Artificial Intelligence in Major Neurological Disorders: A Comprehensive Review

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Abstract:

➢ *Background*

Artificial Intelligence (AI) has emerged as a promising computational approach in clinical neurology for improving diagnostic accuracy, disease monitoring, and prognostic assessment. Neurological disorders present significant challenges due to clinical variability and limitations in conventional diagnostic techniques.

➢ *Methods*

A review was done using PubMed, Scopus and other related databases focusing on AI-based techniques including Machine Learning, Deep Learning, Artificial Neural Networks, Natural Language Processing, Reinforcement Learning, and Transfer Learning in neurological research and clinical datasets such as neuroimaging and electrophysiological recordings.

➢ *Results*

AI-driven models demonstrated improved accuracy in seizure detection, stroke lesion segmentation, neurodegenerative biomarker identification, lesion quantification in demyelinating disorders, and predictive modelling of disease progression across multiple neurological conditions.

➢ *Conclusion*

AI integration in neurology offers significant potential for enhancing clinical decision-making and personalised care; however, challenges such as data heterogeneity, algorithm transparency, and validation remain critical for future clinical implementation.

Keywords: Artificial Intelligence, Specific Neurological Disorders, Clinical Diagnostic Application.

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I. INTRODUCTION

Artificial intelligence (AI) has become a disruptive force that is changing how doctors identify, treat, and manage a variety of disorders in the field of healthcare. AI is being incorporated into clinical practice in the field of neurology, further providing opportunities to enhance patient care and their outcomes (1).

Neurological disorders are one of the main causes of disability and death in the world, which produce progressive cognitive, motor, and behavioural problems that significantly lower a person's quality of life. Due to differences in clinical presentation and current limitations, common neurological conditions like Epilepsy, Stroke, Parkinson's disease, Alzheimer's disease, Multiple sclerosis, Amyotrophic lateral sclerosis, sleep disorders, and Guillain-Barré syndrome present significant challenges in early diagnosis, prognosis, and disease monitoring. In the field of

neurology, artificial intelligence (AI), particularly through machine learning (ML) and deep learning (DL) algorithms, has become a promising tool in recent years for improving clinical decision-making, improving overall quality of life, and improving diagnostic accuracy(2).

This article examines how Artificial intelligence is currently being used to treat specific neurological conditions, emphasizing its value in the healthcare system, its challenges, results, and potential. The application of AI to neurology has many obstacles despite its enormous potential. Additionally, research and development are still being done to improve AI algorithms accuracy and dependability in the diagnosis and treatment of neurological illnesses(1).

II. THEORETICAL FOUNDATIONS AND KEY CONCEPTS OF ARTIFICIAL INTELLIGENCE IN CLINICAL NEUROLOGY

Artificial Intelligence (AI) represents a transformative computational framework in clinical neurology that enables the extraction of latent patterns from electrophysiological, neuroimaging, genomic, and clinical data. Its theoretical strength lies in modelling nonlinear relationships within high-dimensional biomedical systems. This computational shift supports data-driven neurological research(3) Figure 1.

➤ *Machine Learning (ML)*

ML models establish statistical associations through supervised, unsupervised, and ensemble learning strategies. These approaches facilitate probabilistic inference rather than deterministic reasoning in the neurological sciences. By identifying hidden structures within complex datasets, ML enhances the representation of disease variability.(4)

➤ *Deep Learning (DL)*

Deep Learning is a sophisticated area of Machine Learning that employs multilayer neural networks for extracting features hierarchically. In contrast to conventional Machine Learning, it autonomously learns abstract representations, convolutional and recurrent structures from unprocessed input data(3)

➤ *Artificial Neural Networks (ANNs)*

ANN consist of interconnected layers that transform inputs into predictive outputs via weighted optimisation. Through backpropagation, networks adjust parameters to minimise error. This adaptive mechanism supports the modelling of multidimensional clinical and neurobiological relationships (5).

➤ *Natural Language Processing (NLP)*

NLP in neurology consists of substantial information that exists in unstructured clinical documentation. NLP converts narrative text into structured, analysable data using semantic and syntactic modelling techniques. This supports integration of qualitative medical records into computational frameworks(4).

➤ *Reinforcement Learning (RL)*

RL focuses on sequential decision-making through interaction and feedback by maximizing cumulative reward over time. It theoretically models dynamic biological processes and adaptive disease trajectories. This makes RL relevant for evolving neurological system analysis (3).

