EST 30th ANNIVERSARY ANNUAL MEETING

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FACULTY OF MEDICINE CHULALONGKORN UNIVERSITY

Integrating Neurotechnology and AI in Epilepsy Care: Current Applications and Future Potential

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Division of Neurology, Faculty of Medicine, Chulalongkorn University

The AI-Augmented Clinical Workflow

Phase 1: Initial Encounter

1. Introduction to AI in Epilepsy Care
2. AI-Driven Diagnostic Support (LLMs and EEG)

Phase 2: Investigative Testing

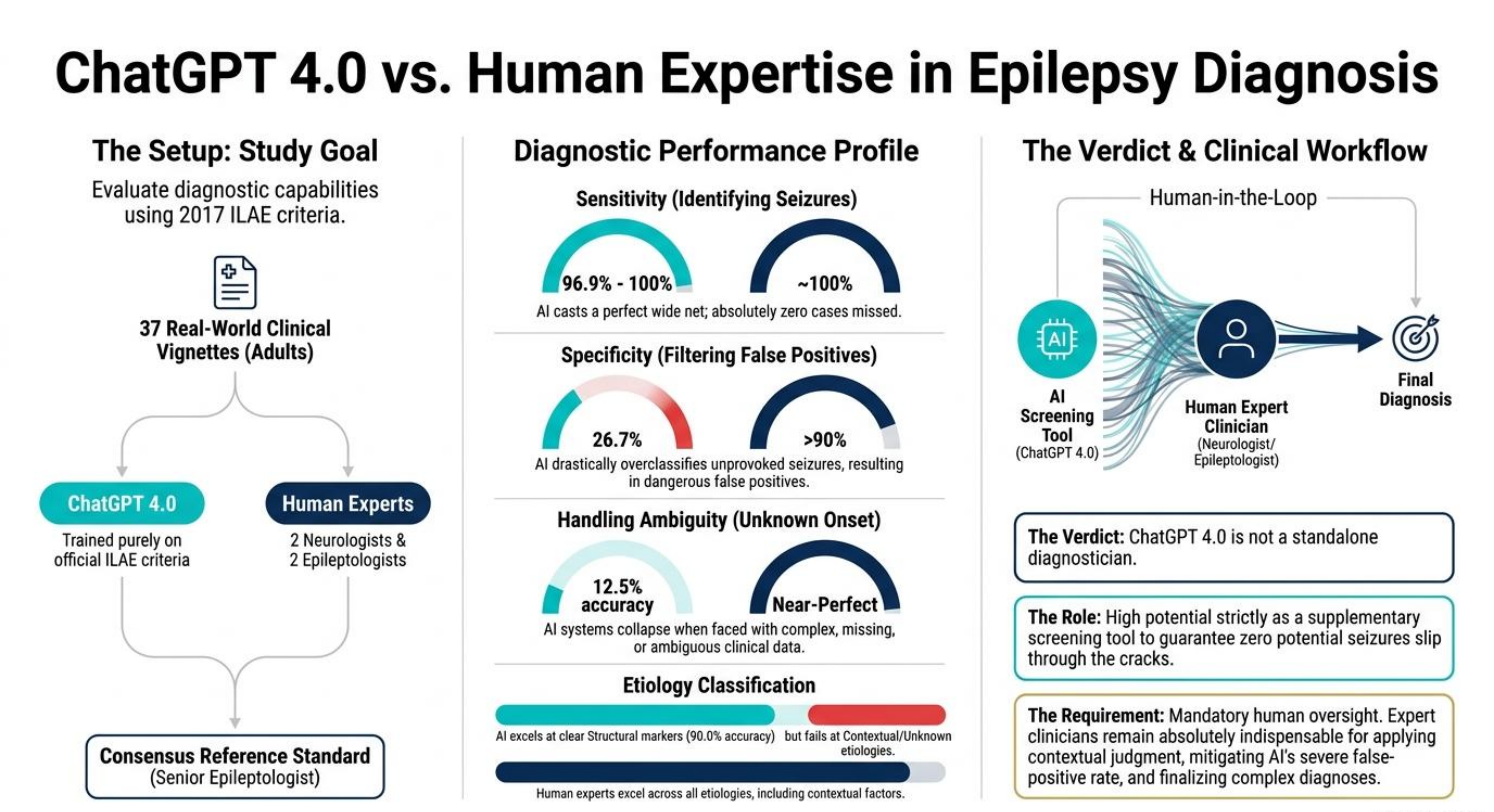
3. AI in Neuroimaging and Lesion Detection

Phase 3: Intervention & Monitoring

4. Advanced Neurotechnology: Targeted Neuromodulation
5. Seizure Detection, Prediction, and Wearables

Phase 4: Long-Term Management

6. Future Directions and Digital Care Pathways



F. Brigo et al. Epilepsy & Behavior 166 (2025)

ChatGPT 4.0 misses the diagnosis in over 40% of real-world epilepsy evaluations

Based on 597 consecutive Emergency Department visits evaluated against the 2014 ILAE criteria.

THE PERFORMANCE GAP

Sensitivity 17.6%

Critically poor at identifying true epilepsy

Specificity 81.4%

Highly conservative; effective at recognizing non-epileptic cases

THE HUMAN CONTRAST

Cohen's kappa $= -0.01$

The agreement between human epileptologists and the AI is worse than random chance.

AI BLIND SPOTS

Linguistic Fails

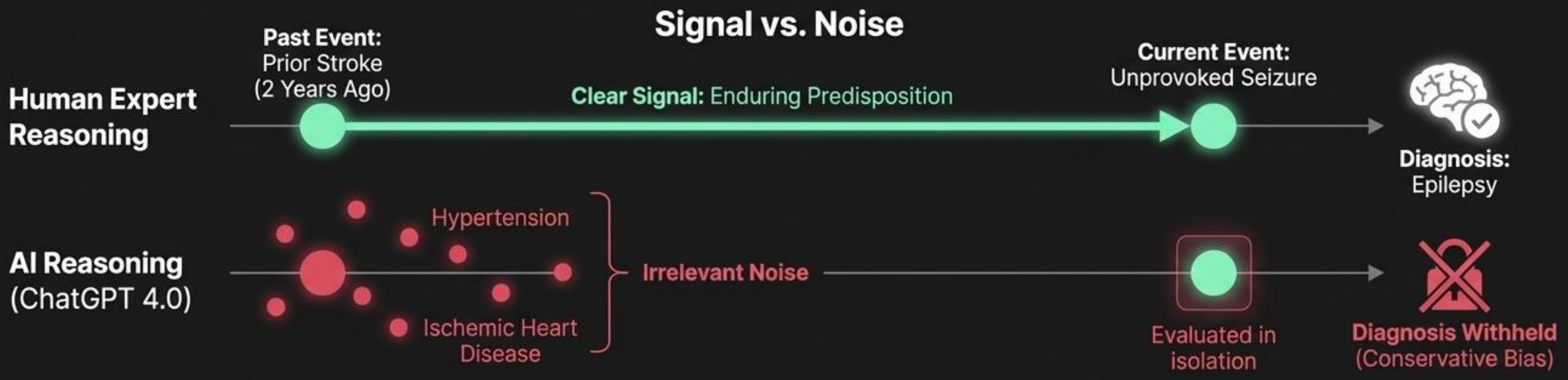
- Misses subtle semiological descriptors (e.g., 'déjà vu')
- Over-weighs non-specific terms (e.g., 'convulsion')

Contextual Gaps

- Ignores patient's age, history, and prior EEGs
- Fails to integrate collateral witness accounts

Brigo et al. J. Clin. Med. 2025

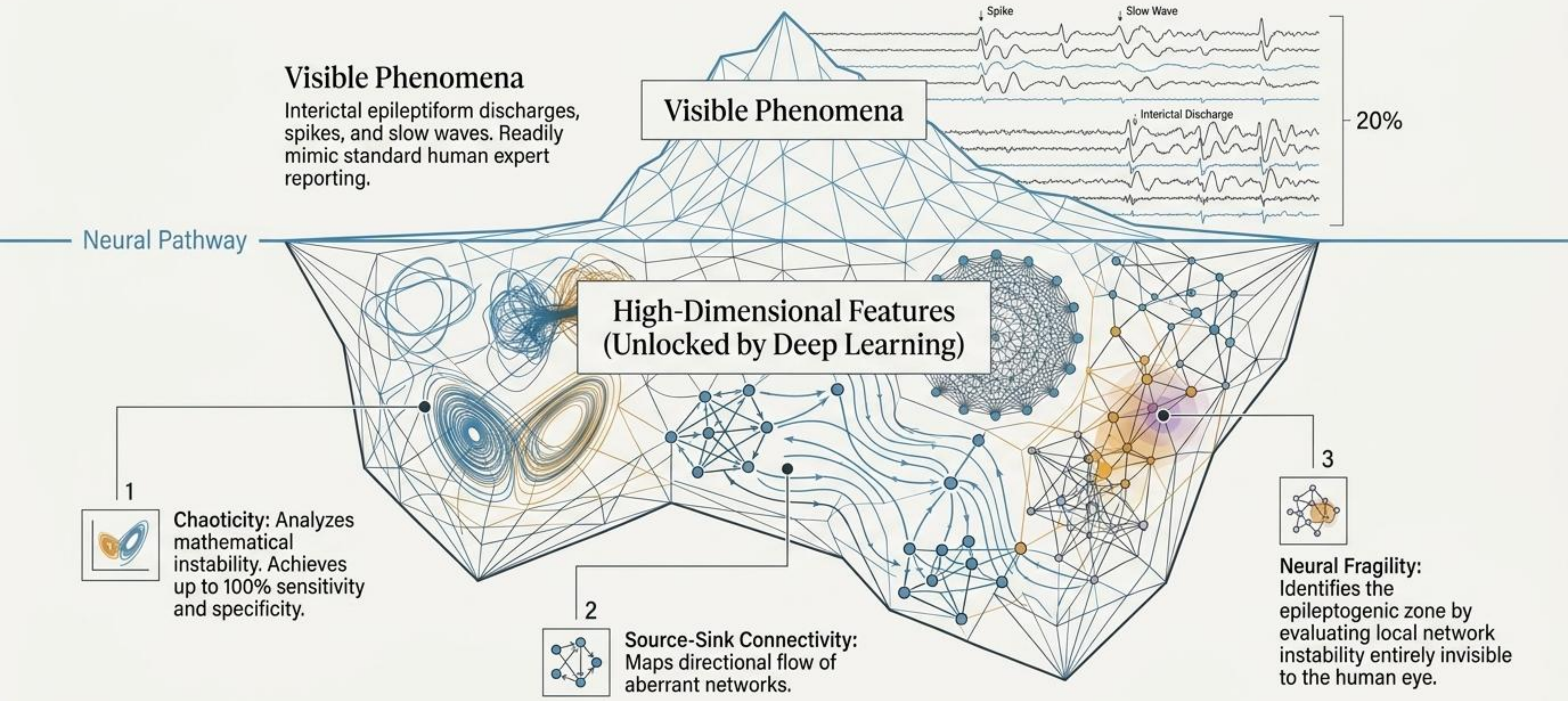
The timeline trap: ChatGPT misinterprets **historical** structural injuries as **acute clinical noise**



1. The Temporal Disconnect	2. Distracted by Comorbidities	3. The Conservative Bias
Human epileptologists link past structural brain injuries to current unprovoked seizures. ChatGPT fails to span this temporal gap, unable to classify the current seizure as a result of remote damage.	Older age introduces complex histories. The AI incorporates ischemic heart disease or prior strokes as acute diagnostic noise, misinterpreting unprovoked seizures as acute systemic events.	ChatGPT performs best when etiology is strictly unknown or acute symptomatic. When faced with complex structural data, the model defaults to a conservative approach and incorrectly withholds the diagnosis.

Brigo et al. J. Clin. Med. 2025

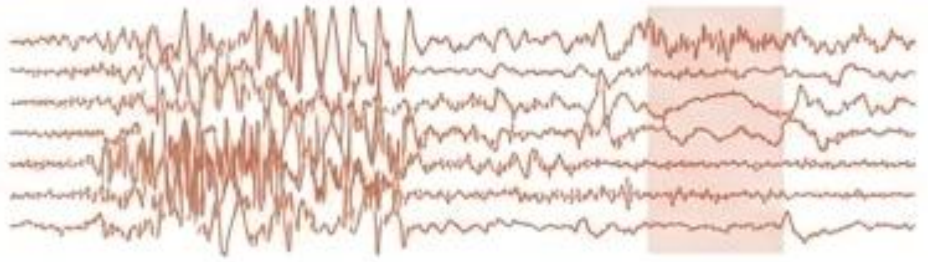
Unveiling the Invisible: Deep Learning & Hidden Biomarkers



NotebookLM

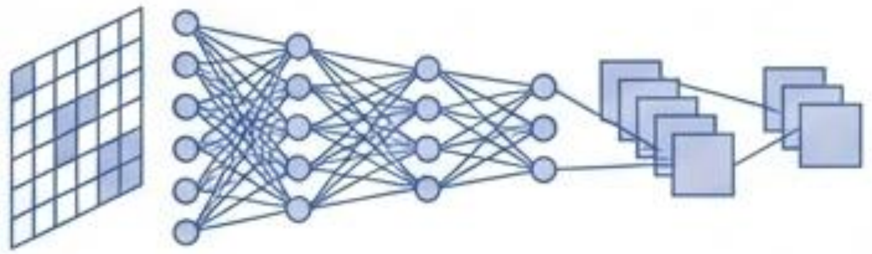
Anatomy of an Automated EEG Algorithm

1. Data Collection & Preprocessing



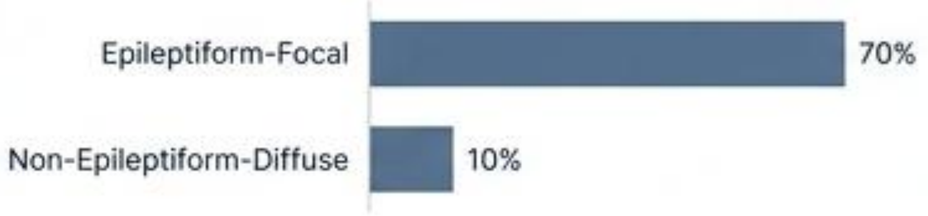
Translating raw, non-stationary 10–20 scalp data into **segmented 1-second chunks**. Noise and artifacts are filtered.

