



ARTIFICIAL INTELLIGENCE IN EPILEPSY: FROM SEIZURE PREDICTION TO PERSONALIZED CARE

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Introduction

Epilepsy affects 50 million people worldwide, with 30% developing drug-resistant epilepsy despite advances in neuroimaging, pharmacology, and surgery.¹ The **varying nature** of epileptic disorders necessitates solutions beyond standardized therapies.

Artificial intelligence offers powerful capabilities for **multimodal data analysis**. AI can integrate **EEG signals, neuroimaging, genetic data, and behavioral patterns** to improve epilepsy diagnosis, monitoring, and personalized treatment.

This review examines **current AI applications** in epilepsy care, evaluates **clinical efficacy**, addresses **implementation challenges**, and explores **future integration** into practice.

Methodology

Literature Search Strategy

This narrative review used **structured methods** with a focused search strategy and predefined inclusion criteria. Publications on **AI applications in epilepsy from 2024–2025** were selected to highlight current trends. Databases included PubMed, IEEE Xplore, and neurology journals.

Inclusion Criteria

- AI/ML algorithms for **epilepsy diagnosis, monitoring, or treatment**
- Clinical validation studies with patient cohorts
- Novel AI architectures for epilepsy applications

Data Extraction & Quality Assessment

Key parameters included AI methodology, performance metrics (**sensitivity, specificity, accuracy, AUROC**), clinical validation status, and implementation challenges.

Results & Analysis

AI PERFORMANCE METRICS

➤ Seizure Detection Systems

- o Laboratory: LTY-CNN achieved **99.9% accuracy** detecting seizures from EEG data²
- o Clinical gap: AI helped only **28% of patients** in real-world use, yet **91% wanted to continue** using seizure forecasting⁴
- o Absence seizures (brief staring spells) detected with **96.3% accuracy** (94 events, 12 patients)³

➤ Brain Imaging Analysis

- o AI identified focal cortical dysplasia (malformed brain tissue) in **55% of MRIs vs. 39% by radiologists** (329 patients)⁵
- o Automates seizure localization, surgical outcome prediction, and multi-modal imaging integration⁶

➤ Brain Wave (EEG) Analysis

- o Combines CNNs (spatial patterns) with RNNs (temporal sequences)⁷
- o Trade-off: "Black box" models achieve **>95% accuracy** but lack interpretability; explainable models lose 5-10% accuracy for transparency (16,200 patients, 23 studies)⁸

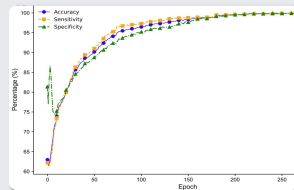


Figure 5A. Training curves show LTY-CNN model achieving near-perfect accuracy, sensitivity, and specificity through successive learning cycles².

CLINICAL IMPLEMENTATION

➤ Personalized Treatment

- o Drug selection trial (234 patients, 14 hospitals) using AI with genetics, imaging, and demographics⁹
- o AI-optimized brain stimulation (2–4 Hz) improved: **seizure control 67%, sleep 23%, memory 31%**¹⁰
- o "Organ-on-chip" (tissue-mimicking devices) predicts drug response with **89% accuracy**, pending regulatory approval¹¹

➤ Global Healthcare Access

- o **80% of epilepsy patients** in resource-limited settings; AI apps **reduce costs 75%, improve diagnosis 40%** vs. non-specialists¹²
- o Digital pathology AI identifies epileptogenic tissue (seizure-causing regions) with **91% accuracy**, reducing specialist dependency¹³

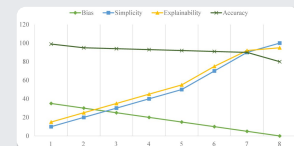


Figure 9. Accuracy vs. interpretability trade-off in epilepsy AI models showing the inverse relationship between model complexity and explainability⁸.

Discussion

KEY INSIGHTS

- **Technical Success vs. Clinical Reality:** Studies show **poor individual forecasting** despite strong group metrics, yet **91% of patients want these tools**, suggesting value beyond accuracy⁴.
- **Multimodal Data Integration:** Combining EEG, imaging, behavioral, and genetic data **captures epilepsy's complexity** better, shifting toward broader neurological health optimization.
- **Explainability Imperative:** Deep learning's **"black box" nature blocks clinical adoption**. Physicians need **understandable reasoning**, not just predictions. LLMs for human-readable explanations show promise.

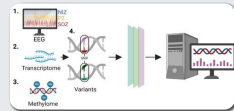


Figure 1A. Overview of multimodal data integration in epilepsy patients. Adapted from Rao et al., JCI Insight (2023). doi.org/10.1172/jci.insight.184518

FUTURE DIRECTIONS

- **Real-time Wearable AI with Privacy:** Lightweight models enable continuous monitoring, while federated learning protects patient privacy.
- **Adaptive Explainable AI:** AI explanations adjust to clinical contexts for better trust and use.

Conclusion

Artificial intelligence offers unprecedented capabilities for **personalizing epilepsy treatment**. While **seizure detection** achievements are notable, clinical translation requires addressing data quality and **model interpretability** challenges. The future lies in augmenting physician capabilities through transparent, validated technologies. This demands collaboration between clinicians, AI researchers, and patients to serve those with **epilepsy worldwide**.

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