on the diagnosis and treatment of neurological diseases

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Abstract

Although AI has immense potential to improve the diagnosis and treatment of neurological diseases, continued progress is needed in system transparency, clinical validation, and regulation to ensure that these tools are safely and effectively adopted in medical practice. Therefore, the objective is to explore the potential of Artificial Intelligence in the early and accurate diagnosis of neurological diseases, highlighting its benefits, technical and ethical challenges, and the need for advancements in transparency, clinical validation, and regulation for its safe and effective adoption in medical practice. The methodology of this study is based on a narrative review of the literature, aimed at analyzing the impact of Artificial Intelligence on the diagnosis of neurological diseases. Despite advances, challenges remain, including the need for high-quality data and population diversity, as well as issues related to model interpretability and large-scale clinical validation. However, with the continuous improvement of AI technologies and their integration with clinical decision support systems, the perspective is that neurology will increasingly benefit from these innovations, improving the quality of patient care. The combination of AI with advances in neuroimaging, genetics, and digital monitoring has the potential to transform neurological care, enabling faster diagnoses, more effective treatments, and better quality of life for patients. Thus, Artificial Intelligence not only enhances the understanding of neurological diseases but also drives precision medicine, establishing itself as one of the pillars of the future of neurology.

Keywords: Artificial intelligence; Neurological diagnosis; Neurological diseases

1. Introduction

Artificial Intelligence (AI) has emerged as a promising tool in transforming the diagnosis of neurological diseases, offering new perspectives in early detection, assessment, and monitoring of complex conditions. Machine learning techniques and deep neural networks have been applied to analyze large volumes of clinical and imaging data, revealing patterns that may be difficult to identify using conventional methods (SIMONASSI et al., 2024).

In the neurological context, AI has proven particularly useful in areas such as the identification of neurodegenerative diseases (such as Alzheimer's and Parkinson's), multiple sclerosis, and vascular neurological disorders. AI models trained with magnetic resonance imaging (MRI) and computed tomography (CT) images have demonstrated impressive accuracy in identifying structural changes in the brain, often before obvious clinical symptoms appear. This can allow for early intervention and more effective treatments, potentially slowing the progression of diseases such as Alzheimer's (BRITO et al., 2021 & SIMONASSI et al., 2024).

In addition to brain images, AI has also been applied to the analysis of clinical data, such as medical histories, neuropsychological test results, and genetic data, to predict the risk of developing neurological diseases and provide

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more personalized diagnoses. This can be particularly valuable in complex disorders where early symptoms can be subtle and difficult to distinguish (BRITO et al., 2021 & SIMONASSI et al., 2024).

Although the benefits of AI in neurological diagnosis are promising, its implementation still faces technical and ethical challenges. The lack of transparency in algorithms — known as "black boxes" — is a significant issue. These systems often operate opaquely, making it difficult for healthcare professionals to understand the decision-making processes. This can affect physicians' trust in using these tools and raise clinical accountability concerns (SILVA et al., 2025).

Furthermore, issues related to clinical validation and regulation need to be addressed. The approval of AI algorithms by regulatory bodies, such as the FDA and ANVISA, is essential to ensure the safety and effectiveness of these systems. It is also crucial that algorithms are tested across diverse populations, taking into account genetic diversity and variations in types of neurological diseases across different geographical and cultural contexts (SILVA et al., 2025).

In summary, although AI has immense potential to improve the diagnosis and treatment of neurological diseases, continued progress in system transparency, clinical validation, and regulation is necessary to ensure that these tools are safely and effectively adopted in medical practice. Thus, the aim is to explore the potential of Artificial Intelligence in the early and accurate diagnosis of neurological diseases, highlighting its benefits, technical and ethical challenges, and the need for advancements in transparency, clinical validation, and regulation for its safe and effective adoption in medical practice.

2. Methodology

The methodology of this study is based on a narrative literature review, aiming to analyze the impact of Artificial Intelligence on the diagnosis of neurological diseases. To achieve this, articles published in the last five years were selected, ensuring the update and relevance of the information. The bibliographic search was conducted in major scientific databases, including PubMed, Scopus, Web of Science, ScienceDirect, and SciELO, covering publications in English and Portuguese.

The descriptors used in the search were selected based on the structured vocabulary of the databases, including terms such as "Artificial Intelligence," "Machine Learning," "Artificial Neural Networks," "Neurological Diagnosis," "Neurodegenerative Diseases," "Magnetic Resonance Imaging," and "Computed Tomography." These descriptors were combined with Boolean operators (AND, OR) to broaden the search scope and ensure the inclusion of relevant studies.

The inclusion criteria were original articles, systematic reviews, and meta-analyses that addressed the use of AI in the diagnosis of neurological diseases, published between 2019 and 2024. Studies outside this period, opinion articles, conference abstracts, and publications without access to the full text were excluded.

