

MEG Localization Errors Associated with a Realistic Cortical Model

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Abstract

The use of a realistic cortical model as a constraint on MEG source localization would be expected to increase accuracy provided the distribution of points in the model matches the subject's cortical gray matter. However, MRI data to create an exact cortical model are not always available. Thus, the effects on source localization accuracy of two standard realistic cortical models are investigated. Magnetic field data from 13 subjects were acquired with a 148 channel MEG system during presentation of 500 Hz tone bursts. Single Equivalent Current Dipole (ECD) localizations were performed for MEG data at the N100m latency peaks on the hemisphere contralateral to the stimulated ear, with three different constraints implemented: 1) ECD solution location only constrained to be within the head volume; 2) ECD solution constrained to be the best of 3000 points distributed on 15 slice planes spaced 1mm apart within the volume of the head; 3) ECD solution generated for a realistic cortical model with the 15 planes spaced 10 mm apart, such that the cortical model included the entire brain. In these standard realistic models each of the 3000 cortical model points was placed to represent an equal volume of cortical gray matter as derived from volumetric MRI data of a normal brain. However, these realistic models were subsequently scaled separately in X, Y, and Z directions to match the MRI-derived head shape to digitized head points from each subject. Solutions 2 and 3 differed from solution 1 by approximately 1cm, somewhat less for group averages. These results demonstrate that standardized realistic cortical models are sufficient unless very high localization accuracy is required.

1 Introduction

Distorting the shape of brain structure ("morphing") to fit a standard brain model is commonly employed in fMRI imaging [1] and is being investigated for constructing realistic volume conductor models for use in EEG and MEG imaging [2]. We are performing the reverse task by morphing a standard brain and head model to match the subject's head. This allows the use of a realistic cortical model to be used as a constraint for our MEG current density imaging for the many MEG studies performed without MRI's of the subjects' cortices. The purpose of this study was to investigate source localization errors that are associated with differences between realistic cortical models and the actual subject's cortex. In particular, the effect of a realistic head model as a constraint on the single equivalent dipole location of the N100m auditory evoked peak was studied. Fortunately, the source of the N100m response is both compact and robust such that a homogenous head model, (source activity constrained to lie inside the skull), can be used to determine the actual N100m source location.

2 Methods

2.1 Data collection

Thirteen normal subjects participated in the study. Tones were presented to the left ear of 7 subjects and the right ear of six subjects. A 148 channel Neuromagnetometer (4D Neuroimaging Magnes WH2500) in a magnetic shielded room was used to obtain whole head magnetic field recordings. MEG data were digitized at

508.63 samples per second from 0.1 Hz to 100 Hz. 150 trials were recorded. The stimulus consisted of a 500 Hz tone burst lasting 500 ms (rise fall time - 15 ms) presented every 2 seconds monaurally (one ear only).

Each patient changed into a hospital gown and removed all metal articles from his/her body, except for dental work, which was adequately demagnetized with a commercial videotape eraser. Five small electrode coils were attached to each subject's head using double-sided tape. Prior to data acquisition these coils were activated and their MEG signals used to calculate the location and orientation of subject head. Disposable foam noise attenuating ear inserts were placed in the canals of both ears. Auditory stimuli were presented via plastic tube through the foam insert from a transducer outside the shielded room.

During the study the subject lay on a bed with his/her head within the Neuromagnetometer helmet such that the detector array was in close proximity to most of the cortical surface. He/she was instructed to keep his/her head as still as possible. The subject's face was visible via video camera image and there was intercom communication available between the technologist and the subject in the shielded room.

2.3 Data Analysis

Waveforms were inspected visually after data were digitally filtered with a bandpass of 1-50 Hz and a notch filter at 60 Hz. Single Equivalent Current Dipole fit (ECD) software [3,4] was used to calculate the location, orientation and strength of the best single equivalent

dipole for each latency within a time window (70 to 130 ms post stimulus onset) that including the N100m peak of magnetic field activity in 36 MEG channels contralateral to the tone presentation ear. For each latency, the ECD results were examined according to the following criteria:

- 1) Correlation coefficient (R) of 0.98 or better
- 2) Root Mean Square (RMS) value of waveforms across all channels of 400 fT or more
- 3) Dipole moment (Q) generally, less than 400 nAm
- 4) Confidence region (CR) of less than 3cm^3 , preferably less than 1cm^3 .

The ECD fit which met the above the criteria, was selected as the best fitting N100m.