2. Feature Extraction (CNNs)



Convolutional Neural Networks automatically identify **epileptiform discharges** hidden in high-dimensional data, bypassing manual visual inspection.

3. Classification & Output



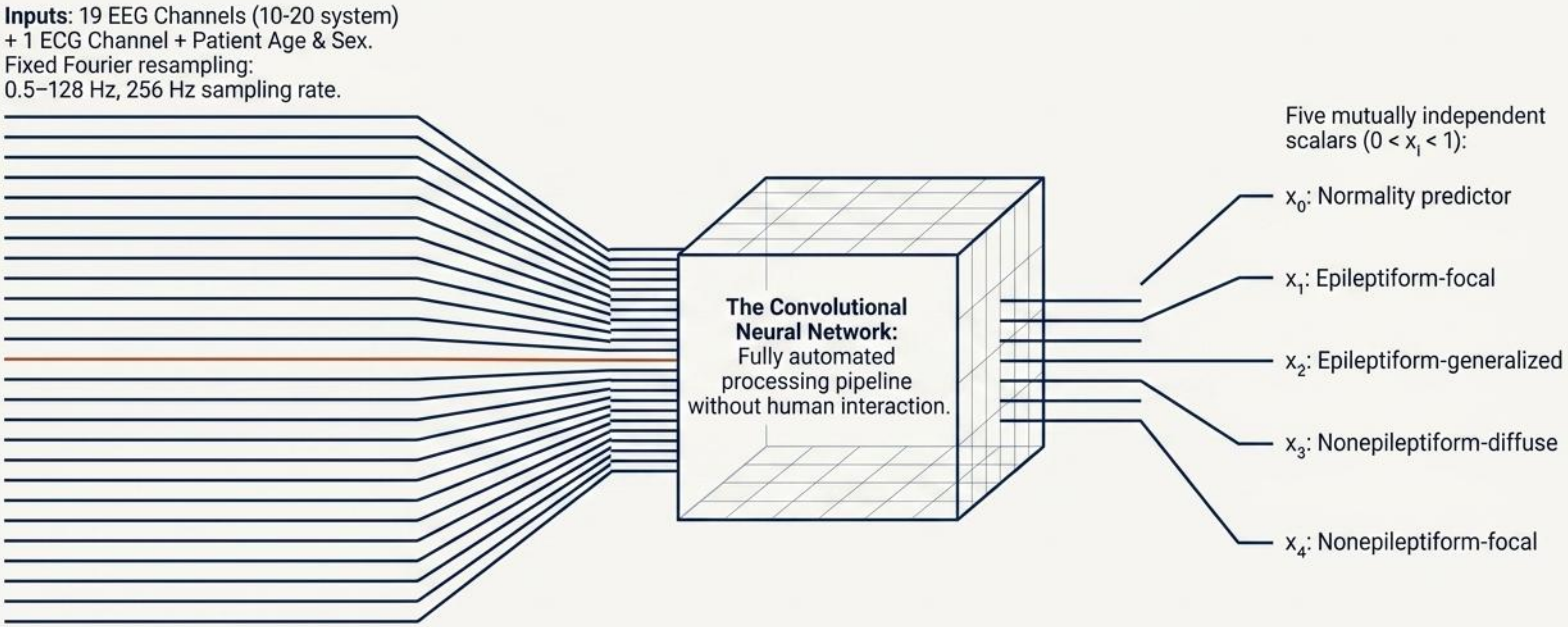
The model outputs a standardized classification (e.g., **epileptiform-focal vs. non-epileptiform-diffuse**).

Current Standards:

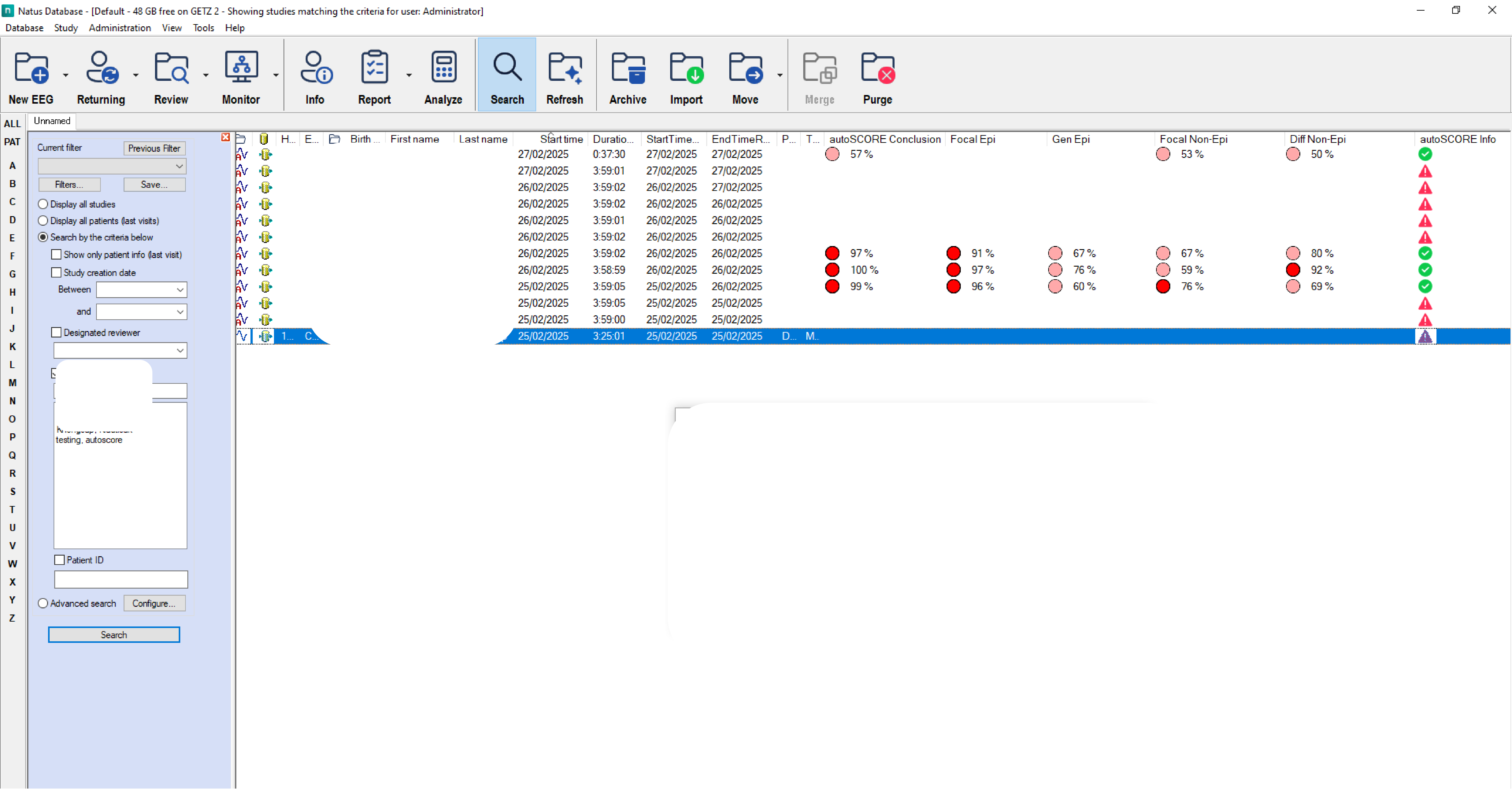
- **SCORE-AI**: The standard for outpatient routine EEGs.
- **SPaRCNet**: The standard for critical care EEG analysis.

Tveit J et al., JAMA Neurology Aug 2023
Jing J et al., Neurology Aug 2023

The Architecture of SCORE-AI



Tveit J et al., JAMA Neurology Aug 2023
Jing J et al., Neurology Aug 2023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New EEG
Returning
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Filters...
Save...
Display all studies
Display all patients (last visits)
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Show only patient info (last visit)
Study creation date
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and
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The Foundation: High-Fidelity Training Data

Volume

30,493 EEGs

(Median age 25.3 years). A massive repository of non-ICU recordings from patients referred for routine EEG.

Expertise

17 Human Experts

High-quality annotations generated by seasoned clinical neurophysiologists.

Standardization

SCORE EEG System

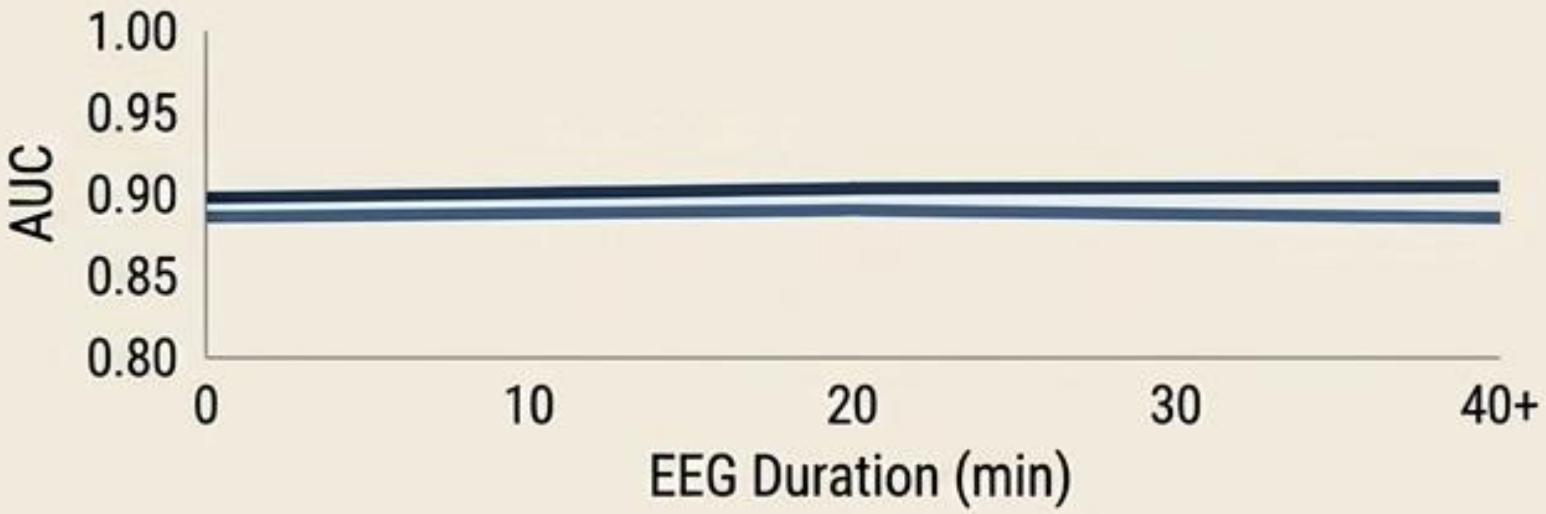
Every recording was labeled using common data elements endorsed by the IFCN and ILAE, mapping clinical features directly into a structured database.

Tveit J et al., JAMA Neurology Aug 2023

Premium Clinical Editorial

Diagnostic Accuracy Across Subcategories

Holdout Test Dataset Performance (N = 2,549)



Robustness:

High performance is maintained regardless of EEG duration (Mean AUC 0.887 for <20 min; 0.903 for >20 min).

Tveit J et al., JAMA Neurology Aug 2023

Competitive Benchmarking

Head-to-head performance against published spike detectors (N=60, external reference standard).

