Functional Connectivity in Focal Drug-Resistant Epilepsy: Seizure Patterns in Subject-Level Analysis

Neelesh Pandey[1,2]; Myriam Abdennadher, MD[2]

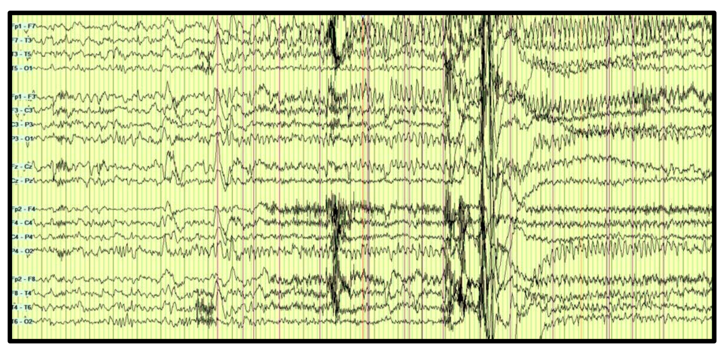
Gulliver Preparatory School, 6575 N Kendall Dr, Pinecrest, FL 33156[1]; Department of Neurology, Boston Medical Center, Boston University Chobanian & Avedisian School of Medicine, 85 E. Concord St, Boston, MA 02118[2]

Introduction

- Epilepsy is a common neurological disorder affecting 65 million people worldwide of which approximately 30% of people suffer from drug-resistant epilepsy.
- Patients with drug-resistant epilepsy continue to have seizures despite taking anti-seizure medications and are often subject to a lower quality of life.
- Functional connectivity is the temporal dependency of neuronal activation patterns of anatomically separated brain regions.
- Given the brain's dynamic nature in excitability, functional connectivity can be leveraged as a tool to determine underlying networks and patterns in relation to the seizure focus.

Aim & Purpose

Our study aims to determine the similarities and differences in electroencephalogram functional connectivity in focal drug-resistant epilepsy patients with different seizure foci during seizure epochs. This can provide more insight into the networks of the brain in focal drug-resistant epilepsy patients, which could be useful for future development of anti-seizure medications and therapeutics.

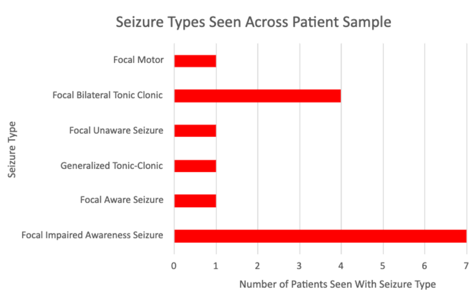


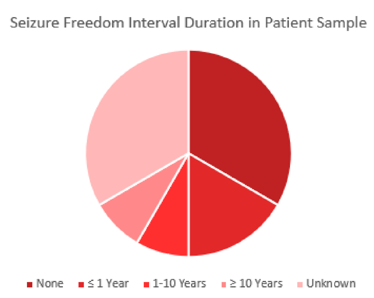
Beginning of a Seizure

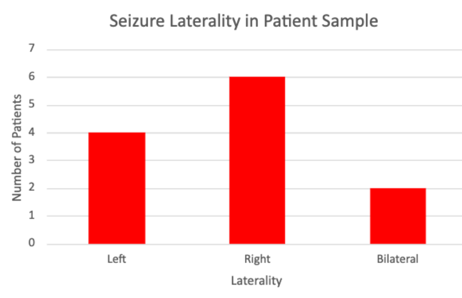
Methodology

Data Collection of Patient Sample

19-channel electroencephalogram data (10-20 International System) was collected at Boston Medical Center. The electroencephalogram data was then cut to select seizure files kept below five minutes to ensure quick and smooth pre-processing and analysis. The patient sample consists of 12 (8 males and 4 females) focal drug-resistant epilepsy patients from Boston Medical Center. Descriptive statistics of clinical variables of the patient sample are shown in Table I.