In addition, three different constraints on cortical source locations were implemented. The homogenous head model allowed the N100m to be located anywhere within the skull. For this simple source structure, the N100m location is assumed to match the location of the source in the individual subject's auditory cortex. The other two cortical constraints were realistic cortical models with approximately 3000 cortical model points distributed to match the gray mater distribution of a normal subject derived from MRI data. One of these cortical models (dense head model) was composed of approximately three thousand points distributed on 15 slice planes spaced 1mm apart and centered on the auditory cortex. A second realistic model (sparse head model) consisted of approximately 3000 points on 15 planes spaced 10 mm apart, such that the cortical model included the entire brain. In addition, these cortical models were morphed such that the corresponding MRI model of the head surface closely matched a large set of digitized points describing the subject's skull surface [5]. This process is shown in Figure 1. The head model was scaled separately in X, Y, and Z directions to match the MRI derived anatomical head to the digitized head points collected from the subject prior to MEG testing.

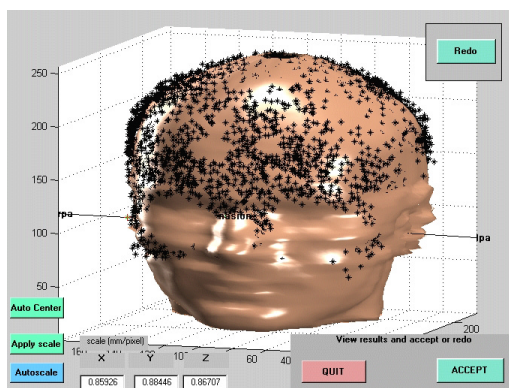


Figure 1. Morphing digitized points to a standard MRI head shape. The black points are the digitized head shape. The MRI is rescaled in the x, y, and z direction until the digitized head shape points and the MRI scalp start to merge.

3. Results

For an individual subject, the densely spaced realistic head model N100m source location differed from the homogenous model location by an average of 1 cm for both left and right ear stimulation. However, the subject group average location differed by 0.5 cm for the left ear and 0.7 cm for the right ear between these two constraint models.

The sparsely spaced head model N100m source location differed from homogenous model location by 1 cm for left and right ear stimulations in individual subjects. N100m source location for the group average differed from the homogenous group average location by 0.7 cm left ear and 0.6 cm for right ear stimulation.

Comparison of the N100m source location for the group averages in the dense and sparse realistic head models found differences between models of 0.1 cm for both right and left ear stimulation. See Figure 2 for source locations of the N100m auditory response by each model. Stars represent the homogenous head model. Diamonds represent the sparsely spaced realistic head model. Asterisks represent the densely spaced realistic head model.

4 Discussion

The accuracy of localizing sources of the auditory

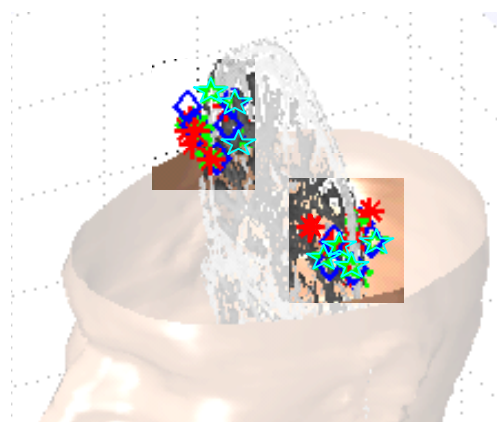


Figure 2. ECD Locations of the N100m response.
 Homogenous solutions - Asterisks
 Sparse solutions - Diamonds
 Dense solutions - Stars

N100m evoked responses was approximately the same for the dense and the sparse realistic head models. These results demonstrate that mismatched cortical geometry between a realistic model and a subject's cortex introduce relatively small location errors. Thus, unless extremely accurate localization of sources is required, a standard realistic cortical MRI head model may be used in place of a homogenous head model. This is especially important for current density imaging techniques used to image the sequence of multiple source activity, such as in language studies. In these studies usually only the relative location and sequence of activation are of inter-

est. Further, for computational efficiency, a sparse realistic head model is preferable and renders similar results to the dense model. Another advantage of the realistic head model is that group results can be graphically displayed in a common MRI model of the head and brain. This feature facilitates group comparisons. These results demonstrate that constraining source activity to a standard MRI is acceptable unless very precise localization is required. Therefore, the subject's MRI volumetric data must be used if the results are to be used as a basis for surgery.

Acknowledgements

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