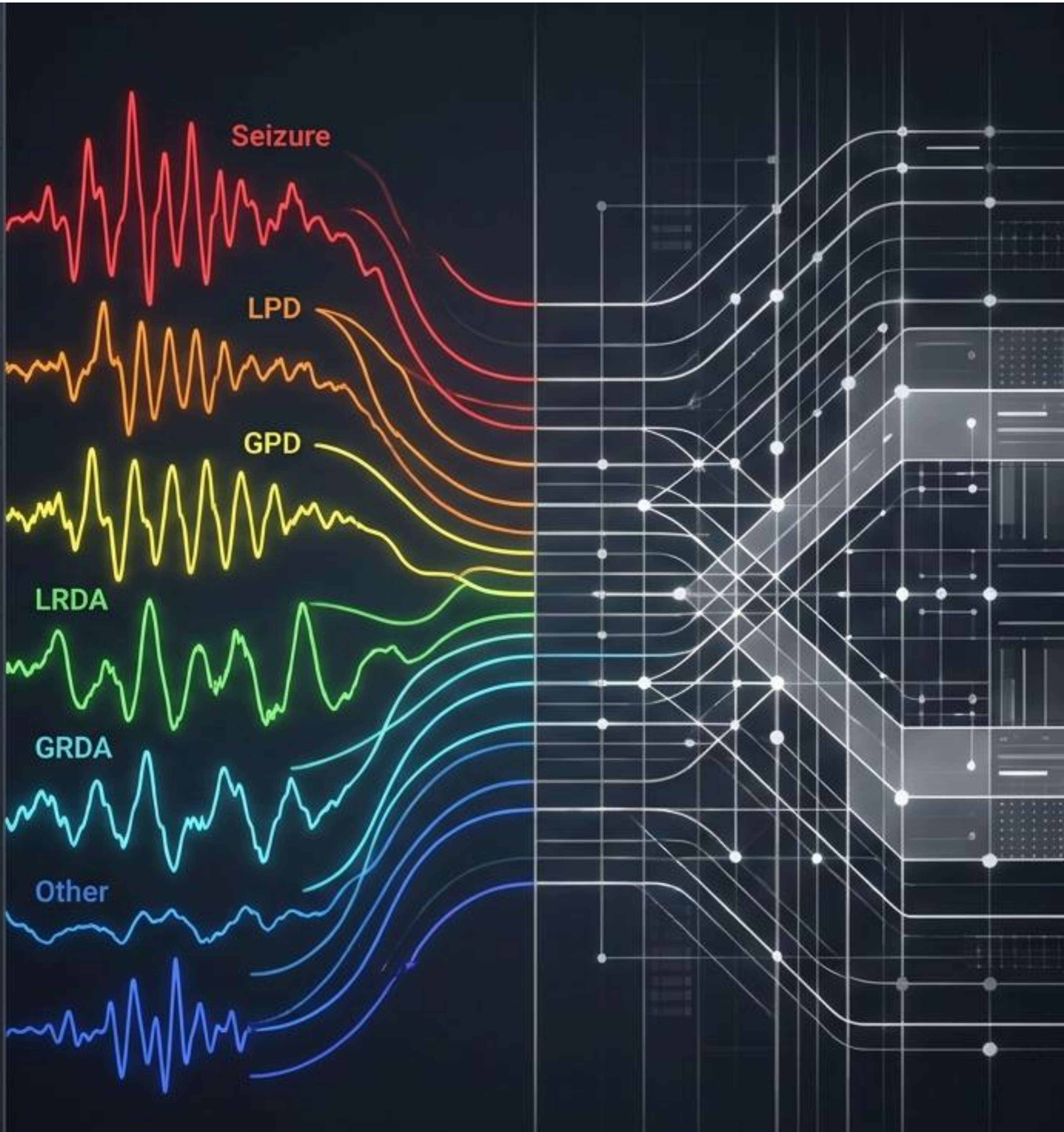
Features	SCORE-AI	encevis	SpikeNet	Persyst
Scope	Comprehensive 4-Category	Spike Detection Only	Spike Detection Only	Spike Detection Only
Overall Accuracy	88.3% (Similar to human experts)	Significantly lower, $P < .001$	Significantly lower, $P < .001$	Significantly lower, $P < .001$
Specificity	**90%**	28.3%	63.3%	3.3%
Clinical Viability	Fully Automated	Requires Human Supervision	Requires Human Supervision	Requires Human Supervision

Tveit J et al., JAMA Neurology Aug 2023

Automating the Gold Standard

SPaRCNet and the future of expert-level EEG interpretation.

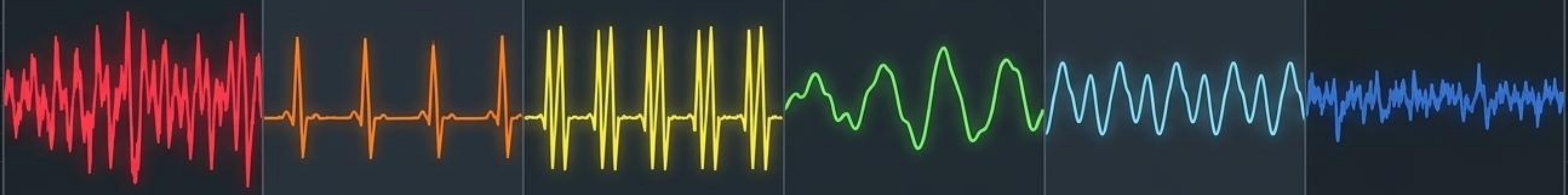
How deep learning matches fellowship-trained neurophysiologists in classifying seizures and the Ictal-Interictal-Injury Continuum (IIIC).



Jing J et al., Neurology Aug 2023

DEFINING THE CONTINUUM (IIIC)

SZ	LPD	GPD	LRDA	GRDA	Other
Seizure	Lateralized Periodic Discharges	Generalized Periodic Discharges	Lateralized Rhythmic Delta Activity	Generalized Rhythmic Delta Activity	Non-IIIC / Noise
Immediate critical intervention required	High-risk, highly epileptiform	High-risk, synchronized epileptiform	Moderate-risk, focal dysfunction	Moderate-risk, diffuse dysfunction	Baseline physiological or artifact



Jing J et al., Neurology Aug 2023

Head-to-Head: SPaRCNet vs. Clinical Experts

	EUROC (% of experts beaten/matched in Discrimination)	EUPRC (% of experts beaten/matched in Precision-Recall)
SZ	45%	50%
LPD	20%	35%
GPD	50%	50%
LRDA	75%	90%
GRDA	55%	70%
Other	40%	45%

Superiority & Non-Inferiority

SPaRCNet achieves statistically superior discrimination on GPD and LRDA, and non-inferior performance on all other classes compared to the 20 fellowship-trained experts.

Jing J et al., Neurology Aug 2023

Jing J et al., Neurology Aug 2023

95%

Better calibration than experts.

This 95% superiority applies to 5 of the 6 classes:

[SZ] [LPD] [GPD] [LRDA] [GRDA]

(And better than 80% of experts across all 6 classes, including [Other]).

SPaRCNet doesn't just guess. Its assigned probabilities are highly accurate, providing reliable confidence levels essential for real-world clinical trust.

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Artificial Intelligence in Epilepsy Neuroimaging

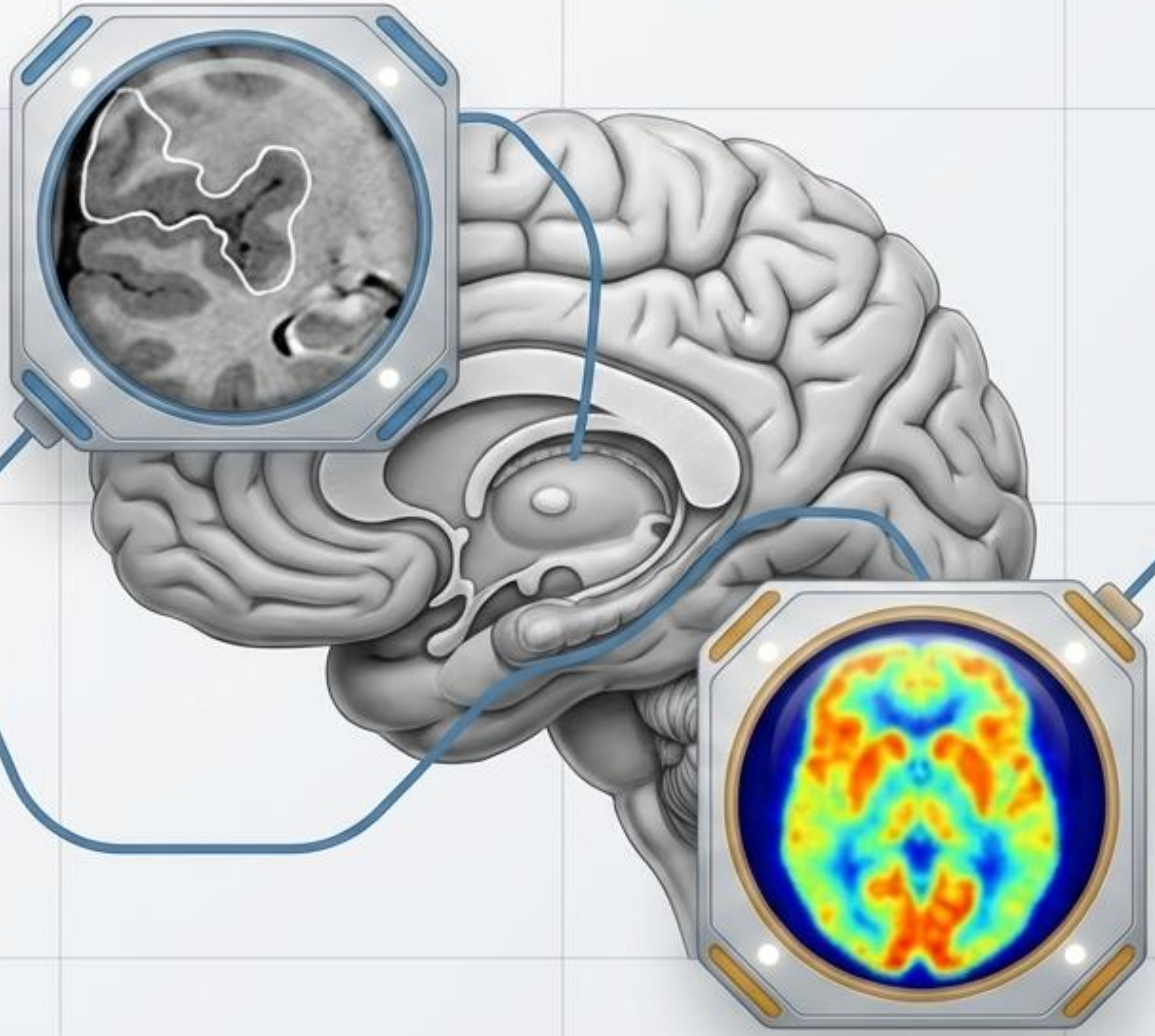
Current Capabilities, The Deep Learning Shift, and the Path to Clinical Reality

Precision Neuroimaging: Enhancing Structural and Metabolic Resolution

Structural AI (MRI CNNs)

Automated “within a minute” detection of subtle Focal Cortical Dysplasia (FCD) and Hippocampal Sclerosis (HS) anomalies often missed by initial human reads.

The Neural Pathway



Metabolic & Functional AI (PET/fMRI)

Deep learning lateralizes Temporal Lobe Epilepsy (TLE) utilizing resting-state fMRI networks and automated 18F-FDG PET feature extraction.

The State of AI in Epilepsy Imaging: Applications, Shifts, and Bottlenecks

The Technological Shift

Classic ML
(SVMs / Logistic Regression)

- Manual feature extraction
- Requires small datasets
- Prone to overfitting (LOOCV)

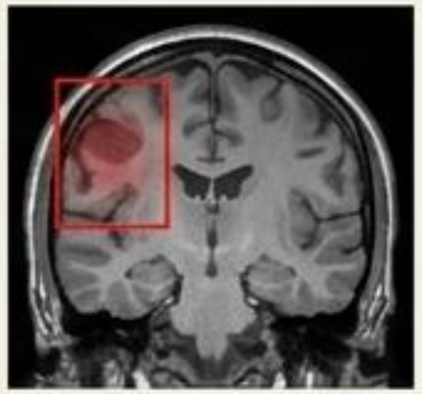
Deep Learning (CNNs)

- Automated complex pattern recognition
- Demands massive, multi-center datasets

The Collaborative Engine: MELD Project

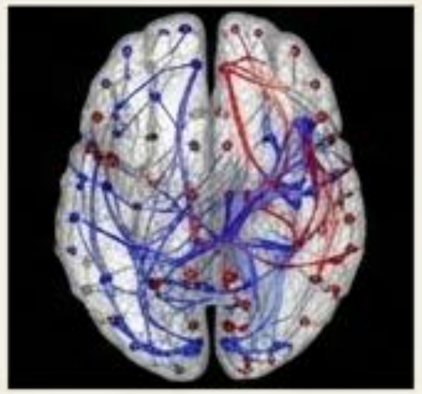
Solves DL's "data hunger" by pooling 600+ patients across 22 global centers.

Primary Clinical Goals



Goal A: Lesion Detection (FCD)

>33% of Focal Cortical Dysplasias are MRI-negative to the human eye. AI highlights subtle morphological anomalies.

