Using Interictal Multivariate Granger Causality to Detect Epileptogenic Hubs

David P Darrow MD MPH; Theoden Netoff PhD

Introduction

Surgical localization of epileptogenic networks requires significant intensive-care stays and facilitation of seizures for visual inspection. Multivariate Granger Causality(MVGC) provides a method of calculating the directional influence from each node to every other node during interictal data before seizures are facilitated after implantation of electrodes. MVGC is an efficient method of detecting biological coupling and has been shown to be robust against noise.(1) Nodes identified as influential by MVGC have recently been shown to correlate with predicted seizure zones.(2)

Methods

Electrocorticography was examined and analyzed for five patients undergoing seizure localization surgery. Used ECOG channels were sampled at greater than 1.5 KHz for all patients. Model estimation was performed, and MVGC was used to calculate patterns of directional coupling over 100 second time windows. MVGC was performed on entire stays for two patients and on subsampled data for 3 patients. Coupling was also examined in the frequency domain to establish frequency basis of information exchange. Comparisons were made after blinded analysis was complete with seizure nodes identified by epileptologists.

Results

Five patients were included with more than 12 weeks of recorded data. MVGC adjacency matrices from interictal data over time from each patient revealed significant dominance by few nodes (average 1.8). Coupling changed little over time with highly accurate reconstructions after an average of 184 minutes when compared to the average matrix over the entire stay. On comparison to seizure onset nodes determined by epileptologist, the analysis found concordance 92.1% of the time with high significance compared to randomly selected channels ($p<0.00001$).

Learning Objectives

1. Multivariate Granger Causality determines directional coupling in ECOG data

2. Influential interictal hubs correlate with ictal seizure onset nodes.

3. Rapid detection of pathological nodes can be determined quickly after surgical implantation

References

1. Barnett L, Seth AK. The MVGC multivariate Granger causality toolbox: a new approach to Granger-causal inference. J Neurosci Methods. 2014;223:50-68.

2. Epstein CM, Adhikari BM, Gross R, Willie J, Dhamala M. Application of high-frequency Granger causality to analysis of epileptic seizures and surgical decision making. Epilepsia. 2014;55(12):2038-2047.

Conclusions

MVGC is a method of detecting directional coupling in ECOG recordings. Previous and current work suggests that influential nodes during interictal data may predict epileptogenic hubs. Data collection may only require a few hours to reproduce the predicted influential nodes, potentially dramatically reducing the required length of stay.

[DEFAULT POSTER]