➤ *Transfer Learning (TL)*

TL is a valuable approach when neurological datasets are limited or heterogeneous. By adapting pre-trained models, transfer learning improves generalizability and efficiency. It reduces computational cost while maintaining predictive robustness(5)
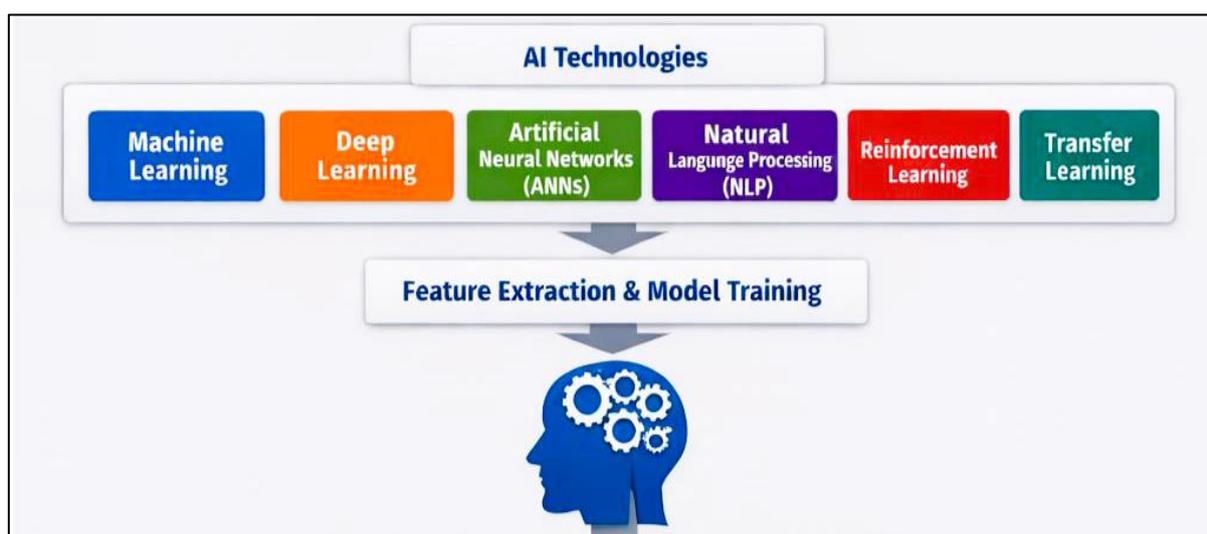

Fig 1- Concepts of Artificial Intelligence

III. AI IN SPECIFIC NEUROLOGICAL DISORDERS

➢ *AI in Epilepsy:*

AI-based techniques have been widely explored for automated electroencephalographic (EEG) signal analysis to improve seizure detection and classification. Machine learning algorithms assist in identifying abnormal electrophysiological patterns associated with epileptiform discharges. Deep learning frameworks further enable recognition of temporal EEG patterns predictive of seizure onset. AI-driven computational models also support localization of epileptogenic regions. These approaches enhance personalised clinical assessment and disease monitoring (6).

➢ *AI in Stroke:*

AI applications in stroke management significantly enhance diagnostic accuracy and prognostic assessment in both ischemic and haemorrhagic stroke. In ischemic stroke, AI-based machine learning and deep learning algorithms enable rapid detection of infarcted brain regions, segmentation of ischemic lesions, evaluation of tissue viability, and prediction of functional recovery outcomes using CT and MRI datasets. These models assist in identifying large vessel occlusion and estimating infarct core and penumbra, thereby supporting timely therapeutic decision-making(7).

In haemorrhagic stroke, AI systems are widely applied for automated detection and volumetric segmentation of intracerebral haemorrhage on non-contrast CT scans with high sensitivity and specificity. Advanced predictive models integrating radiological and clinical parameters also help forecast hematoma expansion, haemorrhagic transformation, and short-term functional outcomes (8,9).

➢ *AI in Parkinson's Disease:*

AI-based systems analyse clinical and physiological data to support disease classification and progression monitoring. Machine learning algorithms assist in differentiating motor symptom patterns. Deep learning approaches facilitate the identification of disease-specific neuroimaging biomarkers. AI models also enable objective evaluation of motor function variability. These computational frameworks contribute to improved disease monitoring strategies(10).

➢ *AI in Alzheimer's Disease:*

AI has demonstrated promising potential in the early diagnosis of Alzheimer's disease through analysis of structural and functional brain imaging datasets. Machine learning techniques assist in identifying cortical and hippocampal atrophic changes. Deep learning frameworks improve the classification of disease stages. Predictive modelling supports estimation of cognitive decline trajectories. AI-based analytical systems thus facilitate timely clinical interventions (11).

➢ *AI in Multiple Sclerosis:*

AI-driven computational techniques are applied for automated lesion detection and quantification using MRI. Machine learning algorithms assist in differentiating active and inactive lesions. Deep learning approaches enable monitoring of lesion evolution and disease progression. Predictive models also support relapse risk estimation. AI integration enhances objective evaluation of disease activity over time(6).