	Current Age	Age at Seizure Onset	Current Number of Antiepileptic Medications	Previous Number of Antiepileptic Medications	Number of Seizure Recorded at EMU
Mean	41.67	22.13	3.58	2.42	3.58
Standard Deviation	11.96	14.59	1.51	1.83	3.92
Median	42.50	20.50	3.50	3.00	3.00
Minimum	25.00	2.50	2.00	0.00	0.00
Maximum	57.00	50.00	6.00	6.00	12.00
1st Quartile	31.50	10.00	2.00	1.00	1.00
3rd Quartile	51.25	31.50	4.25	3.25	3.25

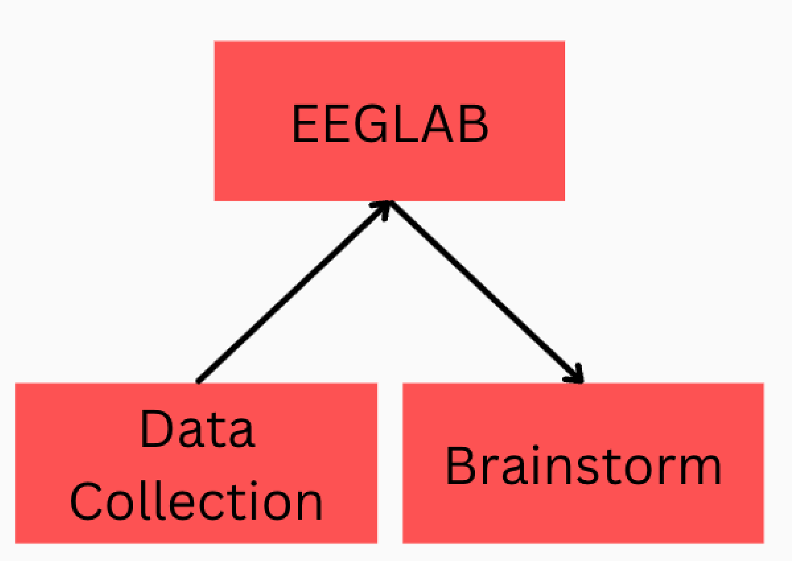
Table I: Descriptive Statistics of Sample; Note: All Statistics Rounded to Nearest Hundredths Place

Tools for Processing Used Alongside EEGLAB and Brainstorm

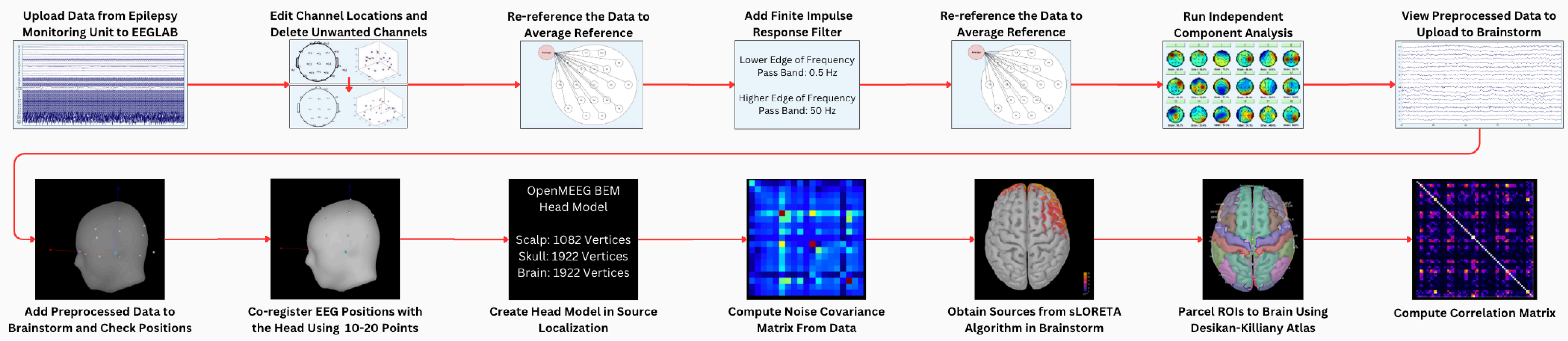
EEGLAB and Brainstorm are platforms for electroencephalogram processing. EEGLAB was used for pre-processing, while Brainstorm was used for source localization and analysis. The following were used inside EEGLAB and Brainstorm:

- ICLabel: classifies brain components from non-brain components after independent component analysis
- OpenMEEG: creates head model for source localization
- Template Anatomy: Montreal Neurological Institute's ICBM152 2023b Template based on averaging MRI scans
- sLORETA: algorithm used for estimating source activity
- Desikan-Killiany Atlas: brain atlas dividing the cerebral cortex into 34 regions of interest (68 in Brainstorm for left and right)

