Brain Connectivity Measures: Application to Epilepsy Networks

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Rationale

Epilepsy is a neurological disorder that involves hyper exited brain regions that can be come overwhelmed leading to seizures. In Focal epilepsy these excited regions are in one location, which are ideal for a surgical resection. In Generalized epilepsy these excited regions can be found all round the brain. Understanding how functional brain networks send and receive information and how strong these networks are in patients with epilepsy may provide new avenues for future treatments as Generalized Epilepsy appears to be a network disorder. Recently we have shown (Elisevich 2011) that using Magnetoencephalography (MEG) coherence source imaging (CSI) to localize brain networks can provide a better outcome for temporal lobe epilepsy surgery (77% for Engels Class Ia outcome) if this area is resected. In the current study we expand the Connectivity measures to include Persistence and Grainger Causality. Effective connectivity is the direct or indirect influence that one neural system exerts over another.

Methods

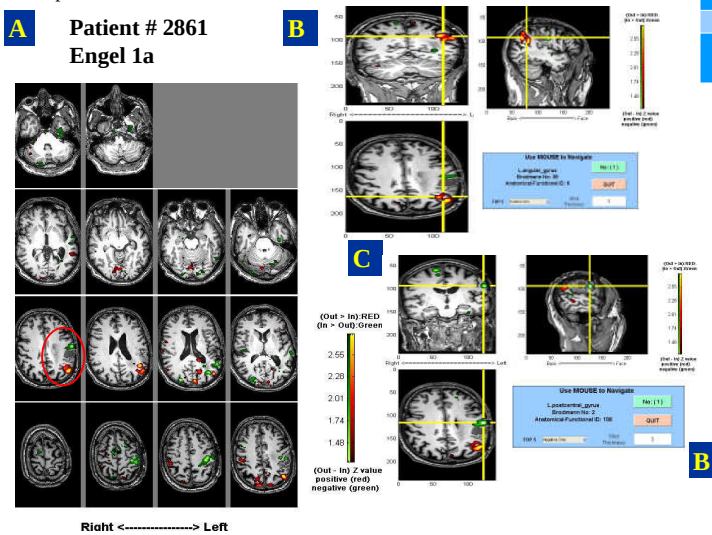
An archival review of 57 presurgical MEG studies from which 25 were included in this analysis; 17 (68%) were female with a mean age at surgery of 30.6 years (S.D. =13.5, range from 8 to 64). The imaged coherence location, classified as Persistent, Sending or Receiving was determined by Granger causality analysis of the MEG-CSI imaged solution from 10 min of spontaneous brain activity. This was compared to surgically resected brain areas. ILAE and Engel outcome classifications were assessed using nonparametric tests.

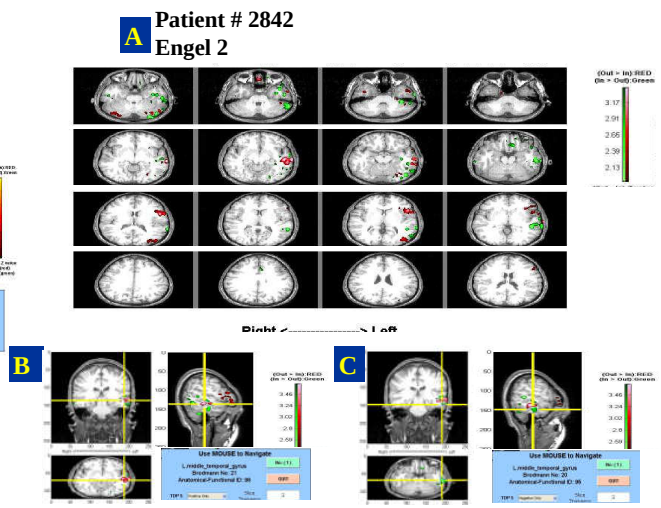
Table 1: Outcomes by receiver resected status

