Magnetoencephalographic Estimates of Language Dominance in Surgical Patients Undergoing Awake Intra-Operative Language Mapping

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Magnetic source imaging of late evoked field responses to speech: MEG Estimations of hemispheric dominance for language

- One goal of neuroimaging is to provide a non-invasive estimation of language laterality

- MEG provides the temporal resolution as well as the source localization necessary to assess hemispheric dominance for language
Language is Not a Unitary System

- Comprised of multiple stages and areas of processing
- With many levels of processing from
  - early speech perceptual systems for decoding the sound signal,
  - lexical retrieval systems,
  - syntactic analyses, emotional decoding,
  - making contact with the conceptual knowledge systems …
- To speech production systems
The Cortical Organization for Speech Perception and Language Processing

- Left Hemisphere Dominance for Language
  - Classical works of Broca and Wernicke
pIFG/dPM (left)  
articulatory-based speech codes

Area Spt (left)  
auditory-motor interface

STG (bilateral)  
acoustic-phonetic speech codes

pITL (left)  
sound-meaning interface
What is the most useful approach for capturing the multimodal nature of language and the corresponding distribution of language subfunction?
MEG recording of neuromagnetic evoked fields is entirely non-invasive
Basic Principles of MEG

Magnetic Fields Sources

Orientation of Neurons

Detection Device
- Liquid Helium
- SQUID
- Superconducting Coils
- Magnetic Field

Magnetic Field Pattern
- Recording Surface
- Weak Field
- Strong Field
- Iso-Field Contours

Model
- Right
- Left
- M100 Dipole

\( \bar{q} = \bar{T} \Delta \lambda \)
Nose
Left Right
Sensor coils
148 Channel Sensor Array
Magnetic Field Contour Map
Left and Right Hemisphere
Auditory Cortical Dipolar Activity
A prototype auditory evoked neuromagnetic field detected by MEG; 37 channels with y-scale representing evoked response magnitude in units of femtotesla (fT) are shown collapsed on the same horizontal time axis.
Hemispheric Asymmetries in Language Processing

Neural mechanisms for early (~100 ms) sensory processing of phonetically-relevant features in speech sounds reflect largely symmetric levels of activity in the two hemispheres, with evidence for differential computation biases in left and right auditory cortical fields.


MEG correlates of cerebral dominance for language: left-ward asymmetries in sustained focal activity in the late (250-400ms) fields in healthy adults and in neurosurgical patients with awake intra-operative language mapping.
MEG Estimates of Language Dominance in Healthy Adults

- MEG late fields in 7 right handed adults with normal hearing and free of neurological damage
- Responses to simple speech sounds (vowels) are recorded simultaneously over left and right temporal lobes
- Sources of the recorded magnetic fields were modeled as single equivalent current dipoles (SECD) at 1-msec intervals
- Sustained focal activity (SECD) serves as the dependent measure

Laterality Index

$$LI = \frac{(N_L - N_R)}{(N_L + N_R)}$$
MEG Estimates of Language Dominance in Healthy Adults

- Results showed that late sustained activity was approximately twofold greater in the left hemisphere vs. the right in the time window 200-400 ms post stimulus onset.
- Source localizations were more focal in the left hemisphere, more distributed in the right.

Laterality Index

\[ LI = \frac{N_L - N_R}{N_L + N_R} \]
What is the most useful approach for estimating cortical language dominance in surgical patients?
Measures to Estimate Language Dominance in Pre-Surgical Patients

- WADA
- MEG
- MAPPING
What is the concordance among the measures estimating language dominance?

Sensitivity vs. Specificity

WADA
MEG
MAPPING
MEG Estimates of Language Dominance in Surgical Patients: Initial Study

Goal: To determine whether the late neuromagnetic field elicited by simple speech sounds may be used to estimate hemispheric dominance for language and to guide or constrain the intra-operative search for essential language sites.

Patients:
• 15 patients (14 right-handed, LH tumors, 1 left-handed, RH tumor) undergoing surgery with intra-operative language mapping

• 2 patients (left-handed, RH tumors) in whom intracarotid amobarbital testing confirmed right-hemisphere language dominance, without intra-operative language mapping
Waveforms of a patient prior to brain-surgery

Existence of “normal” M100

Intraoperative brain mapping and result of surgery
MEG Estimates of Language Dominance in Surgical Patients: Initial Study

MEG Results: In 14 right handed patients, 10 had displayed left asymmetries as estimated by MEG LI. Both right-hemisphere dominant patients displayed right asymmetries.

MEG Laterality Indices for right handed patients
Concordance Between Language Processing Sites Found through Pre-surgical MEG Mapping and Awake Intra-Operative Stimulation

14 right-handed patients:

Intra-operative language sites were found for 7/14 patients. MEG LI’s were leftward for 6 of these 7 cases.

Of the 7 patients without language sites, MEG LI’s were leftward for 4 patients, rightward for 3.

3 left-handed patients:

No intra-operative sites were found for 1 patient with RH tumor, MEG LI could not be determined.

Both patients without language mapping, with right hemisphere dominance by WADA, had MEG LI’s that were rightward.
Comparison with Intra-operative Mapping

MEG

Intra-op mapping
Concordance Between Language Processing Sites Found through Pre-surgical MEG Mapping and Awake Intra-Operative Stimulation

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Estimates of Language Dominance in Surgical Patients: Follow-Up Study

Subjects:
- 42 patients (right-handed, LH tumors)
- 5 patients (left-handed, 4 LH tumors with intracarotid amobarbital testing confirmed left-hemisphere language dominance)

Methods:
- Passive listening to vowels
- Word Recognition Task
Language Mapping Paradigm

Word Recognition Task
Study (Pre MEG recording) -- Listen to 33 target words

Test (during MEG recording)
Listen to 43 words (33 targets + 10 distracters)
Task: Identify ‘New’, ‘Old’ words

“belief”
“devotion”
“quality”
“essence”
“intellect”

pIFG/dPM (left) articulatory-based speech codes
Area Spt (left) auditory-motor interface
STG (bilateral) acoustic-phonetic speech codes
pITL (left) sound-meaning interface
Concordance Between Language Processing Sites Found through Pre-surgical MEG Mapping and Awake Intra-Operative Stimulation

- MEG late fields -- sources of focal sustained activity in each hemisphere are co-registered onto patients’ structural MR images

- Results of intra-operative stimulation (locations of speech arrest, anomia) are registered onto Stealth MR images
Concordance Between Language Processing Sites Found through Pre-surgical MEG Mapping and Awake Intra-Operative Stimulation
MEG Language Mapping Protocol
Brain Center
Scripps Clinic, La Jolla

• Focal activity in MEG late evoked field provides a non-invasive estimate of language dominance in pre-surgical patients.

• Passive protocol may be used with young children and patients unable to perform the more complex task.

• Dipole cluster analyses improves sensitivity of measure.