MEG Coherence Imaging in Localization of Epileptogenic Focus

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Introduction

Rational:

Coherence is a measure of synchronization between brain regions [1]. Synchronized activity within a neuronal network is determined by the strength of network connections. How well two or more brain regions are connected can be determined by measuring the coherence between these regions. This study assessed the use of MEG imaging of brain coherence, in presurgical patients with refractory epilepsy, to provide localizing data concordant with the epileptogenic zone.

Background:

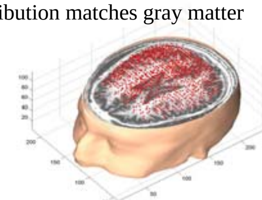
Epileptic activity is characterized by abnormal synchronized neuronal activity within a distributed network. Identification of the site's driving the network enhances the likelihood of a successful surgical resection. A measure of synchronization between brain regions is coherence. Focal regions that sporadically drive the network will exhibit high coherence with all other regions. Coherence mapping of spontaneous MEG data is easy to automate and highly specific for identification of focal epileptic sites.

Methods

- A retrospective analysis of MEG data acquired during the presurgical evaluation of patients with refractory partial epilepsy was completed.
- 26 Epilepsy patients with intractable localization-related epilepsy evaluated for Surgical planning who are now at least 1 year seizure free.
- 5 Control subjects with no history of epilepsy or other neurological disorder.
- 148 channels MEG : Magnetometers (4-D Neuroimaging Magnes WH2500)
- 32 channels EEG (Neuroscan) Collected simultaneously with the MEG recording.
- 24 channels EEG (Nihon Koden) Collected during prolonged video/EEG recording.
- 10 minutes of spontaneous brain activity was collected by MEG and EEG.
- Data sampled at 508 Hz, lowpass filtered 100 Hz, bandpass filtered 3-50 Hz.
- MEG data was imaged using MR-FOCUSS [2] and ICA [3] source separation techniques.
- For active brain sources, average coherence with all other active sites was calculated [4]. Epochs of 7.5 seconds were used to calculate coherence. These epochs were then averaged together. Total analysis included 600 seconds of data per patient. Filtering of data to exclude major artifacts (ECG) was done in selected cases.
- Brain maps showing high coherence were compared to the region of surgical resection on post-operative MRI studies. Brain maps from Epilepsy patients were compared to images from normal controls. This was a visual analysis predominantly utilizing coronal cuts. These normal control subjects were usually in stage I-II sleep.

Cortical Model

- Created from volumetric MRI
- Approximately 4,000 cortical points
- 3 dipoles at each point that represent x, y, z
- Distribution matches gray matter



Images

Epilepsy Patients

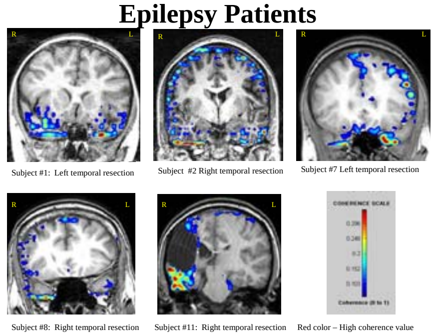


Figure 1. Coherence imaging in selected epilepsy patients who underwent surgery and were seizure free. High value of coherence matches with the area of resection. Scale settings are similar in these patients.

Normal Control Subject

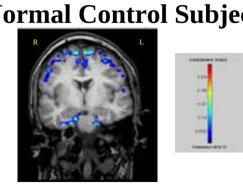


Figure 2. Coherence imaging in a subject with no neurological disorder. Distributed patterns of high coherence are seen. This scale is similar to the epilepsy patients above. Note no areas of high coherence seen.

Comparison of MEG coherence with surgical outcome in seizure free Epilepsy Patients