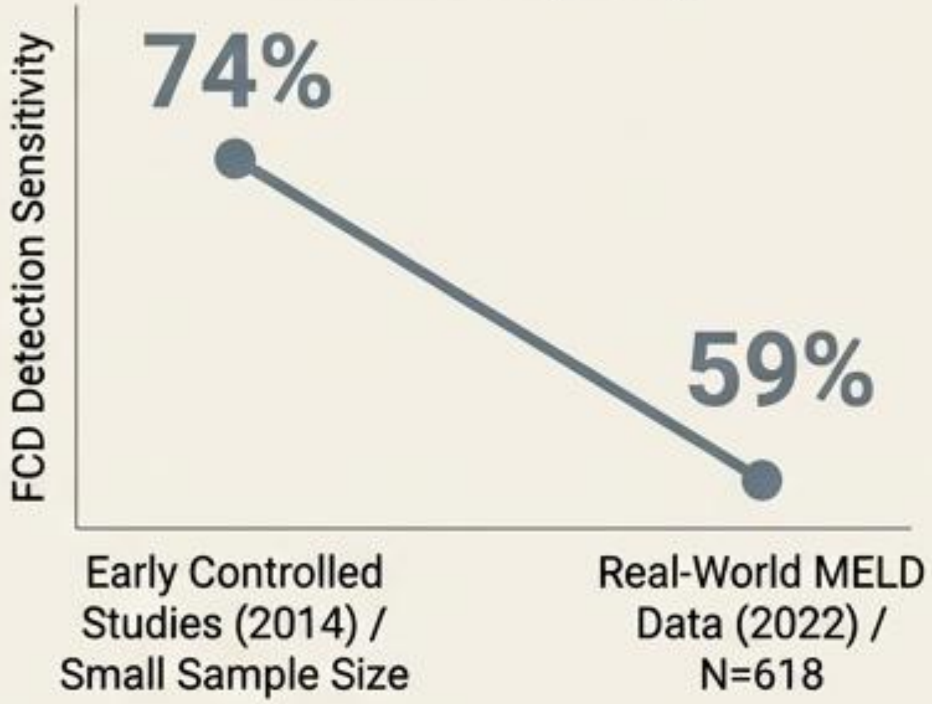


Goal B: Localization & Outcomes

AI defines epileptogenic networks via DTI/fMRI connectomes to predict post-surgical cognitive and seizure outcomes.

The Clinical Reality

The Reality Gap



Zero Regulatory Approvals

Currently, no algorithms possess FDA or CE approval.

The Path Forward:

Bridging the gap requires abandoning retrospective LOOCV in favor of prospective, real-world, multimodal studies.

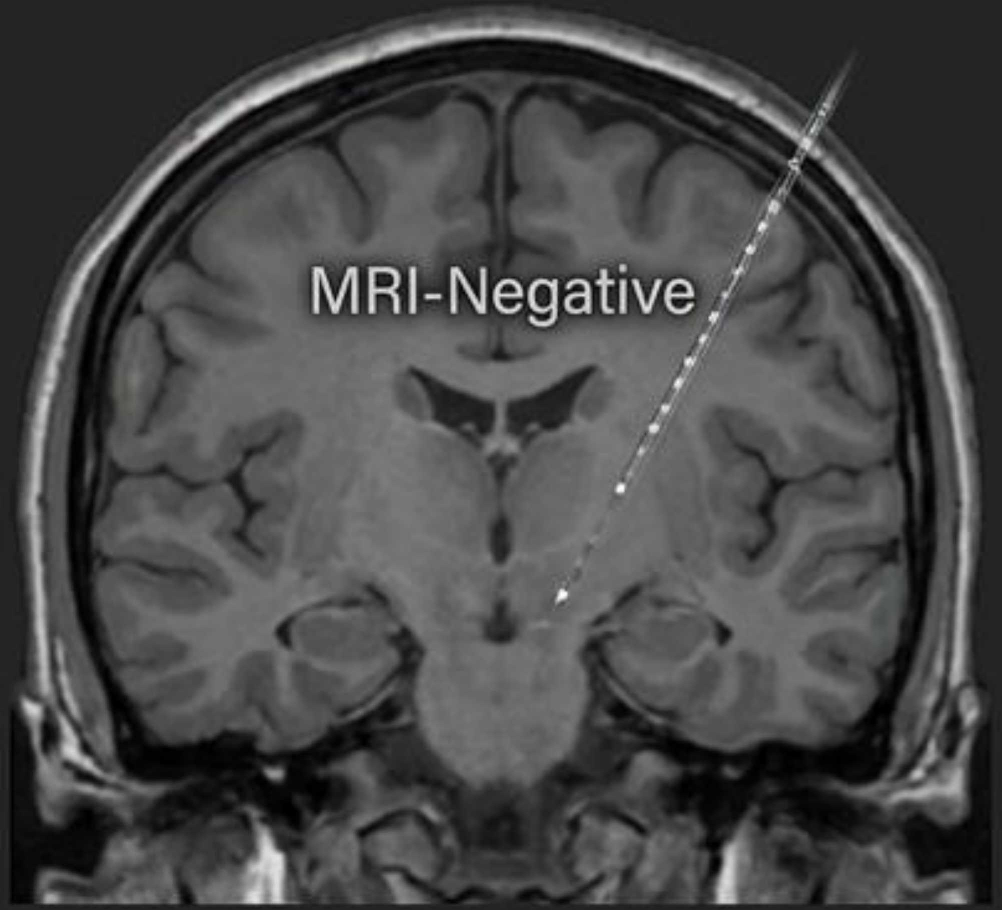
Berger M et al., Revue Neurologiiqe et al., 2025

The “MRI-Negative” Challenge

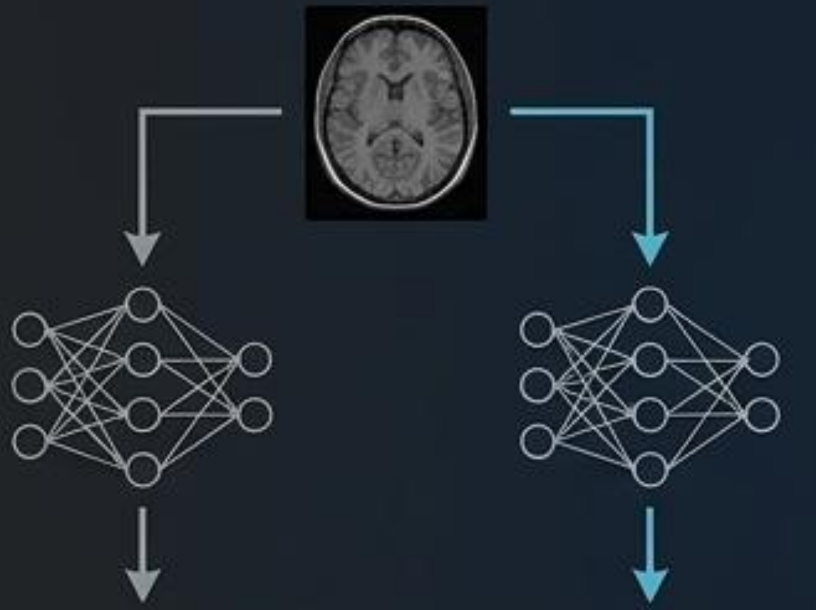
Focal Cortical Dysplasia (FCD) is a primary driver of drug-resistant epilepsy.

Yet, standard visual inspection frequently misses subtle dysplasias.

This diagnostic blindspot leads to inconclusive surgical planning or reliance on invasive, highly localized stereoelectroencephalography (sEEG).



The Dual Algorithmic Lens



Extracted Metrics (Pathway A)

Human-Engineered. Preprocessing extracts surface features (thickness, deformation). Highly interpretable. 56%–88% sensitivity.

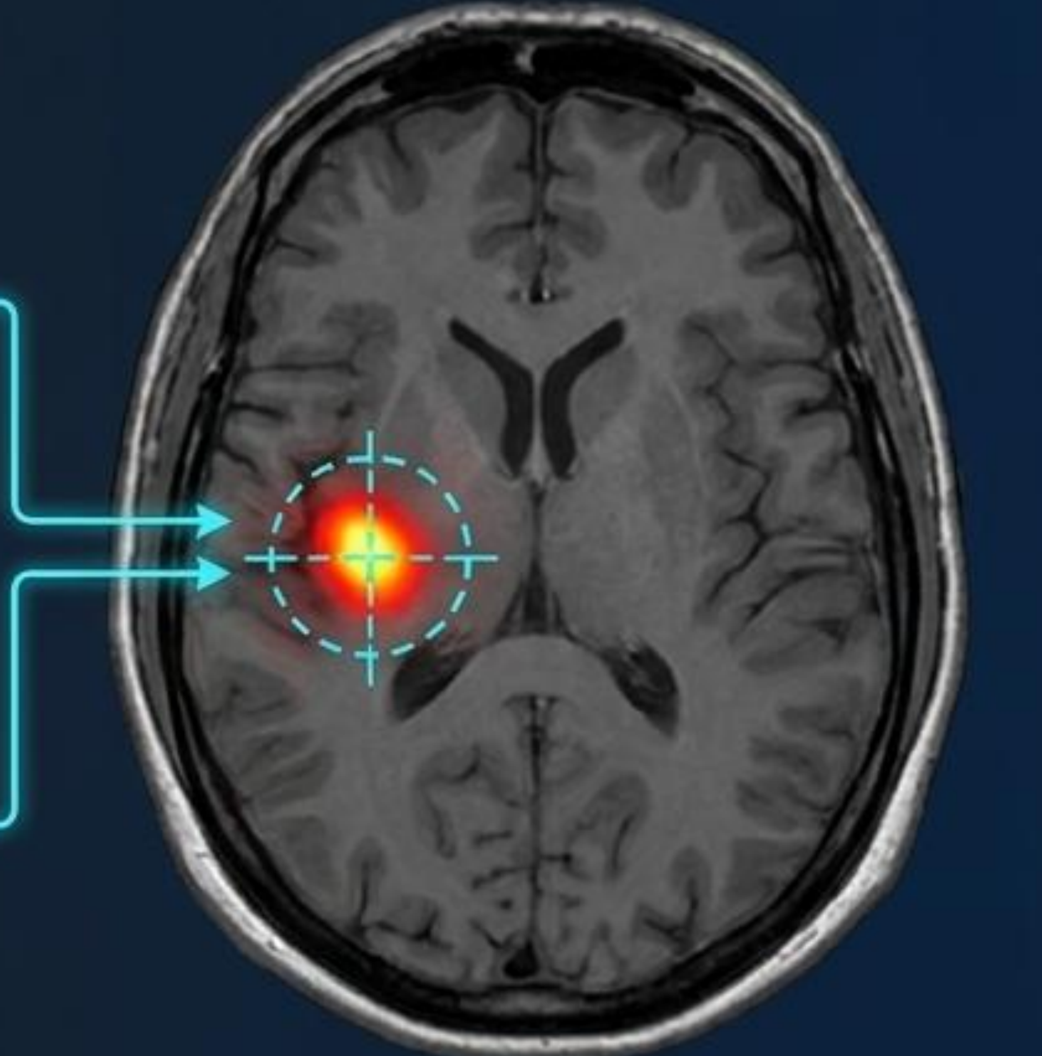
Direct Image Input (Pathway B)

Machine-Engineered. Raw 3D patches fed directly into CNNs. **75%+ sensitivity in MRI-negative cases**. Black-box nature.

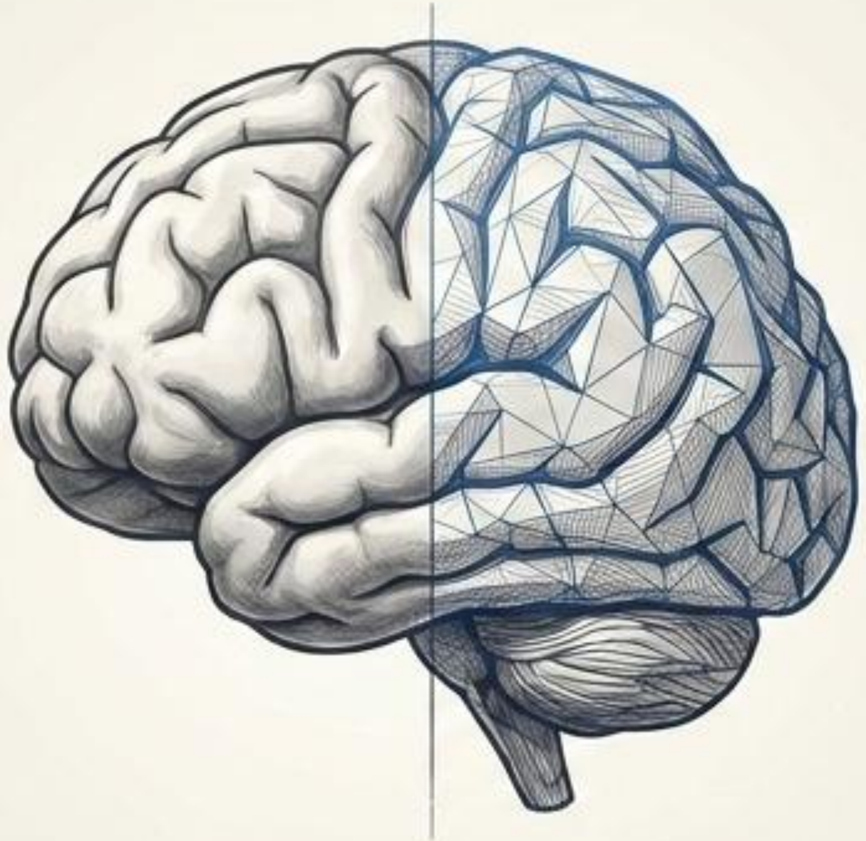
Bridging to Surgical Success

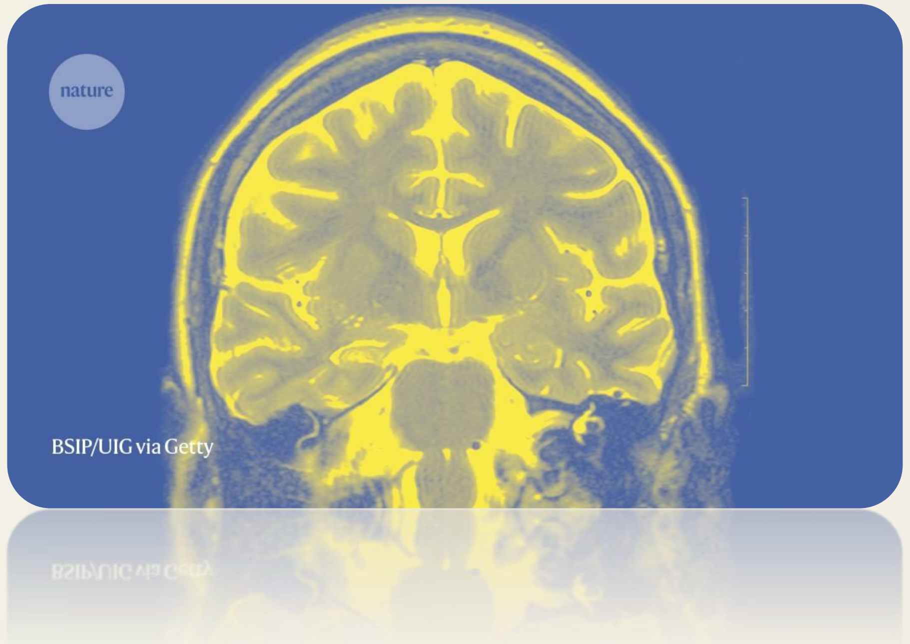
By acting as a digital contrast agent, DL algorithms localize the Epileptogenic Zone (EZ) with unprecedented precision.