➢ *AI in Amyotrophic Lateral Sclerosis:*

AI-based models have been increasingly investigated in Amyotrophic Lateral Sclerosis for analysing neurophysiological and imaging biomarkers. Machine learning techniques assist in disease classification and progression prediction. Deep learning algorithms facilitate the identification of neuromuscular degeneration patterns. Predictive modelling frameworks contribute to survival analysis. These AI-driven approaches support improved patient stratification (10).

➢ *AI in Sleep Disorders:*

AI methodologies have also been utilised in evaluating sleep disorders through automated analysis of polysomnography recordings. Machine learning algorithms assist in sleep stage classification and sleep scoring. Deep learning models facilitate the detection of sleep-related abnormalities. AI-driven systems enhance the interpretation of physiological sleep signals. These computational approaches improve diagnostic accuracy in sleep medicine(11).

➢ *AI in Guillain-Barre Syndrome:*

AI-based techniques are being explored for early diagnostic differentiation from other peripheral neuropathies. Machine learning models assist in analysing electrophysiological parameters. Deep learning approaches facilitate the interpretation of nerve conduction studies. Predictive modelling contributes to prognosis estimation. AI integration may improve early identification of disease severity(6).
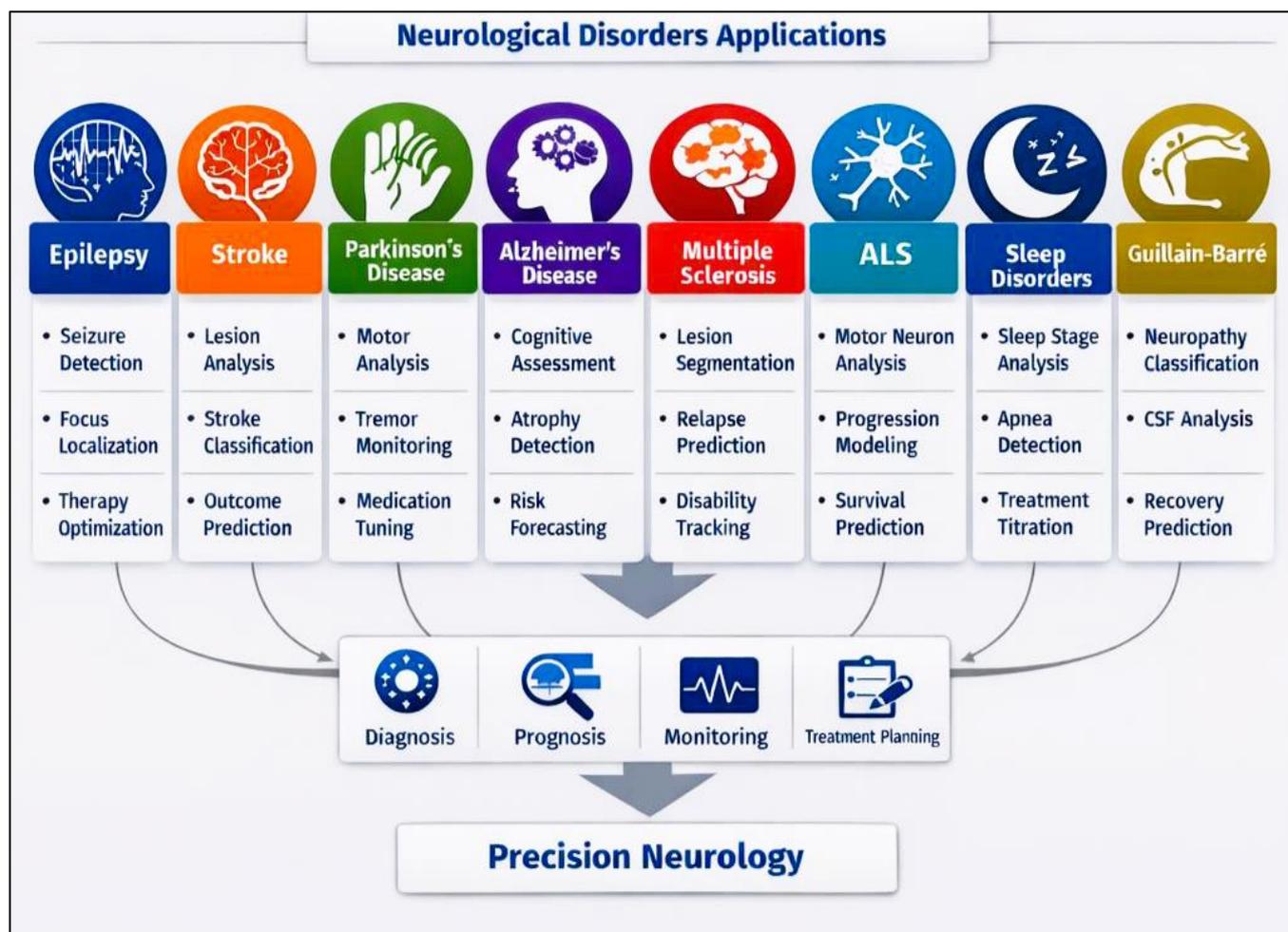
Fig 2- Applications of Neurological Disorders