Subject .#	Coherence MEG results	Single ECD MEG results	Surgical Resection	M/F	Age	Match
1	Bi T L > R	L T neo	L T .	F	37	Y
2	Dif Bi H , R T > L T	R T	R T	F	24	Y
3	Dif Bi H	R F	R mes F	M	27	N
4	Bi T	R F, L ins	L T.	F	49	_
5	Bi T, R > L	R T, R F P	R T	F	16	Y
6	Bi H , R T > L T	NEA	R T angioma	F	21	Y
7	Bi T , L > R	NEA	L T	F	41	Y
8	Bi H R T max	R T	R T	M	57	Y
9	Bi H , L T > R T	NEA	L T	F	43	Y
10	Bi H , R T >L T	NEA	R T	F	40	Y
11	R F T	R M T	R T	F	24	Y
12	Bi T, L>R	NEA.	R T	F	43	N
13	R H	NEA.	R T	F	51	N
14	Bi T	R F op	R I F op	F	36	N
15	R T	NEA.	R T	F	28	Y
16	L T perilesional	L T	L T.	M	21	Y
17	R T perilesional	R OrF	R T	F	36	Y
18	Bi T R > L	NEA	R T	F	24	Y
19	R T > L T	R T	R T	F	38	Y
20	L T	L T	L T	M	64	Y
21	L T	L H	L T	F	17	Y
22	R T > L T	R mes T	R T	F	41	Y
23	Bi T , L > R	L T	L T	M	22	Y
24	Bi T , R > L	R T	R T	M	32	Y
25	Bi T , L > R	NEA	R T	M	26	N
26	Bi T	R T, R I F	R T	M	35	_

Abbreviations: Bi = Bilateral, H = Hemispheric, T = Temporal, R = Right, L = Left, M = Middle, mes = Mesial, neo = Neocortical, P = Parietal, F = Frontal, I = Inferior, S = Superior, Dif = Diffuse, ins = insula, op = operculum, OrF = Orbital Frontal, NEA= No Epileptic Activity, - = undecided.

Statistical analysis : t- test

Coherence values of left vs. right hemisphere, $p<0.01$

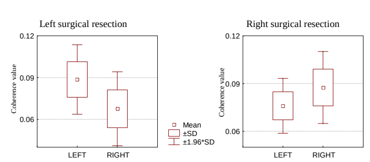


Figure 3. Mean coherence values of left and right hemisphere in epilepsy patients. A) Coherence value higher on left hemisphere for patients with left surgical resection. B) Coherence value higher on right hemisphere for patients with right surgical resection.

Results

- Twenty-six epilepsy patients (24 temporal lobe epilepsy, 2 frontal lobe epilepsy) were identified who were seizure–free with post surgical follow-up ranging from 15-78 months (average 44.2 months). Anterior temporal lobectomies including amygdalohippocampectomy were performed in 19 of the 24 temporal lobe epilepsy patients. Four resections included removal of a lesion (1), cyst from ischemia (2), or posttraumatic cicatrix (1). Two extratemporal resections included removal of dysplastic tissue in the right frontal operculum (1), and left precentral gyrus (1). The remaining surgery consisted of left frontoparietal subpial transaction.
- Initial localization of the epileptogenic zone was based on results of studies completed in the presurgical MEG evaluation and localized intracranial ictal patterns. Seizure-free postoperative course of long duration were included. Localization of coherence was considered accurate if it was concordant with the area of resection (or transaction).
- Increased coherence (presurgical) was localized to the area of resection in 19/24 temporal lobe cases. Statistically significant mean coherence values were found to be higher on the hemisphere to be resected. In the five temporal lobe cases that were not localized, two cases showed bitemporal coherence changes but prominence could not be determined. Two other temporal lobe cases showed a pattern of bitemporal coherence, but coherence appeared more prominent contralateral to the site of resection. In the remaining temporal lobe case, the increased coherence lateralized correctly to the right hemisphere, but did not appear maximal in the temporal region. In the 2 frontal lobe cases increased coherence did not localize to the resected site.
- Control subjects presented scattered patterns of coherence compared to the more focal patterns seen in Epilepsy patients.
- Table shows the 9 patients where ECD failed 6 patients had coherence patterns that showed focal patterns of activity.

Conclusions

- In summary, 19/26 cases demonstrated increased coherence concordant to the epileptogenic zone. 5/6 cases with a normal presurgical MRI were correctly localized by coherence measures.
- Interesting questions arising from the above results include: 1) the potential variable effects of electrocerebral activity of dysplastic tissue; 2) the localizing value of coherence measures in nonlesional extratemporal cases; 3) the accuracy of connectivity measures (work in progress) when compared to coherence values.
- Retrospective analysis of MEG coherence maps in patients with refractory partial epilepsy suggests that valuable localizing data may be obtained with this technique. Imaging high coherence between brain regions can be used to identify zones of epileptic activity characterized by abnormally synchronized neuronal activity within a distributed network. MEG and EEG are sensitive to small changes in synchrony within neuronal populations, but these changes do not necessarily require increased metabolism, and may remain invisible in fMRI and PET recordings.
- Additional studies evaluating coherence measurements in various states (awake, drowsy, sleep) in both normal controls and in epilepsy patients will be helpful in determining the localizing value of increased coherence and address inter- and intrasubject variability.

References and Acknowledgment

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4. MEG-TOOLS available at megimaging.com

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