



Boston Children's Hospital



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Combining Brain Connectivity and Excitability to Plan Epilepsy Surgery in Children:

A New Tool to Get the Most Out of Intracranial EEG

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FNNDESC at Boston Children's Hospital

Background

Epileptogenicity is a very complex brain property that depends on the **interplay between altered excitability and connectivity**

In children with drug-resistant epilepsy (DRE), identifying the **epileptogenic zone** in the brain can be **challenging**, even when using intracranial EEG (icEEG).

We propose a **novel twofold approach to optimize icEEG analysis**, that is able to quantify both **brain excitability (via phase-amplitude coupling, PAC)** and **functional connectivity (FC)**, using interictal data.

Our goal is to develop a new computer-aided tool to **boost the interpretation of interictal icEEG and improve surgical planning in children with DRE.**

Methods (Fig 1)

42 children who had epilepsy surgery at Boston Children's Hospital (28 good outcome) after icEEG implantation (Fig. 1A).

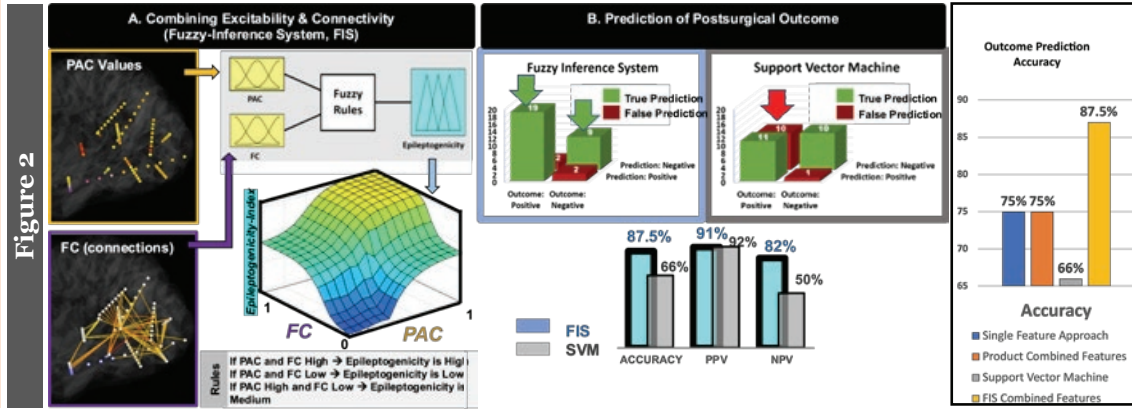
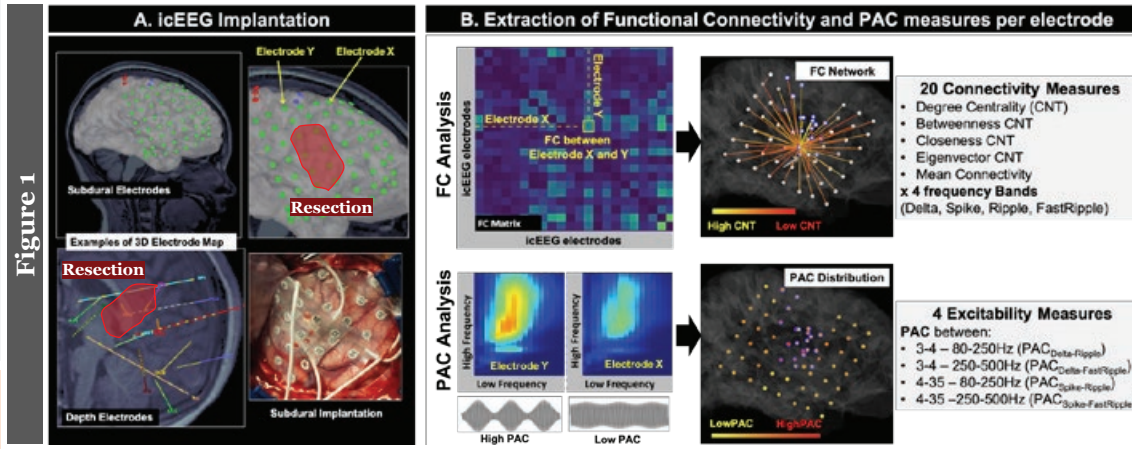
icEEG Feature Extraction

- **FC analysis (Fig. 1B top)**: - Five measures of network centrality (Betweenness, Degree, Eigen Vector, Closeness) in 4 frequency bands (20 measures)
- **PAC analysis (Fig. 1B bottom)** - Four Excitability Features between two low- and two high-frequency ranges.
- **20 new combined features** of epileptogenicity as the product of PAC and centrality in each frequency band.

Resection: we built 3D models of the resected brain volume using a semi-automated region growing method

Estimation of EZ + Outcome Prediction

- **Support Vector Machine** was trained on good outcome to identify the resection (using 44 features); then, we tested whether its output predicts outcome.
- We estimated the **predictive value of each individual feature** (in identifying the electrode to remove for the patient to be seizure-free)



Methods (Fig 2A)

Estimation of EZ + Outcome Prediction

- We built a **Fuzzy Inference System (FIS)** that combined the most predictive FC and PAC features to obtain an **overall value of "epileptogenicity"** per electrode (Fig. 2A), and tested whether its output predicts outcome

Results (Fig. 2B)

- The individual features of excitability and connectivity presenting the highest predictive performance were: 1) PAC between spike and ripple frequencies and 2) closeness centrality in the ripple frequency

- Removing the brain tissue that identified by the FIS as the most epileptogenic presented higher accuracy in predicting postsurgical outcome (87.5%) than the SVM, with high NPV and PPV

- SVM classifier presented an accuracy in predicting outcome of 66%, with low ability to predict poor outcome (NPV=50%)

- We developed a Matlab-based graphic user interface (GUI) to integrate and visualize the child's brain network along with the PAC distribution onto the 3D MRI space.

Conclusion

We developed a **new inference system (fuzzy-logic based)** that **integrates measures of excitability and connectivity** to estimate the level of epileptogenicity of on each icEEG electrode (and thus estimate the EZ).

Our **novel FIS system** provides the **highest accuracy** in the predicting postsurgical outcome, when **compared to single-feature approaches** or to a **multi-feature SVM approach**.