Dynamic Decomposition of Interictal Intracranial EEG Predicts Surgical Outcome in Children with Drug Resistant Epilepsy: An Unsupervised Machine Learning Approach

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Introduction

- Accurate delineation of the epileptogenic zone (EZ) can help either control or free children with drug resistant epilepsy (DRE) from seizures and the associated symptoms.
- **Unsupervised machine learning** (**ML**) **methods** have been recently proposed as tools to automatically localize the EZ since they can detect information from iEEG data that epileptologists might miss during the presurgical epilepsy evaluation.
- We therefore used an unsupervised ML technique to decompose iEEG signals into dominant spectral components and automatically identified iEEG channels that contain epileptogenic activity.
- We **hypothesize** that the proposed biomarker can delineate the EZ with high precision and predict the surgical outcome of children with DRE.

Methodology

- We analyzed interictal iEEG data from 41 children with DRE (16 females, median age:13 years).
- We dissected iEEG signals into 0.25 sec windows and stacked vertically into a single matrix (Z_p).
- We used dynamic mode decomposition (DMD) on the Z_p to extract the (i) dominant temporal components common to all channels; and (ii) channel-in-mode participation factors.

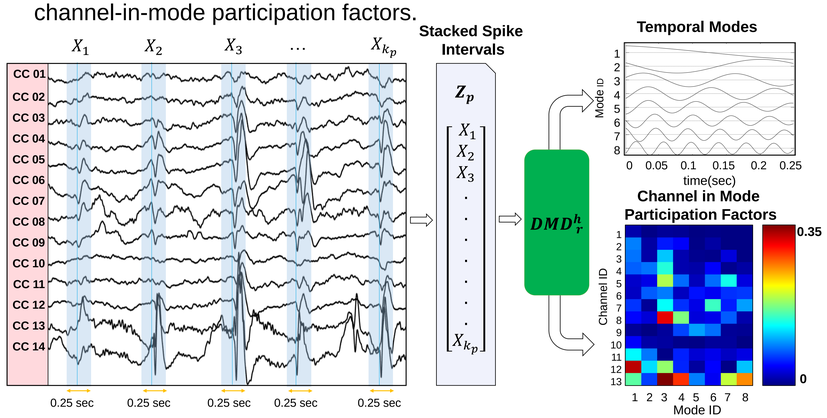

Fig. 1 Pipeline of the methods. Left: iEEG from a 11-year-old DRE patient. Right : temporal components (common to all windows) and channel-in-mode participation factors for each window.

Results

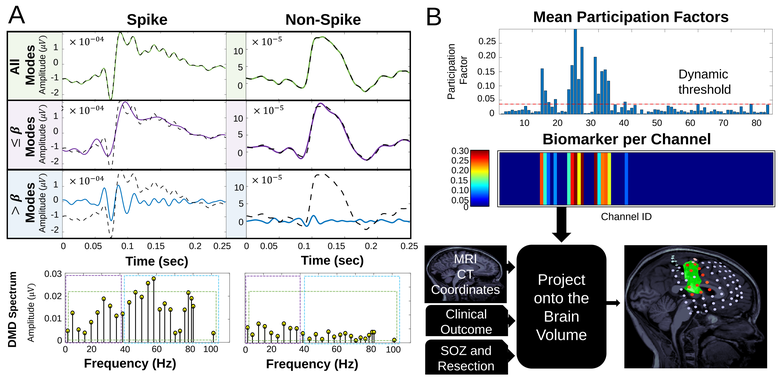

Fig. 2 Postprocessing the Participation Factors. (**A**) Comparative analysis of a spike and a non-spike signal in terms of reconstruction using all the modes ([1-70] Hz), the low-frequency modes (<30 Hz), and the higher frequency modes ([30-70] Hz) and their spectra. (**B**) The participation factors are averaged, thresholded, and projected onto the 3D brain images computed from the MRI.