General Use of Platforms

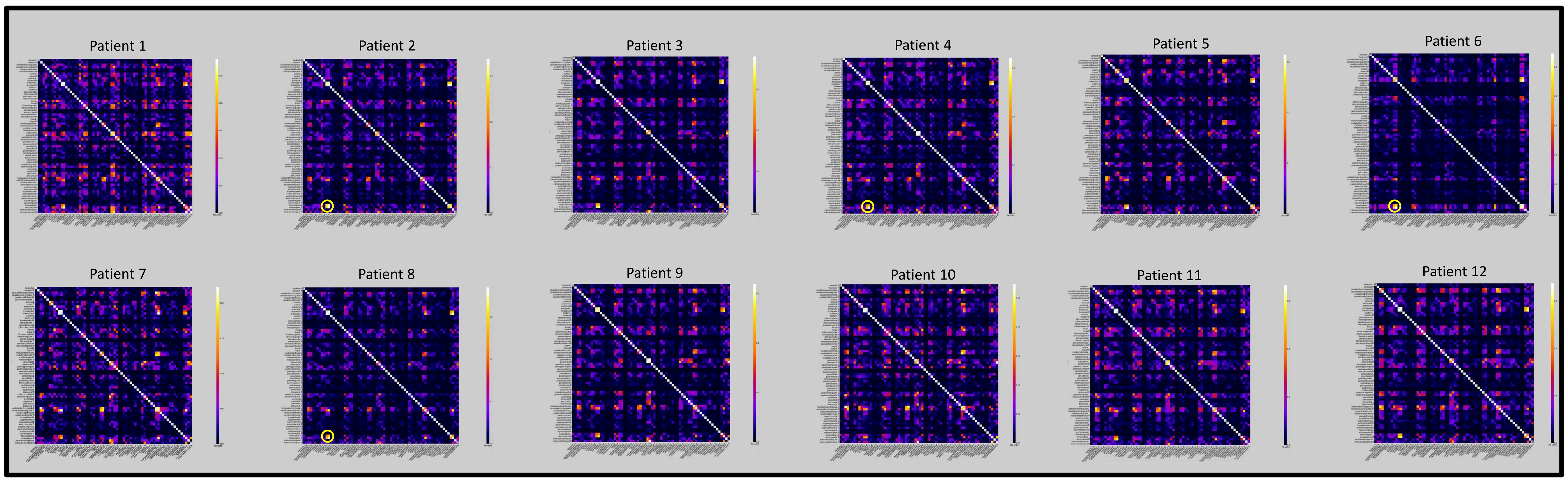


Pipeline for Source-Spaced Functional Connectivity in Focal Drug-Resistant Epilepsy Patients



Images were collected from EEGLAB (top row) and Brainstorm (bottom row) or self-created (average reference).

Results



Patient	Seizure Focus
Patient 1	Left Occipital Early Spread to Left Temporal
Patient 2	Right Fronto-Temporal
Patient 3	Right Fronto-Temporal
Patient 4	Bitemporal
Patient 5	Left Temporal
Patient 6	Right Temporal
Patient 7	Right Temporal
Patient 8	Bitemporal
Patient 9	Right Temporal
Patient 10	Right Temporal
Patient 11	Left Occipito-temporal
Patient 12	Left Fronto-temporal

Table II: Patients and Their Respective Seizure Foci

Seizure foci and functional connectivity matrices were then compared.

Discussion/Conclusion

There was a stronger functional connectivity in participants with temporal lobe epilepsy between the seizure focus and ipsilateral frontal pole as well as the contralateral frontal and temporal poles. We highlight the following participants to illustrate this:

- Patient 2 has a right fronto-temporal seizure focus: the correlation between the right temporal pole and the right frontal pole (0.33768), revealing strong ipsilateral frontotemporal network connectivity.
- Patient 4 has bitemporal seizure foci: there was a strong connectivity between the left temporal pole and the right frontal pole (0.24140) and the right temporal pole and the left frontal pole (0.24905), although the strongest of the four correlations between the right temporal pole and the right frontal pole (0.32172). Pattern differs from observed on unilateral temporal lobe epilepsy cases.
- Patient 6 has a right temporal seizure focus: there was strong connectivity between the right temporal pole and both the right (0.54521) and left (0.43537) frontal poles.
- Patient 8 has bitemporal seizure foci: similar to Patient 4's results, there was strong bilateral connectivity between the left temporal pole and the right frontal pole (0.29278) and the right temporal pole and the left frontal pole (0.27636).

Left Temporal Pole x Left Frontal Pole	Left Temporal Pole x Right Frontal Pole
Right Temporal Pole x Left Frontal Pole	Right Temporal Pole x Right Frontal Pole

Overall, the results show strong connectivity mostly consistent with seizure laterality and focality between the right and left temporal poles correlated to the right and left frontal poles among the temporal lobe epilepsy patients in the sample.

Future Directions

We will look at group-level analysis based on seizure focus localization and network connectivity in different states including interictal (sleep and awake stages away from seizure) and peri-ictal (stages before, during, and after seizure). We hope these results can provide a roadmap and baseline for the processes and potential results these future steps might encompass.

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