> *Futuristic Approaches in Artificial Intelligence for Neurological Disorders:*

The future of Artificial Intelligence is moving toward highly integrated, autonomous, and precision-driven systems capable of transforming disease prediction, diagnosis, and therapeutic monitoring across major neurological disorders. Emerging frameworks emphasise multimodal data integration, combining neuroimaging, electrophysiology, genomics, and electronic health records to enable disease-specific predictive modelling. In epilepsy, next-generation deep learning systems are being designed for real-time seizure forecasting and closed-loop neurostimulation, improving pre-ictal detection and therapeutic responsiveness[12].

In ischemic and haemorrhagic stroke, AI-driven platforms are expected to evolve into fully automated acute stroke triage systems capable of rapid infarct core estimation, hematoma expansion prediction, and individualised recovery modelling through advanced radiomics and explainable AI architectures [7,8].

For neurodegenerative disorders such as Alzheimer's and Parkinson's disease, focus on digital biomarker discovery, ultra-early disease prediction using multimodal MRI-PET-genomic models, and personalized disease trajectory forecasting[13,14]. AI-enabled digital twins virtual computational representations of patients are anticipated to simulate disease progression and optimize individualized therapeutic strategies.

In multiple sclerosis and amyotrophic lateral sclerosis, machine learning models are advancing toward automated lesion quantification, progression risk scoring, and adaptive monitoring systems capable of continuously analysing longitudinal datasets[15,16]. Similarly, in sleep disorders and Guillain–Barré syndrome, real-time AI analysis of EEG and electrophysiological signals may enhance automated classification and severity prediction[17].

Future developments also emphasize explainable AI, federated learning for privacy-preserving multi-centre data collaboration, reinforcement learning in adaptive neurostimulation, and integration with brain computer interface systems. These advances are expected to facilitate precision neurology, reduce diagnostic delays, and improve outcome stratification across diverse neurological conditions.

Table 1- Benefits And Techniques of AI in Neurological Disorders

Neurological Disorder	Application Area	Benefits	AI Techniques Used
Epilepsy	Seizure Detection & Prediction	Early seizure warning, improved patient monitoring	Machine Learning (ML), Deep Learning (DL), Artificial Neural Networks (ANN)
Stroke	Diagnosis & Prognosis	Faster diagnosis, improved treatment planning	Machine Learning (ML), Deep Learning (DL), Artificial Neural Networks (ANN)
Parkinson's Disease	Motor Symptom Monitoring	Personalised therapy, symptom tracking	Machine Learning, Neural Networks
Alzheimer's Disease	Early Diagnosis & Cognitive Decline Prediction	Early intervention and improved disease monitoring	Deep Learning, Support Vector Machine (SVM)
Multiple Sclerosis	Lesion Detection & Disease Monitoring	Monitoring disease progression	Deep Learning, Image Segmentation Algorithms
Amyotrophic Lateral Sclerosis (ALS)	Disease Progression Prediction	Prognostic assessment, optimised management	Predictive Modelling, Machine Learning
Sleep Disorders	Sleep Pattern Analysis	Improved diagnostic accuracy	Neural Networks, Signal Processing
Guillain-Barré Syndrome (GBS)	Early Diagnosis & Outcome Prediction	Early intervention, prognosis estimation	Machine Learning, Predictive Analytics

IV. CONCLUSION

Looking forward, the integration of multimodal datasets, explainable AI models, and real-time adaptive systems will likely redefine clinical neurology. However, challenges related to data heterogeneity, algorithm transparency, ethical governance, and large-scale validation remain critical barriers to widespread implementation. Continued interdisciplinary collaboration between neuroscientists, clinicians, and computational experts is essential to translate AI innovations into safe, reliable, and globally accessible neurological care. Ultimately, AI-driven precision neurology holds the potential to shift healthcare paradigms from reactive treatment to predictive, preventive, and personalised brain health management.

Availability of Data and Materials: This is a review article all data are attained from published literature.

Ethical Approval: Not required

Declaration of Patient Consent: Not applicable

Financial Support and Sponsorship: Nil

Conflicts of Interest: Nil

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