Characterizing Grey Matter and White Matter SEEG Electrodes Signals

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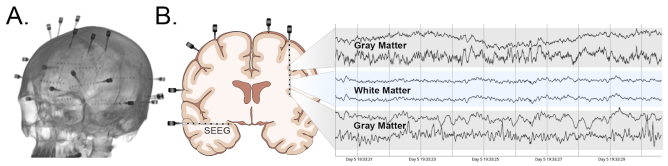
1. Background and Clinical Problem

- **Drug Resistant Epilepsy:** Approximately one third of epilepsy patients are resistant to drugs. For these patients, epilepsy surgery is a potential treatment option. Evaluation for surgery requires classification and localization of seizure areas.[1]
- **SEEG:** Stereoencephalography is an increasingly popular, minimally invasive procedure that involves electrodes placed directly into the brain (Fig. 1A) to capture seizure activity. Because these electrodes can record deeper structures, they can capture both white matter and grey matter tissues.[2,3]

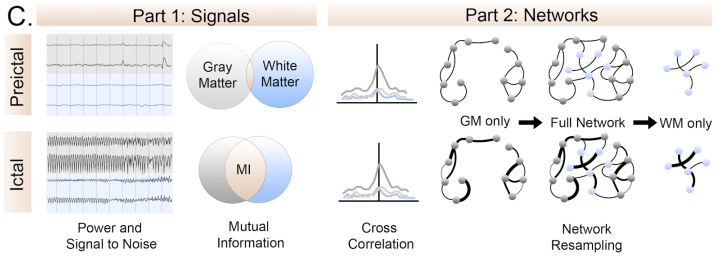


- **Clinical Problem:** Figure 1B shows the EEG recordings along the same SEEG electrode with contacts localized to different tissue types. Visually, the white and grey matter recordings look different.
- **Implications:**
  1. EEG Interpretation: Current interpretation is done through visual inspection. Proper interpretation given the visual differences needs to be further studied in order to further inform EEG best practices.[4]
  2. Computational Models: Past and current models used to diagnose and treat drug resistant epilepsy are informed by signal properties of EEG data.[5,6] Identifying best practices for interpretation of white and grey matter SEEG electrodes can better inform current and future models.

2. Study Questions and Methodology

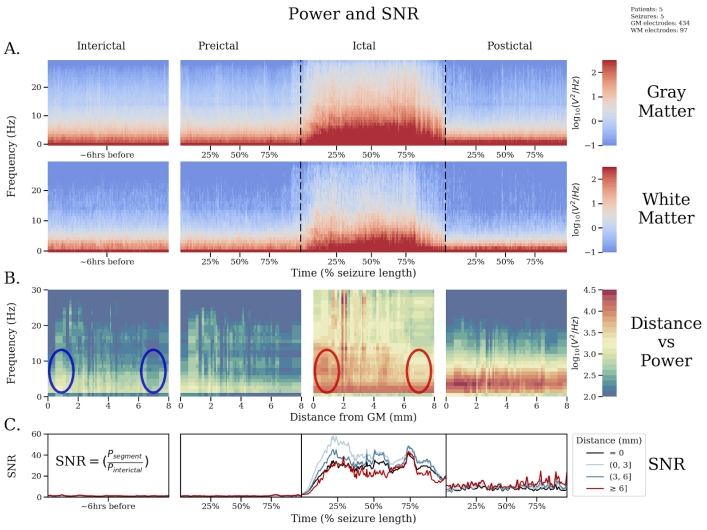
- **What are the signal and network properties between grey matter and white matter recordings?**
- **Should research involving SEEG electrodes eliminate white matter recordings?**
- **How can these findings inform how epileptologists interpret SEEG recordings?**

Hypothesis: A spectral power and mutual information analysis would show that white matter and gray matter provide different signal features. Gray matter may provide more information/unique signals than white matter.

