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Motivation

EEG is used as a diagnostic tool for epilepsy with **high specificity but low sensitivity**. This study introduces an epilepsy risk index, derived from routine EEG (10-20 setup) to quantify the likelihood of a patient having epilepsy. It is tested in patients experiencing their initial seizure event.

Dataset

798 patients admitted to the hospital after a first event

→ clinically relevant population aimed at **differential diagnosis of epilepsy**

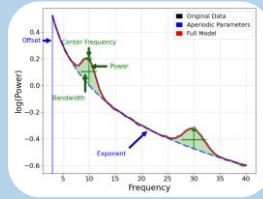
*diagnosis confirmed after >2y follow-up

Diagnostic data	Results	Demographic & clinical	Results	Neuroimaging	Results
Diagnosis, n (%)		Age, mean (std)	52 (217)	MRI lesion, n (%)	546 (68.4)
Epilepsy	464 (58.1)	Sex, n (%)		None	128 (16.0)
Other	124 (15.5)	Male	455 (57.0)	Vascular	95 (11.9)
Cardiovascular	60 (7.5)	Female	343 (43.0)	Tumor	95 (11.9)
Vagal syncope	58 (7.3)	Medication, n (%)		Trauma	20 (2.5)
Psychogenic	57 (7.1)	None	519 (65.0)	CT lesion, n (%)	
Provoked seizure	35 (4.4)	Benzodiazepine	123 (15.4)	None	567 (71.1)
Epilepsy type, n (%)		Anti-epileptic	102 (12.8)	Vascular	131 (16.4)
Lesional	326 (77.3)	Other	40 (4.3)	Tumor	99 (12.4)
Non-lesional	54 (12.8)	Anti-depressants	19 (2.4)	Other	50 (6.3)
Generalized idiopathic	34 (8.1)	Neuroleptic	1 (0.1)	Trauma	27 (3.4)
Undetermined	8 (1.9)				

Methodology

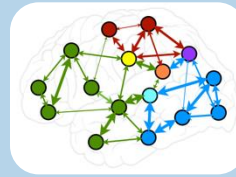
Processing

- High-pass filter (0.5Hz) + notch filter (50Hz)
- ICA removal of eye movements
- 5s epochs + autoreject to remove epochs
- Current Source Density to make reference-free and reduce volume conduction
- Spectral and connectivity features
- 70% train – 30% test
- Performance assessment using AUROC for classical machine learning and Brier Score for probabilistic machine learning



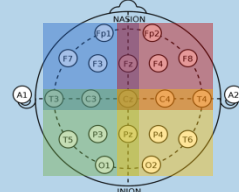
Spectral - FOOOF analysis

- Aperiodic: $1/f$ exponent and offset
- Periodic: Peak frequency, peak power, bandwidth.



Functional Connectivity

- Imaginary Coherence (IMCOH)
- Phase Locking Value (PLV)
- Mutual Information (MI)
- Partial Directed Coherence (PDC)
- Amplitude Envelope Corr. (AEC)

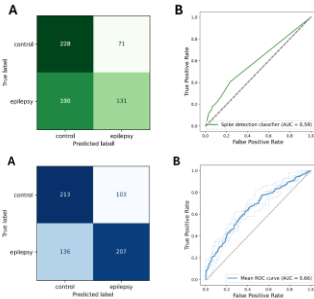


Regional Clustering

- Front/back, left/right
- 7 electrodes per grouping
- Per grouping: mean

Results

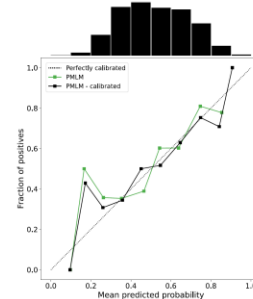
Classical Machine Learning



	SPIKE	SPECTRAL	CONNECTIVITY
AUROC	0.59	0.66	0.60
ACC	0.58	0.64	0.59
SENS	0.41	0.60	0.61
SPEC	0.76	0.67	0.57

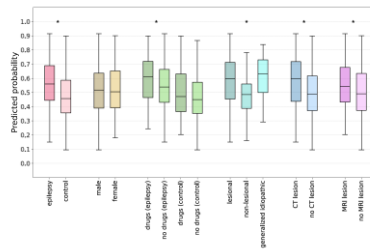
The trained classifier based on spectral features is more sensitive in diagnosing epilepsy compared to a classifier based on spike detections, but it is less specific.

Probabilistic Machine Learning



	Logistic Regression (calibrated)	Random	50%
Brier Score	0.23	0.36	0.25
Calibration	0.002	0.11	0.0004
Resolution	0.02	0.002	0
Sharpness	0.03	0.08	0

A Brier score of 0.23, along with predicted probabilities that closely match the actual fraction of positives, indicates good performance of the epilepsy risk index.



- The epilepsy risk index is significantly higher for epilepsy patients compared to controls.
- A significant difference is observed between patients who are on medication and those who are not.
- The epilepsy risk index is significantly higher for patients with CT or MRI lesions.

Conclusions

- Binary classification of epilepsy versus non-epilepsy using classical machine learning based on the spectral content of routine EEG outperforms classification based on detected interictal epileptiform discharges.
- The Epilepsy Risk Index, derived from routine EEG using probabilistic ML, is higher in patients with epilepsy compared to those without, in patients on medication versus off medication, and in patients with lesions observed on MRI or CT compared to those without.