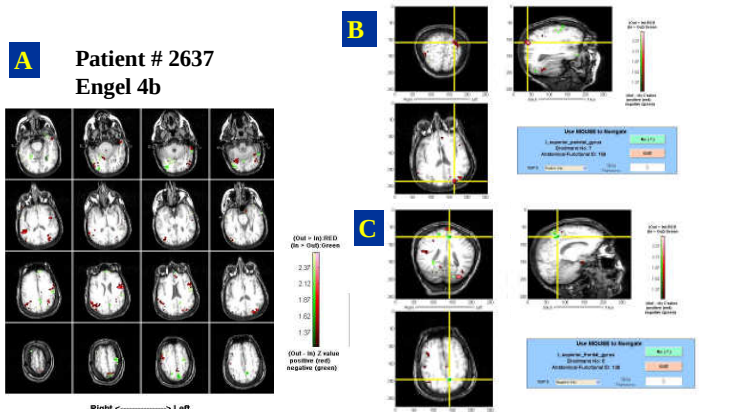
Variable	Response	No resection (N= 16)	Resection (N= 9)	p-value
Outcome ILAE	1	12 (75%)	3 (33%)	
	2	4 (25%)	2 (22%)	
	4	0 (0%)	3 (33%)	
	5	0 (0%)	1 (11%)	
	Mean± S.D. Median (Range)	1.25 ± 0.45 1 (1 to 2)	2.67 ± 1.58 2 (1 to 5)	0.023
Outcome Engel	1	16 (100%)	5 (56%)	
	3	0 (0%)	3 (33%)	
	4	0 (0%)	1 (11%)	
	Mean± S.D. Median (Range)	1.00 1	2.00 ± 1.22 1 (1 to 4)	0.010

Table 2: Outcomes by sender resected status

Variable	Response	No resection (N= 16)	Resection (N= 9)	p-value
Outcome ILAE	1	9 (56%)	6 (67%)	
	2	5 (31%)	1 (11%)	
	4	2 (13%)	1 (11%)	
	5	0 (0%)	1 (11%)	
	Mean± S.D. Median (Range)	1.69 ± 1.01 1 (1 to 4)	1.89 ± 1.54 1 (1 to 5)	0.898
Outcome Engel	1	14 (88%)	7 (78%)	
	3	2 (13%)	1 (11%)	
	4	0 (0%)	1 (11%)	
	Mean± S.D. Median (Range)	1.25 ± 0.68 1 (1 to 3)	1.56 ± 1.13 1 (1 to 4)	0.512







Figures are examples of the effective connectivity measures from three different patient
A) Coronal MRI slices with receiving (GREEN) and sending (RED) MEG CSI locations after Granger causality was applied.
B) The top most significant sending location determined by the computer, based on amplitude and connectivity is in Left Hemisphere.
C) The top most significant receiving location determined by the computer, based on amplitude and connectivity is also in Left Hemisphere.

Results

- Pairwise comparisons of the patient groups for ILAE and Engel classification showed significant differences in both outcomes after resection of the receiver node of the network (Table1).
- Patients with any receiver resection had on average worse outcomes when compared to patients with no receiver resection.
- No significant differences were detected in both outcomes for resections of the sender nodes (Table 2) or highly persistent brain regions (Table not shown).
- The difference between patients with and without Phase II was significant for ILAE {with 2.21 (s.d.=1.42) vs without 1.18 (s.d.=0.4), p=0.047} and showed a trend for Engel {with 1.64 (s.d.=1.08) vs without 1.0 (s.d.=0), p=0.077}.
- For both outcomes, patients with Phase II testing had on average worse outcomes than patients without Phase II testing.
- The presence or absence of MRI lesion did not make any significant difference in either outcome.

Conclusions

We used MEG to determine the network properties in patients with epilepsy to identify the flow of information in the epileptic network. The MEG results from coherence source imaging (CSI) can provide information on the location of brain regions that are dominant and the direction and level of communication between brain regions. Our study found that resection of high coherent areas that were receivers as opposed to a sender appeared to result in a worse outcome. This may be due to the nature of a receiving area in the brain being the regions where the epilepsy propagated to, as opposed to the location where the epilepsy initiated. We hypothesize that the epileptic network is very dynamic and highly plastic and therefore may be able to change the direction of information flow.

References/Acknowledgement

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Research supported by: NIH NINDS Grant RO1 NS 30914.