This unmasks non-lesional scans, reduces reliance on invasive mapping, and directly guides targeted, successful surgical resection.



García-Ram´o KB et al., Clinical Neurology and Neurosurgery 2023





The Next Frontier: Digital Twins and Personalized Modeling

While regulatory and real-world data hurdles remain the immediate barrier, the ultimate trajectory of AI in epilepsy is the creation of individual virtual brain models. By mapping a patient's unique structural and functional network, these digital twins will enhance clinical decision-making, accurately target epileptogenic zones, and secure superior surgery outcomes.

Wang HE et al., Nature Computational Science 2025

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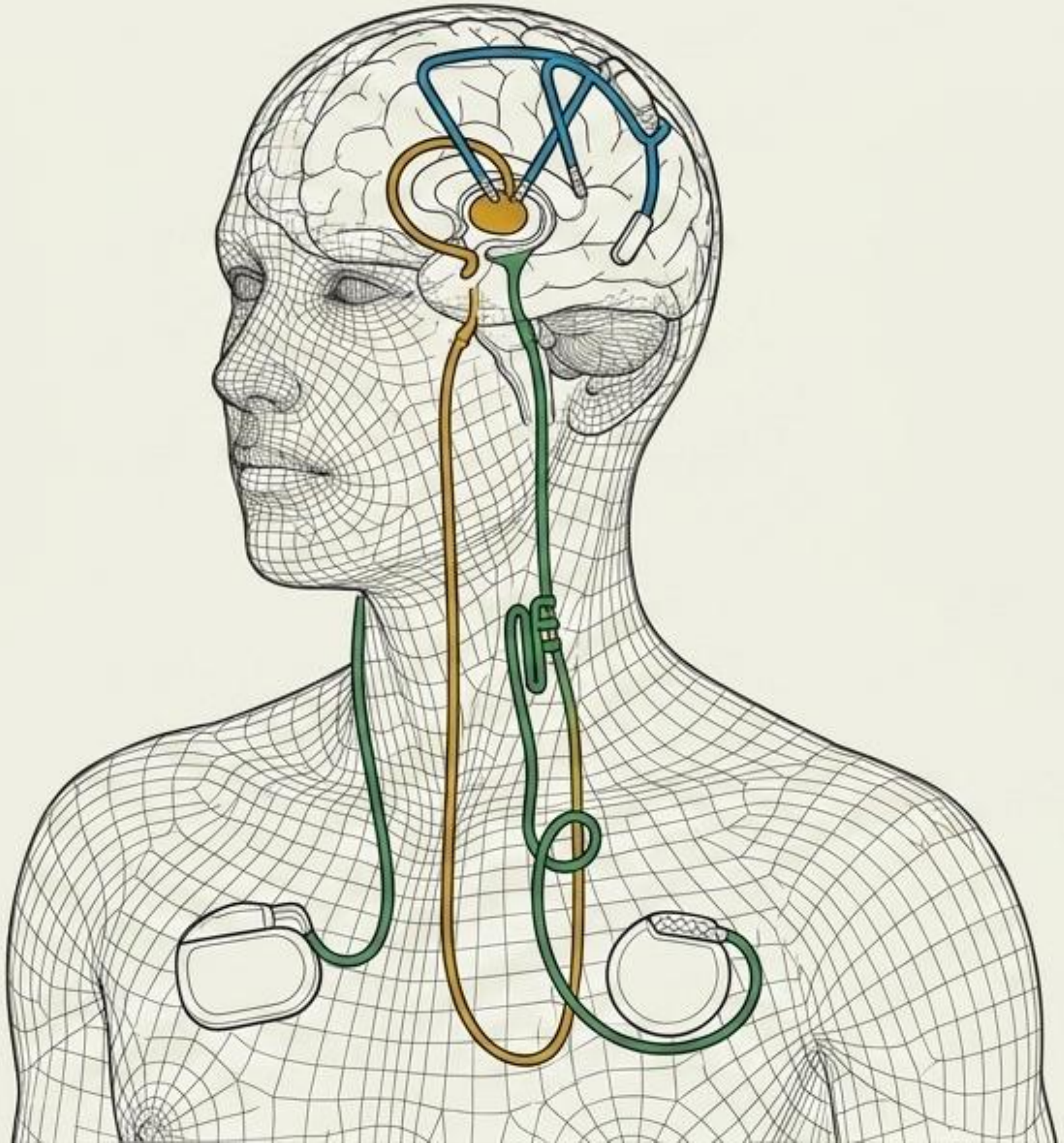
The Role of Neuromodulation in Drug-Resistant Epilepsy (DRE)

State-of-the-Art Interventions: VNS, DBS, and RNS

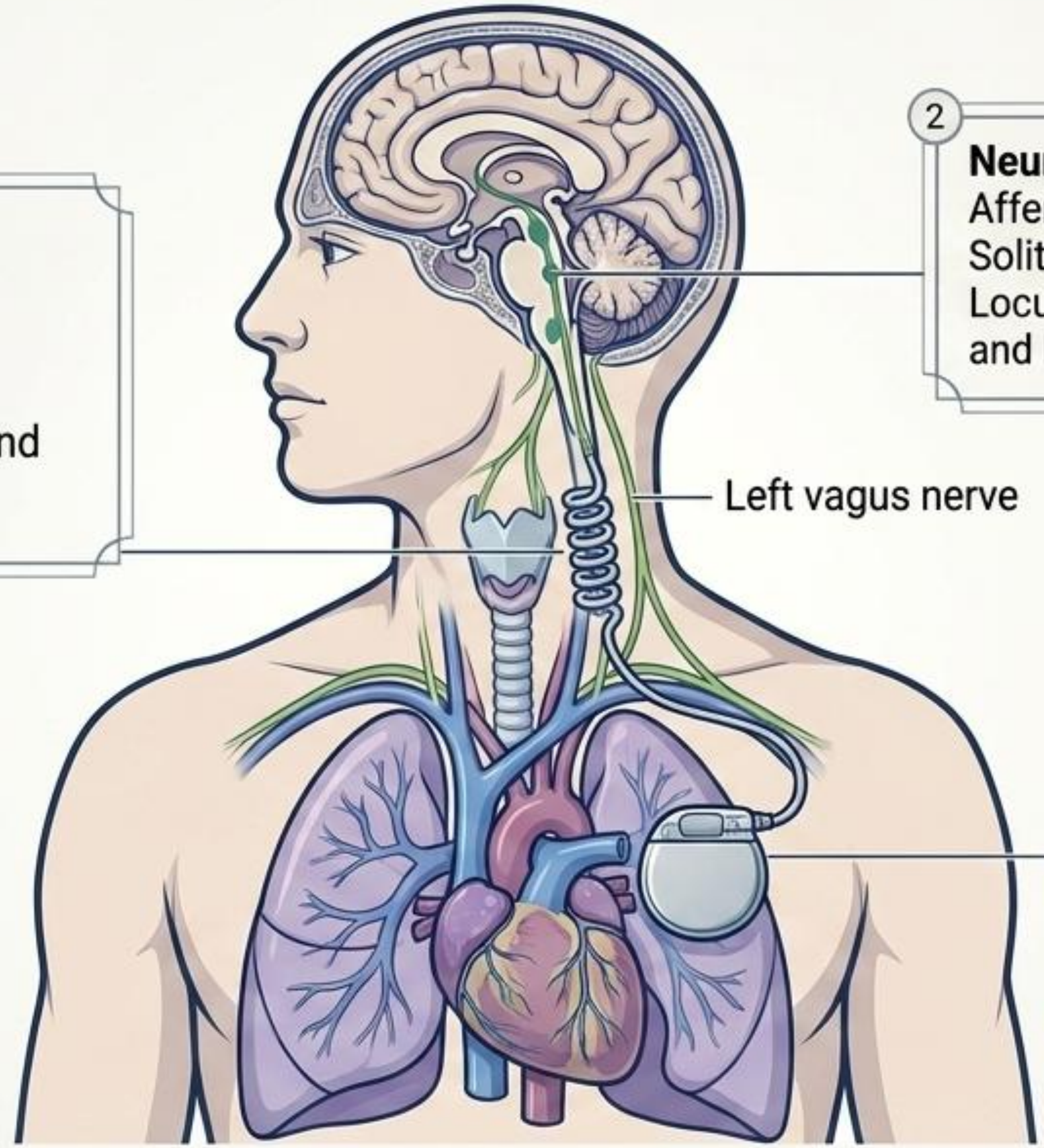


VNS: The Autonomic Gateway

Open-loop continuous stimulation with emerging closed-loop tachycardia detection, altering neurotransmitter balance to inhibit motor cortex excitability.

1 **Why the Left Vagus?** The right vagus nerve regulates the SA node; left-sided placement prevents bradycardia and arrhythmias.

2 **Neurotransmitter Modulation:** Afferents reach the Nucleus Tractus Solitarius (NTS), projecting to the Locus Coeruleus (Norepinephrine) and Dorsal Raphe Nucleus (Serotonin).

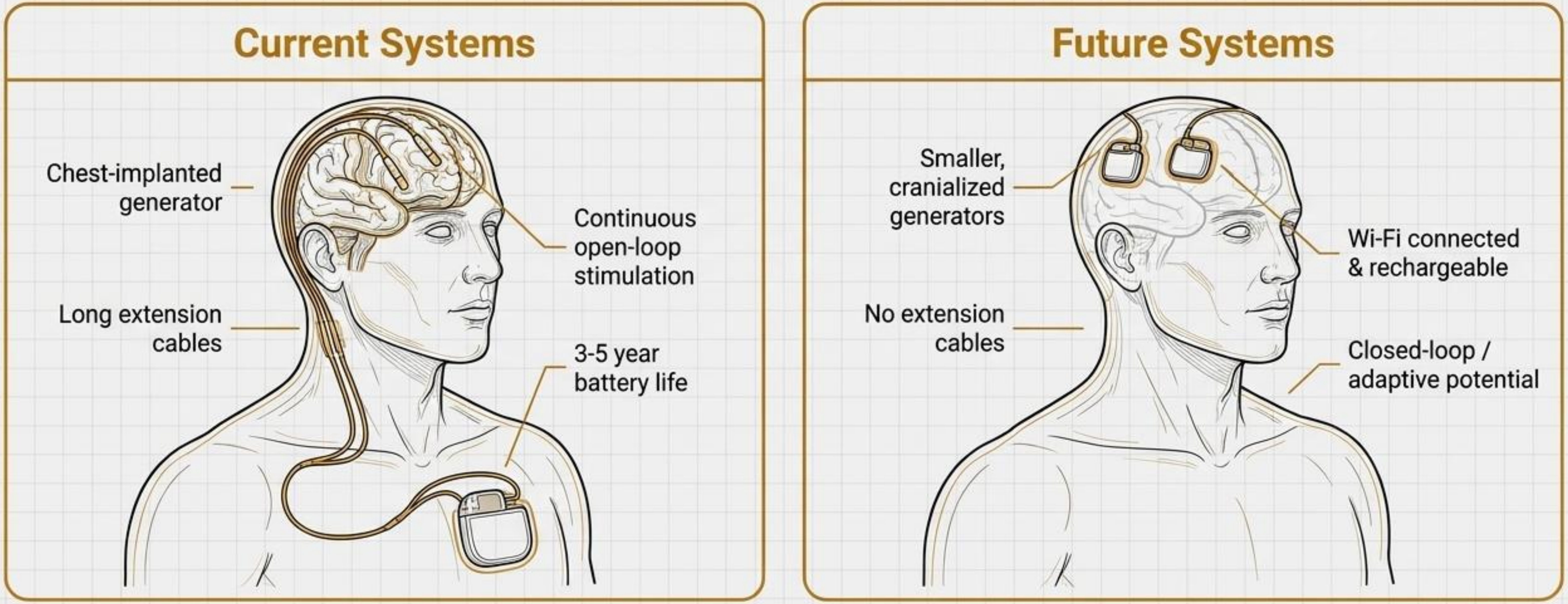


3 **Smart Detection:** Emerging AspireSR models utilize closed-loop heart rate monitoring, triggering stimulation upon detecting ictal tachycardia (HR >100 bpm with >55% baseline increase).

