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Source Localization of Epileptic Foci from EEG

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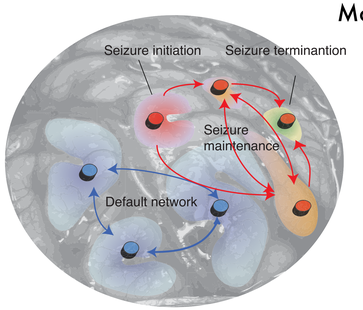
Aim/Method

introduction

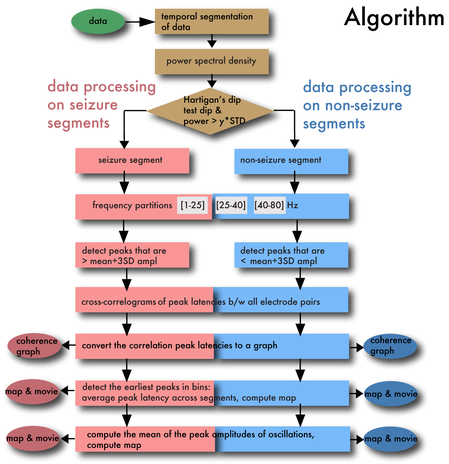
The main objective of this study was to develop a computational method for improving the localization of epileptic seizure foci in the brain based on multi-channel ECoG/EEG recordings. Unlike other EEG source localization methods such as LORETA, we were looking for a solution that specifically localizes epileptic activity relative to the background of normal EEG activity and that does so at a higher than electrode grid resolution.

Because seizures are dynamic, from a surgical planning point of view, four types of information are critical:
- The location of seizure initiation
- The location of seizure maintenance
- Seizure propagation
- The difference between default state and seizure state

Model

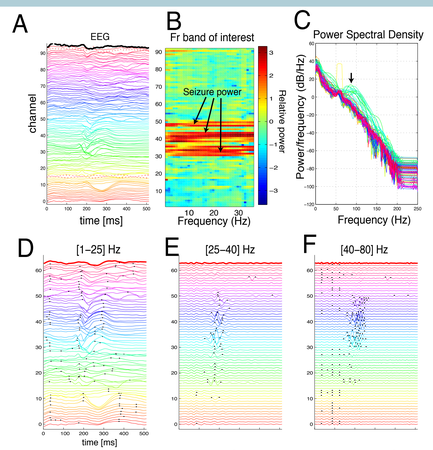


Algorithm



Analysis

ECoG



The main steps of computing the seizure wave fronts. **(A)** A 500 ms segment of the original wide band signal from 92 electrodes. **(B)** Power spectral density: frequency aganinst channels. **(C)** Power spectra of all channels collapsed (colorcoded). **(D-F)** All channels are decomposed to 3 frequency ranges and peaks of events are detected (black dots).

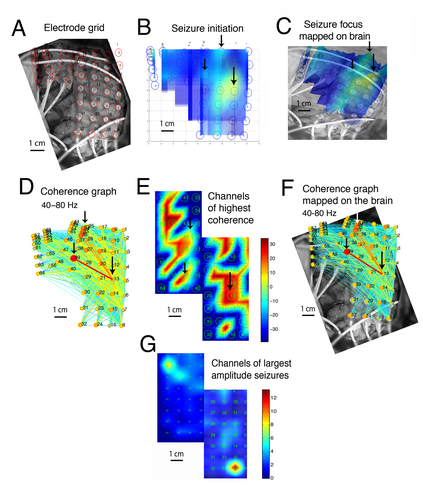
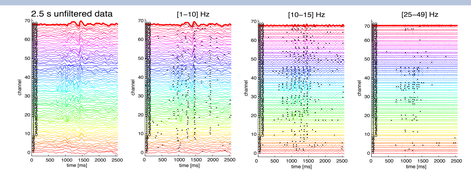


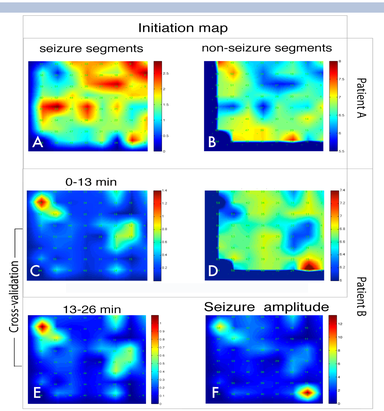
Figure 2. Localization of seizure sources. **(A)** The subdural grid electrode in the brain. **(B)** Average map of seizure initiation calculated by using the algorithm outlined at the left. **(C)** The seizure initiation is mapped on the electrode grid. **(D)** The coherence graph of electrodes from weak to strong. **(E)** The magnitude of coherence over the grid. **(F)** The coherence graph is overlaid on the digital photo of the electrode grid in the brain. **(G)** The map of electrodes with the largest amplitude seizure. Arrows repr sent the nodes of initiation and highest coherence. Note that while the nodes of initiation match with the nodes of highest coherence, neither of them matches the largest amplitude nodes. This suggests that amplitude is not a reliable source localizer.