The analysis of the selected articles was performed qualitatively, highlighting the main advances of AI in the detection of neurological diseases, its implementation challenges, and the perspectives for clinical adoption. The narrative review allowed for a broad and critical approach to the topic, providing an extensive view of the applications and limitations of AI in neurology.

3. Literature Review

Artificial Intelligence (AI) is a multidisciplinary field of computer science aimed at developing systems capable of simulating aspects of human cognition, including perception, learning, reasoning, planning, and decision-making. These systems are designed to interact with the environment and, often, with humans, either autonomously or assisted. In the medical context, AI has shown a significant impact on optimizing diagnoses, therapeutic planning, and patient monitoring, especially in high-complexity areas like neurology (SIMONASSI et al., 2024).

Advances in AI in healthcare are supported by the development of robust computational infrastructures, the availability of large volumes of biomedical data, and the evolution of algorithms capable of processing complex information. These algorithms can be classified into four main categories: linear models, used in smaller datasets and suitable for well-defined cause-and-effect relationships; nonlinear models, applied to more complex data through kernel functions; decision trees, used to classify information and predict output variables; and artificial neural networks, inspired by the architecture of the human brain and composed of multiple layers of artificial neurons that learn patterns from large data volumes. The implementation of these models in medicine, particularly in radiology and neurology, has enabled advances in diagnostic accuracy, personalized treatments, and the prediction of neurological disease progression (CARBONE et al., 2024).

In the field of neurodegenerative disorders, AI has played a fundamental role in the early detection and monitoring of diseases such as Alzheimer's, Parkinson's, and Amyotrophic Lateral Sclerosis (ALS). Machine learning models are used to analyze structural and functional neuroimaging, such as magnetic resonance imaging (MRI), positron emission tomography (PET), and electroencephalography (EEG), allowing for more precise assessment of the progression of these pathologies. In epilepsy, one of the main clinical challenges is predicting seizures, and AI has been applied to analyze EEG signals using advanced techniques such as Support Vector Machines (SVM) and fuzzy logic. Additionally, hybrid systems combining SVM with Particle Swarm Optimization (PSO) have shown high accuracy in the automatic classification of epileptic signals, aiding therapeutic decision-making (ESPÍNDOLA; RIBAS; MARIN, 2024).

AI has also been used in the development of brain-computer interfaces (BCI) for ALS patients, enabling communication through neural signal decoding. Moreover, deep learning models have been employed to predict disease progression and identify relevant genomic and transcriptomic biomarkers. In Alzheimer's Disease (AD), convolutional neural networks (CNNs) have been applied to analyze structural MRI and PET, aiding in early detection and the differentiation of patients with mild cognitive impairment (MCI). In Parkinson's Disease (PD), AI has been employed in the analysis of gait data through wearable sensors, allowing for the identification of motor patterns characteristic of the disease. Models such as Support Vector Machines (SVM) and deep neural networks help classify stages of PD and predict patient responses to deep brain stimulation (DBS), while AI algorithms in functional neuroimaging have enabled early identification of changes associated with the disease (ABN, 2021).

The application of Artificial Intelligence in neurology represents a significant advancement in the personalization of diagnosis and treatment of neurological diseases. The use of machine learning algorithms and neural networks has allowed for more precise analysis of neuroimaging, electrophysiological signals, and clinical data, contributing to early detection and monitoring of disease progression. Despite the advancements, challenges remain, including the need for high-quality data and population diversity, as well as issues related to model interpretability and large-scale clinical validation. However, with the continuous improvement of AI technologies and their integration with clinical decision support systems, the perspective is that neurology will increasingly benefit from these innovations, improving the quality of patient care (ESPÍNDOLA; RIBAS; MARIN, 2024 & ABN, 2021)

4. Conclusion

The application of Artificial Intelligence in neurology has revolutionized the diagnosis, treatment, and monitoring of neurological diseases, enabling significant advancements in the personalization of therapeutic approaches. The use of machine learning algorithms, artificial neural networks, and data analysis techniques has provided greater accuracy in identifying patterns in neuroimaging, electrophysiological signals, and biomarkers, enabling early diagnosis and predicting the progression of various pathologies, such as Alzheimer's Disease, Parkinson's Disease, Amyotrophic Lateral Sclerosis, and epilepsy.

However, despite the progress, challenges still need to be overcome. The quality and diversity of the data used to train AI models are determining factors for the reliability of the analyses. Additionally, the interpretability of the algorithms and their validation in real clinical contexts remain obstacles that require attention. The adoption of these technologies must be accompanied by strict ethical and regulatory protocols to ensure the safety and effectiveness of medical decision support systems.

In light of this, the perspective is that AI will continue to evolve and increasingly integrate into clinical practices, becoming an essential tool for neurologists and other healthcare professionals. The combination of AI with advancements in neuroimaging, genetics, and digital monitoring has the potential to transform neurological care, promoting faster diagnoses, more effective treatments, and better quality of life for patients. Thus, Artificial Intelligence not only enhances the understanding of neurological diseases but also drives precision medicine, solidifying itself as one of the pillars of the future of neurology.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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