Salama H et al., Neurological Sciences 2024

DBS: The Deep Network Interceptor

An open-loop system delivering continuous electrical pulses to deep brain nuclei, designed to interrupt the cortical-striatal-thalamic network and prevent the spread of seizures to the neocortex.



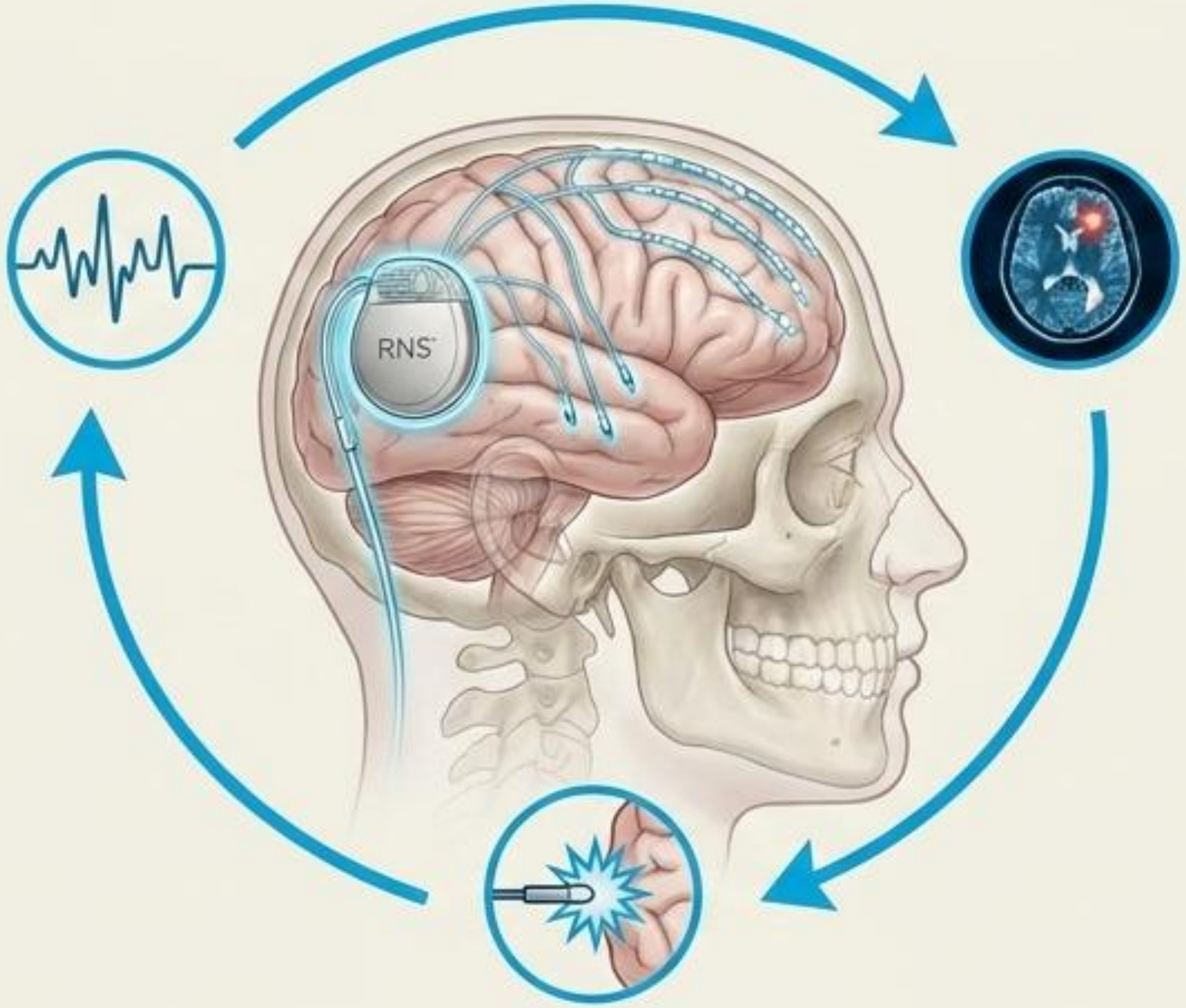
Salama H et al., Neurological Sciences 2024

NotebookLM

RNS: The Closed-Loop Sentinel

The only FDA-approved true closed-loop system for DRE. Adapts to the patient's unique brain activity, providing highly personalized, tailored therapy that minimizes total stimulation time.

Sense
Continuously monitors electrocorticography (ECoG) in real-time.



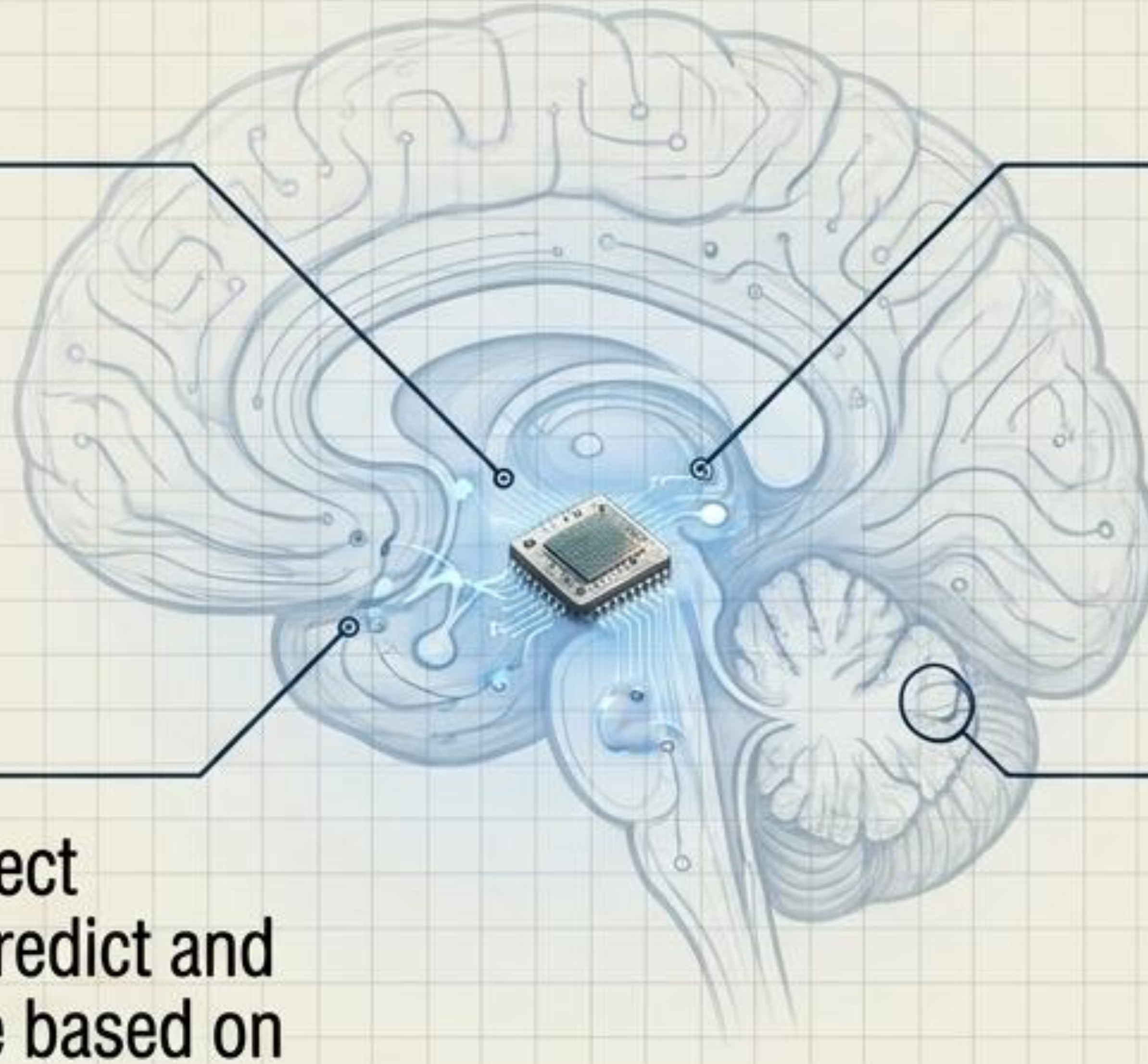
Detect
Algorithms identify patient-specific abnormal electrical biomarkers (seizure onset).

Stimulate
Delivers precise micro-pulses immediately to abort the seizure before clinical manifestation

Health Economics
9-year expected costs are offset by vastly fewer epilepsy-related adverse events, resulting in an ICER consistently below $50,000/QALY.

The Future of Neuromodulation

The shift from open-loop pacemakers to intelligent, miniaturized, closed-loop neural interfaces is accelerating.



Miniaturization

Eradicating extension cables; moving toward entirely cranialized, Wi-Fi enabled, rechargeable systems.

Predictive AI

Algorithms that do not just detect seizures as they happen, but predict and prevent them hours in advance based on network connectivity shifts.

Closed-Loop DBS

Applying the ECoG sensing success of RNS directly to deep subcortical structures (e.g., hippocampal closed-loop models).

Non-Invasive Frontiers

Maturation of transcutaneous VNS (tVNS) as a patient-friendly, rapidly deployable alternative to surgical implantation.

Editorial Telemetry

Donner E et al.; NEJM 2024

Profile 1: The Detectable Crisis

Patient Profile:
Sam, 17. Juvenile myoclonic epilepsy. Experiences generalized tonic–clonic (convulsive) seizures.

The Event:
At 4:00 AM, a severe seizure occurs in his second-floor bedroom.

The Technology:
A wrist-worn accelerometer detects violent movement, triggering a smartphone alarm that wakes his parents on a different floor.

The Outcome:
Immediate aid provided. A potentially fatal event averted. The technology worked exactly as designed.

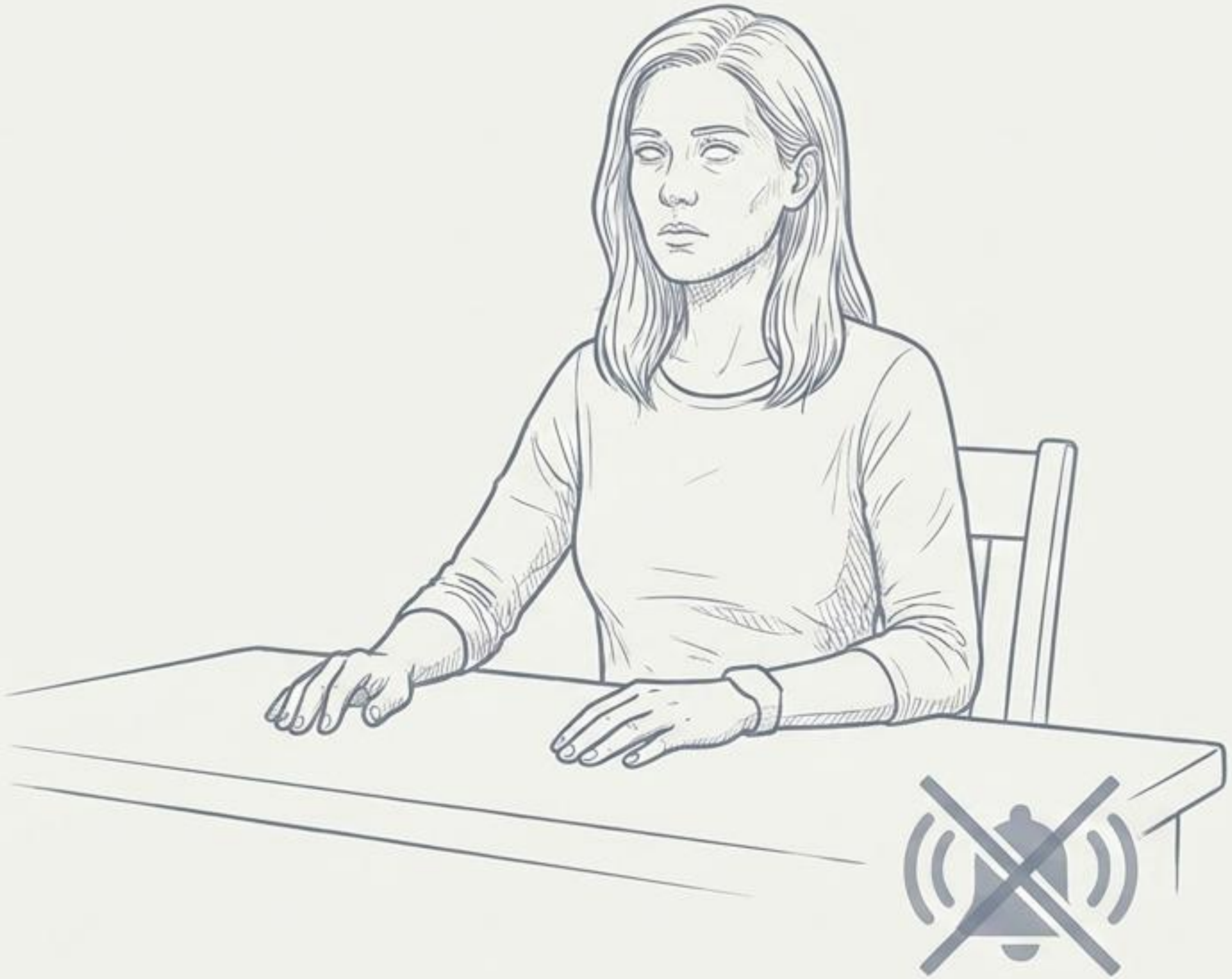
Profile 2: The Silent Void

Patient Profile:
Julie, 35. Focal epilepsy. Experiences nonconvulsive episodes (unresponsiveness, hand automatisms). Lives alone.