Results

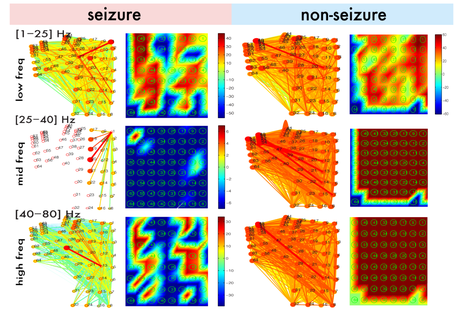
ECoG



Frequency decomposition of a seizure event to low (1-10 Hz), mid (10-15 Hz) and high (25-49 Hz) from another patient's data. Peaks exceeding a threshold are detected in order to track the propagation dynamics.



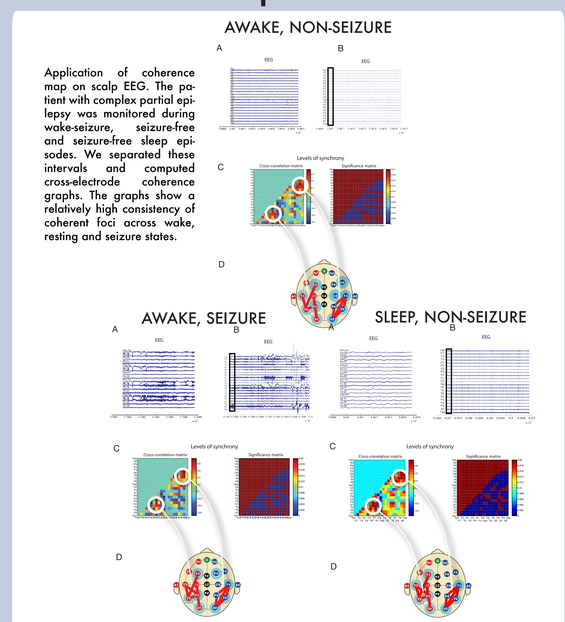
Seizure initiation and seizure amplitude. **(A)** The topography of wave fronts at 25-49 Hz from patient A during seizures. **(B)** The topography of wave fronts from the same patient during non-seizure intervals. **(C-D)** Same as (A-B) but from another patient at 40-80 Hz. **(E)** Cross-validation of wave fronts across two nonoverlapping time intervals. **(F)** Seizureamplitude topography. Note the inverse relationship between seizure and non-seizure initiation maps and the difference between seizure initiation and amplitude topography.



Comparison of coherence across seizure/non-seizure intervals at different frequency bands. At the left side of each panel is the coherence graph and at the right is the corresponding map representing the nodes that share the highest coherence. During seizures, the coherence is high between electrodes at low and high frequency bands but not at the middle. Note also that non-seizure epochs do not show the concentration of coherency as seizure epochs do.

Application

Scalp EEG



Application of coherence map on scalp EEG. The patient with complex partial epilepsy was monitored during wake-seizure, seizure-free and seizure-free sleep episodes. We separated these intervals and computed cross-electrode coherence graphs. The graphs show a relatively high consistency of coherent foci across wake, resting and seizure states.

Conclusions

We developed an algorithm to separately compute seizure initiation from seizure coherence and seizure magnitude. The algorithm takes advantage of the high density electrode grid, which can either be applied to subdural grid recordings or to surface EEGs. The algorithm detects seizure events and computes the wavefront maps from seizures separately from the wavefront maps from non-seizures, thus allows us to track the propagation of activity in the brain during normal and abnormal states. Using the algorithm we observed:

- Seizure activity is predominantly in the low (1-25 Hz) and high (40-80 Hz) frequency bands.
- Seizure initiation is relatively consistent in time.
- Seizure coherence is also consistent in time.
- Both seizure initiation and consistence are confined to the low and high frequency bands.
- However, initiation and coherence show different patterns, which is also different from the seizure amplitude map.
- The topography of seizure initiation is the inverse of the topography of wavefronts during non-seizure episodes.
- Coherence during seizures is topographically highly concentrated but is dispersed during non-seizure epochs. The latter could be an artifact of insufficient sampling rate.

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