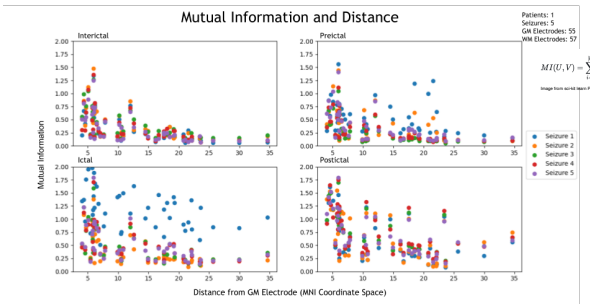


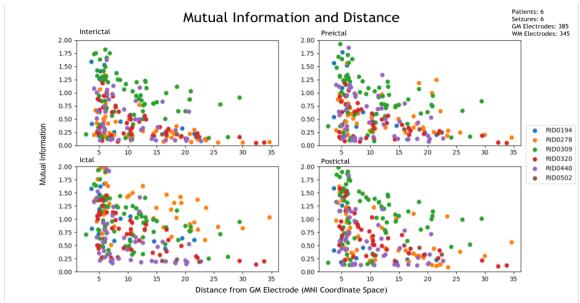
- **Methodology:**
  1. SEEG recordings were pre-processed with referential montaging and bandpass filtration.
  2. Electrodes were separated based on grey matter and white matter placement in the MNI coordinate space.
  3. Grey matter and white matter power spectral density and signal to noise ratio was averaged over 5 patients for 4 time periods: interictal, preictal, ictal, postictal
  4. Pairwise distances were calculated for each white matter localized electrode and nearest grey matter localized electrode.
  5. Mutual information between pairs were calculated based on filtered voltages for each time period.

3. Results



- On average the white matter power is less than the grey matter power for all frequency bands, especially within the ictal time period.
- As electrode moves farther away from grey matter structures, average power is markedly decreased. Blue and Red circles show decrease in average power from 0-2 mm to 6-8 mm.
- Electrodes 0 to 3 mm from grey matter show the highest signal to noise ratio (light blue line) in the ictal period. Electrodes > 6 mm from grey matter show highest signal to noise ratio (red line) in postictal period.





- Over 5 seizures for 1 patient, mutual information falls over larger distances from white matter electrodes and nearest grey matter electrodes.
- Over 6 seizures for 6 patients, mutual information shows a similar pattern: decreases as distance increases

4. Future Directions and Acknowledgements

- Next Steps:
  1. Mutual Information Research: calculate mutual information in smaller time segments within a seizure period. Compare mutual information as a function of time.
  2. SEEG Preprocessing Study: Compare signal properties from bipolar or referential montaging.
  3. Larger population and seizure analysis: Include information from more patients and more seizures. Include information about seizure type and localization into analysis.

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References: **(1)** Anyanwu, C., & Motamedi, G. K. (2018). Diagnosis and surgical treatment of drug-resistant epilepsy. *Brain sciences*, *8*(4), 49. **(2)** Youngerman, B. E., Khan, F. A., & McKhann, G. M. (2019). Stereoelectroencephalography in epilepsy, cognitive neurophysiology, and psychiatric disease: safety, efficacy, and place in therapy. *Neuropsychiatric disease and treatment*, *15*, 1701. **(3)** Young JJ, Friedman JS, Panov F, et al. Quantitative Signal Characteristics of Electrocorticography and Stereoelectroencephalography: The Effect of Contact Depth. *J Clin Neurophysiol*. 2019;36(3):195-203. doi:10.1097/WNP.0000000000000577 **(4)** Vaid, S., Singh, P., & Kaur, C. (2015). EEG Signal Analysis for BCI Interface: A Review. 2015 Fifth International Conference on Advanced Computing & Communication Technologies. doi:10.1109/acct.2015.72 **(5)** Usman, S. M., Khalid, S., Akhtar, R., Bortolotto, Z., Bashir, Z., & Qiu, H. (2019). *Using scalp EEG and intracranial EEG signals for predicting epileptic seizures: review of available methodologies. Seizure*. doi:10.1016/j.seizure.2019.08.006 **(6)** Cosandier-Rimélé, Delphine[1]; Merlet, Isabelle[2]; Bartolomei, Fabrice[2,3]; Badier, Jean-Michel[2,3]; Wendling, Fabrice[2] Computational Modeling of Epileptic Activity: From Cortical Sources to EEG Signals, Journal of Clinical Neurophysiology: December 2010 - Volume 27 - Issue 6 - p 465-470 doi: 10.1097/WNP.0b013e3182005dcd

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