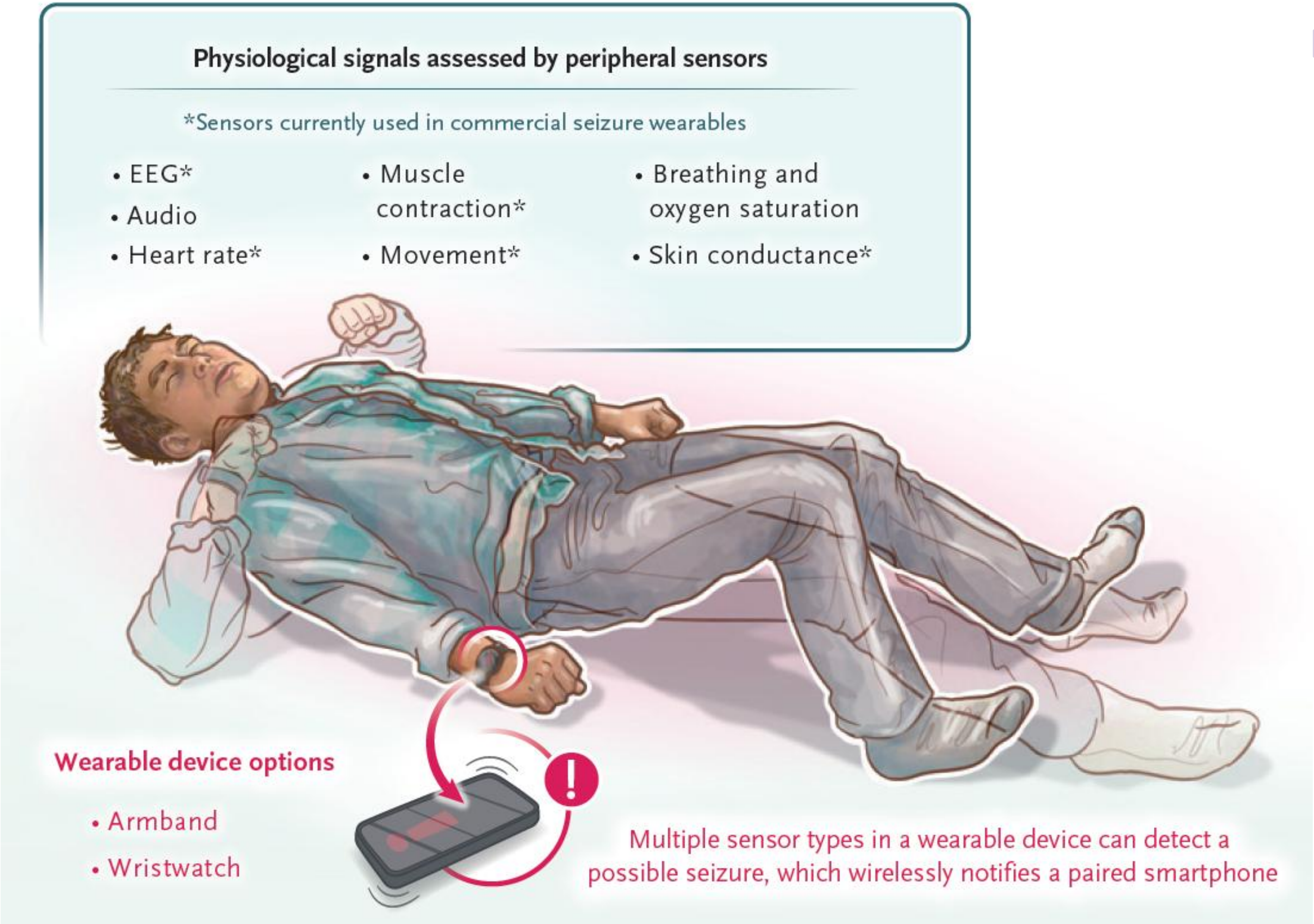
The Event:
Subtle seizures occur daily without her awareness.

The Technology:
Because she lacks robust physiological markers (convulsions), current wearable devices fail to detect her seizures entirely.

The Outcome:
Her medical team cannot quantify her seizure frequency, making it impossible to assess if her new medication is working.

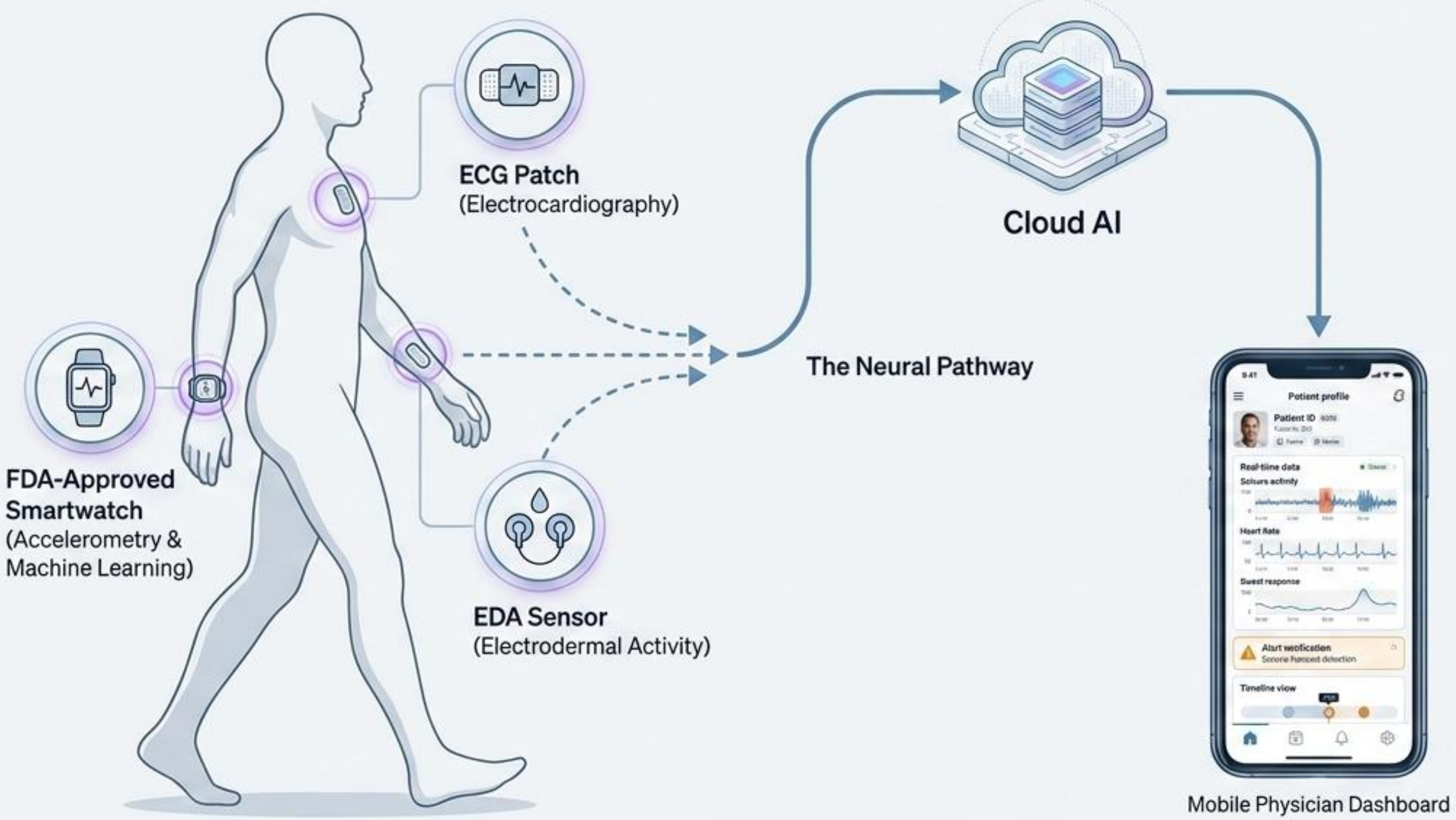


Donner E et al.; NEJM 2024



Donner E et al.; NEJM 2024

Continuous Outpatient Care: Multimodal Wearable Sensors



Clinical Impact:

Reliable detection of Generalized Tonic-Clonic Seizures (GTCS), precise seizure frequency tracking, and reducing the risk of SUDEP outside the hospital.

The Current Hardware Landscape

Device Type	Target Seizure	Clinical Sensitivity	False Alarm Rate
Wrist-Worn (Accelerometer + EDA)	Tonic-Clonic	93% Average	2.5 per 24 hours (FDA Class II / CE Marked)
Armband (EMG + Pulse)	Tonic-Clonic	90% Average	0.96 per 24 hours (FDA Class II / CE Marked)
Mobile App (Smartwatch Paired)	Tonic-Clonic	Unknown	Unknown (No FDA Approval)
EEG-Based Headset	Most Types (incl. Absence)	99.6% Average	5 per day (No Home-Use Approval Yet)

The Algorithmic Compromise

The tension between catching every event and destroying quality of life.

Patients with Frequent Seizures
Will tolerate 0.1 to 0.3 false alarms per day.

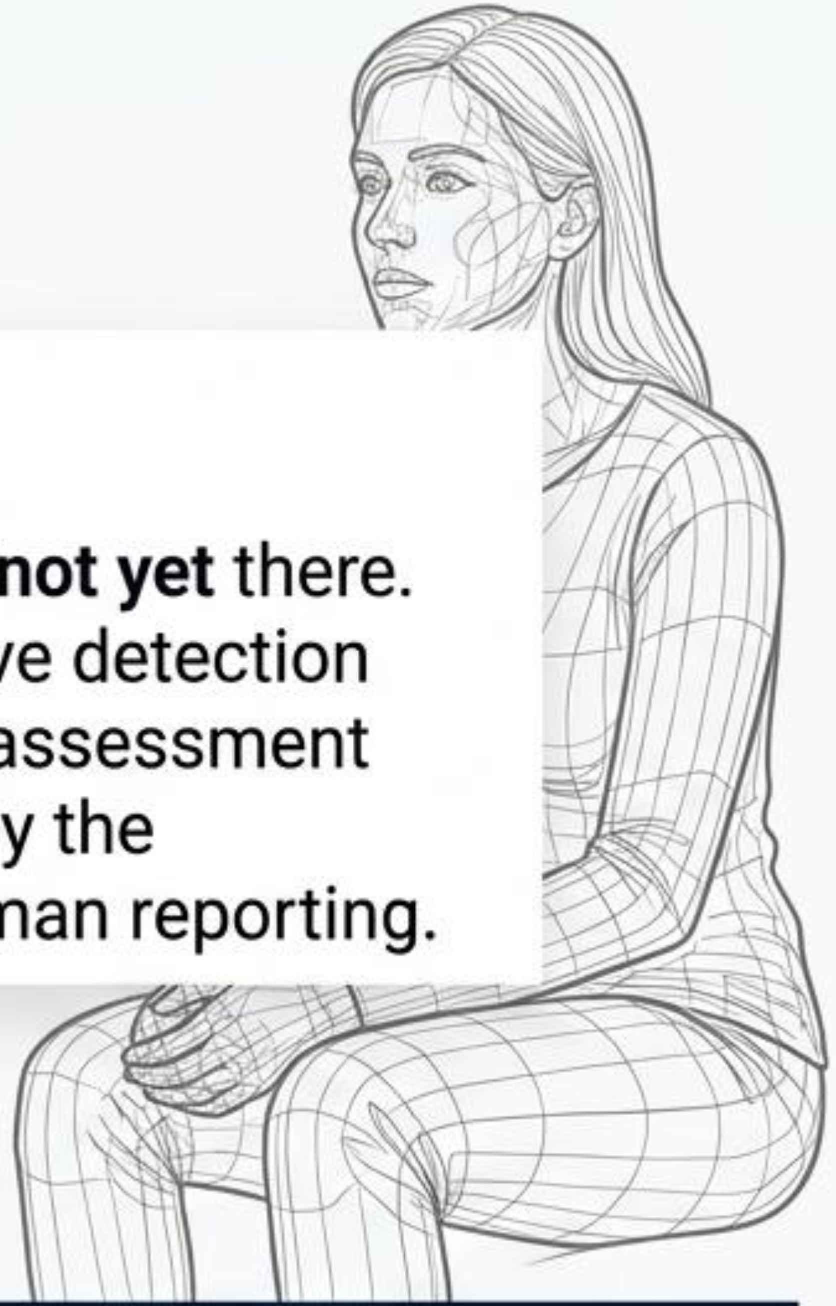
Patients with Infrequent Seizures
Will only tolerate < 2 false alarms per month.