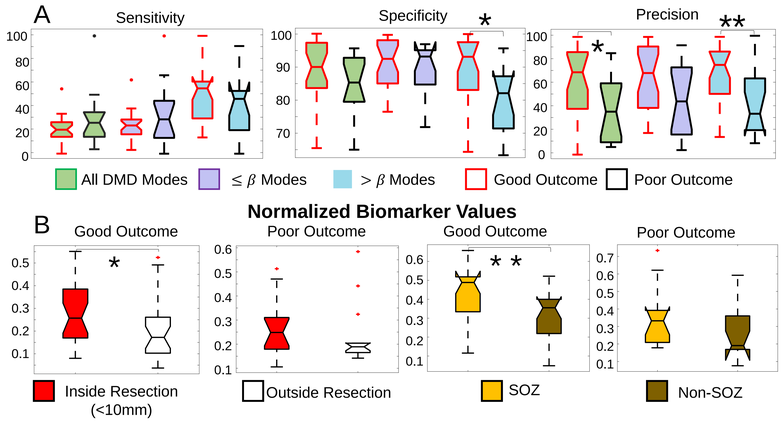

Fig. 3 Performance Results of the proposed biomarker. (**A**) Good outcome patients showed significant differences from poor outcome patients in terms of specificity (p=0.0106) and precision (p=0.00076) (Wilcoxon rank sum) . (**B**) Contrarily to poor outcome patients, good outcome patients showed significant differences between inside and outside resection and SOZ (p<0.05, Wilcoxon signed rank).

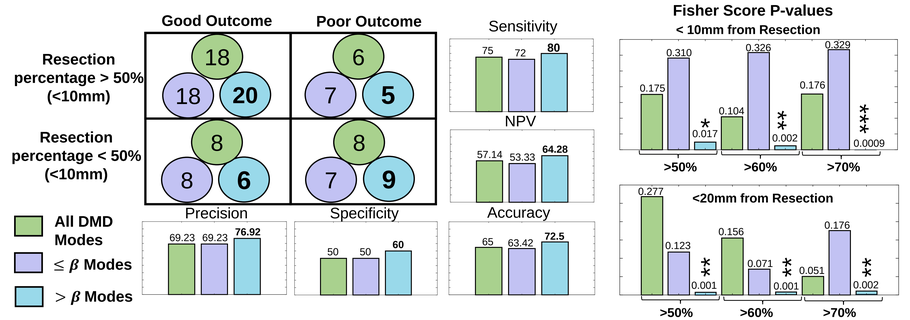

Fig. 4 Outcome Prediction of the proposed biomarker. The confusion matrices and the corresponding performance metrics (sensitivity, negative predictive value (NPV), precision, specificity, and accuracy). Fisher scores showed significant values (p<0.017) when the biomarker was computed in the higher frequencies (> β case).

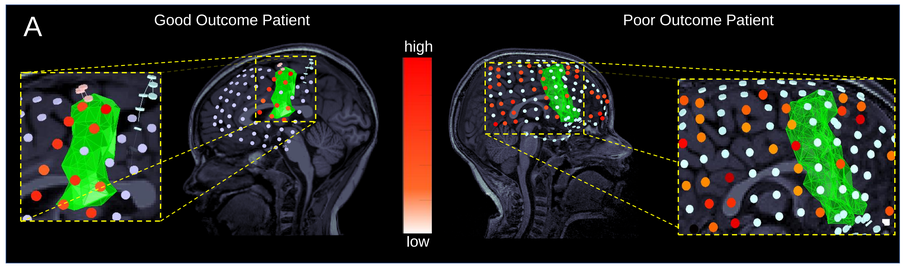

Fig. 5 The distribution of the biomarker in good and poor outcome patients- The projected biomarker channels form a cluster near the resected area in good-outcome patients and are scattered in poor-outcome patients.

Conclusion

- Data-driven SOZ and EZ biomarker
- Interictal EZ delineation
- High-frequency components (>β) performs better than lower frequencies or broadband
- Predicts surgical outcome for patients with DRE

References

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