A device that cries wolf 3 times a day is a device that gets left on the nightstand.

Finding the Signal

For Sam:

Wearable DHT is a viable lifeline today. It grants independence and safety, provided the device is consistently worn, charged, and connected to nearby responders.



For Julie:

The technology is **not yet** there. Until non-convulsive detection improves, clinical assessment remains clouded by the **unreliability** of human reporting.

The Final Word: The next leap in digital health is not just building more sensitive hardware—it is designing algorithms that predict the storm before it breaks, for every type of patient.

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Epilepsia™

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RESEARCH ARTICLE

Wrist-worn smartwatch and predictive models for seizures

Waroth Pipatpratarnporn[1] | Wichuta Muangthong[1] | Suda Jirasakuldej[2] | Chusak Limotai[1,2]

TABLE 4 Univariate and multivariate analysis using generalized estimating equa
type.

Seizure types	Univariate analysis	*p*	Multivariate analysis	*p*	odel and cut-points
Over all seizure types	HR	<.001	HR	<.001	$y = -4.507 + .046$ (HR) + 24.570 (ACC) Cut-point y value for overall seizures ≥ −.35
	ACC	.001	ACC	.008	
	EDA	.092			
	TEMP	.651			
BTCs	HR	.017	ACC	.005	$y = -6.772 + 33.066$ (ACC) + .040 (HR) Cut-point y value for BTCs ≥ −2.47
	ACC	.001	HR	.133[a]	
	EDA	.173			
	TEMP	.466			
Non-BTCs	HR	.001	ACC	.003	$y = -4.344 + 28.554$ (ACC) + .037 (HR) Cut-point y value for non-BTCs ≥ −.87
	ACC	<.001	HR	.025	
	EDA	.213			
	TEMP	.785			
Isolated auras	HR	<.001	HR	<.001	$y = -7.838 + .0691$ (HR) Cut-point y value for isolated auras ≥ −1.69
	ACC	.916			
	EDA	.883			
	TEMP	.789			

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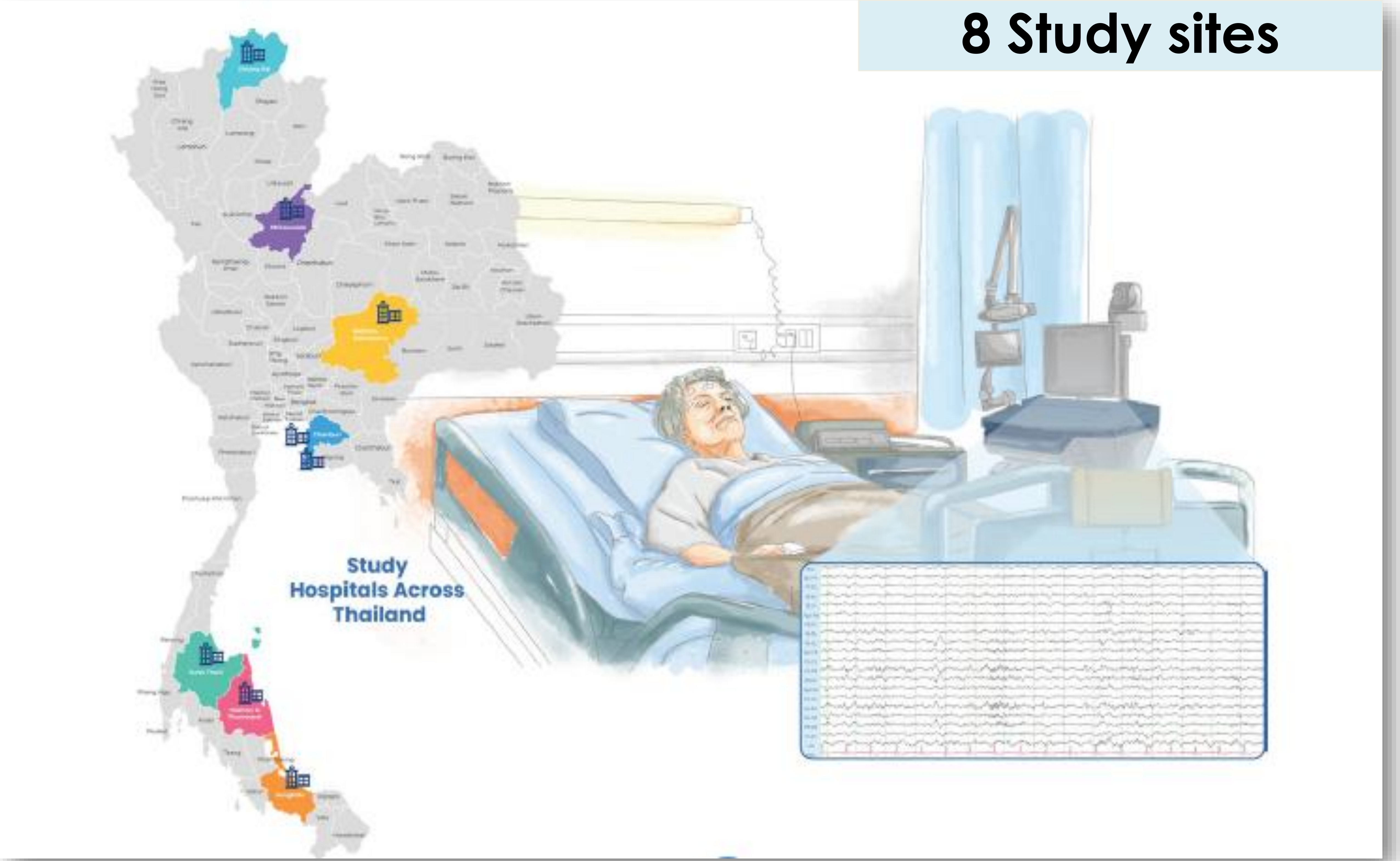
Efficacy of delivery of care with Tele-continuous EEG in critically ill patients: a multicenter randomized controlled trial (Tele-cRCT study) study

Chusak Limotai[1,2,3], Suda Jirasakuldej[2,3], Sattawut Wongwiangiunt[4], Tipakorn Tumnark[5], Piradee Suwanpakdee[6], Kwuanrat Wangponpattanasiri[7], Piyanuch Rakchue[8], Chaiwiwat Tungkasereerak[9], Polchai Pleumpanupatand[10], Phopsuk Tansuhaj[11], Phattarawin Ekkachon[12], Songchai Kittipanprayoon[13], Apiwoot Kerddonfag[14], Thippamas Pobsuk[15], Anuchate Pattanateepapon[1], Kammant Phanthumchinda[3], Nijasri C. Suwanwela[3], Iyavut Thaipisuttikul[3], Kanokwan Boonyapisit[4], Atiporn Ingsathit[1], Oraluck Pattanaprateep[1], John Attia[16], Gareth J. McKay[17], Andrea O. Rossetti[18], Ammarin Thakkinstian[1*], Chutima Rukrung[1], Patcharapun Kangsananont[1], Jeerawan Mokkaew[1], Nittaya Phayaph[1], Supak Pukpraman[1], Warangkana Ritrhathon[1], Youwarat Jarungjitapinan[1], Jintana Pinpradab[1], Netphit Khamhoi[1], Mayuree Nookaew[1], Patchareeporn Chauywang[1], Pichai Rojdmapitayakorn[1], Paworamon Sribussara[1], Wasunon Tinroongroj[1], Wisan Teeratantikanon[1], Tabtim Chongsuvivatwong[1], Watchara Viratyaporn[1], Witoon Jantararotai[1], Komkrit Panyawattanakit[1], Nopparat Rujirarongrueng[1], Pornnapat Damthong[1], Pattama Udom[1], Molvipa Siengsuwan[1], Phatcharamai Phonprasori[1], Karnpidcha Wanmuang[1],

Limotai C et al., Critical Care 2025

doi: 10.1186/s13054-024-05246-x. PMID: 39773282; PMCID: PMC11707894.

8 Study sites



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The AI-Augmented Clinical Workflow

Phase 1: Initial Encounter

1. Introduction to AI in Epilepsy Care
2. AI-Driven Diagnostic Support (LLMs and EEG)

Phase 2: Investigative Testing

3. AI in Neuroimaging and Lesion Detection

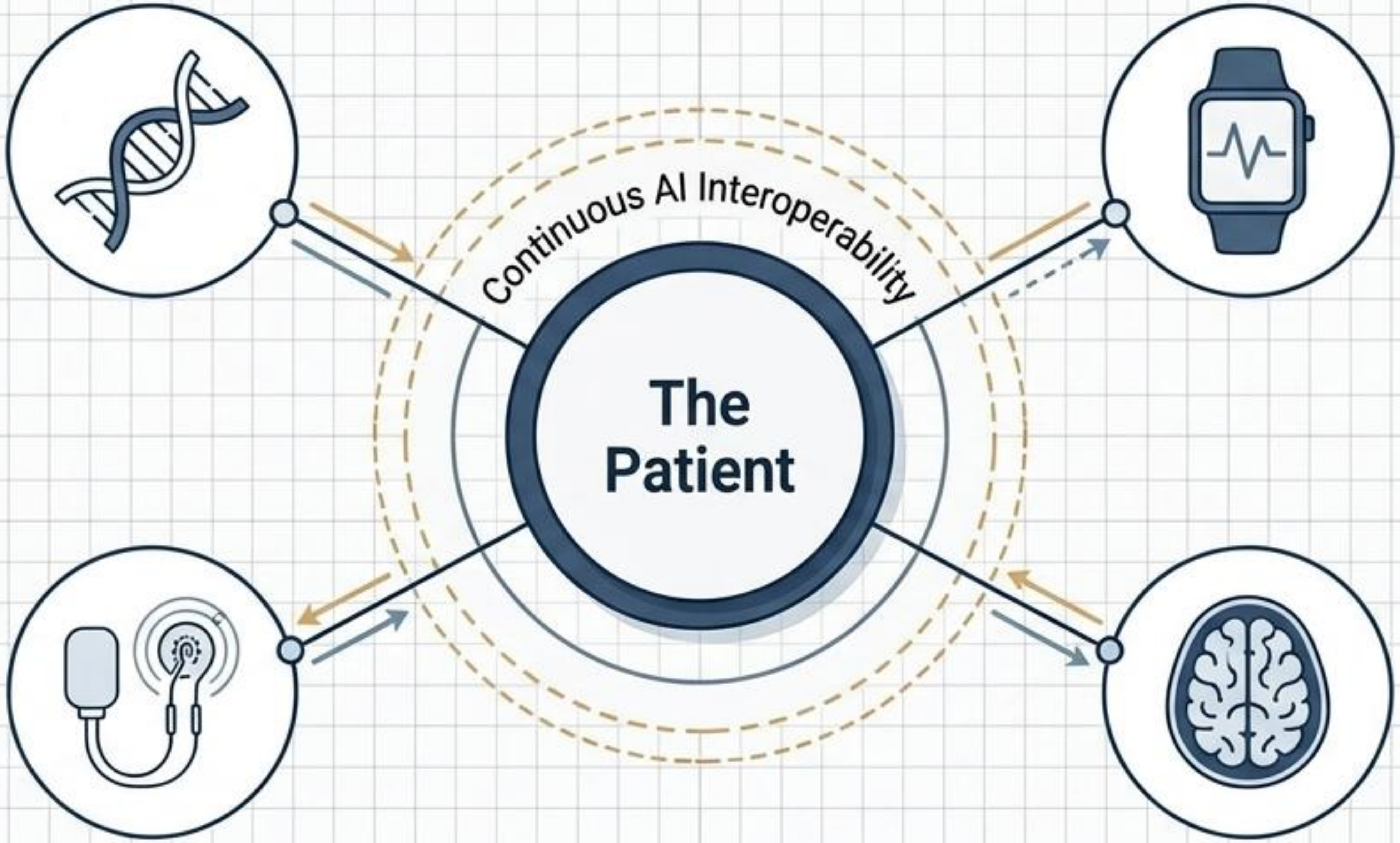
Phase 3: Intervention & Monitoring

4. Advanced Neurotechnology: Targeted Neuromodulation
5. Seizure Detection, Prediction, and Wearables

Phase 4: Long-Term Management

6. Future Directions and Digital Care Pathways

Synthesis: The Future Patient Ecosystem



Genomics & Precision Traits

Analyzing genetic markers to predict onset and customize ASM regimens.

Real-Time Wearables

Smartwatches with EEG/heart-rate sensors providing continuous physiological data for ambient seizure prediction.

Closed-Loop Interventions

Implanted RNS devices delivering immediate, targeted stimulation based on real-time AI forecasting.

Advanced Diagnostics

Automated EEG and MRI pattern recognition operating in the background of clinical visits.

All data flows seamlessly back into the secure, federated-learning AI layer, continuously updating the patient's individual care model.

The Future of Epilepsy Care

Artificial intelligence is transforming epilepsy management from reactive trial-and-error to proactive, personalized precision medicine.

By converging automated EEG, advanced neuroimaging, predictive wearables, and LLM diagnostic support, we can close the clinical loop.

In the future, AI will not replace epileptologists, but epileptologists equipped with AI will replace those who are not.