American Clinical Magnetoencephalography Society Clinical Practice Guideline 1: Recording and Analysis of Spontaneous Cerebral Activity*

*Anto I. Bagić,† Robert C. Knowlton,‡ Douglas F. Rose,§ and John S. Ebersole,‖; for the ACMEGS Clinical Practice Guideline (CPG) Committee***

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The following are considered "minimum standards" for the routine clinical recording and analysis of spontaneous magnetoencephalography (MEG) and EEG in all age-groups.

Practicing at minimum standards should not be the goal of an MEG center but rather a starting level for continued improvement. Minimum standards meet only the most basic responsibilities of the patient and the referring physician.

These minimum standards have been put forth to improve standardization of procedures and to facilitate interchange of recordings and reports among laboratories (centers) in the United States. Epilepsy is currently the only approved clinical indication for recordings of spontaneous cerebral activity.

LABORATORY (CENTER) ENVIRONMENT

General Layout of the Center

Magnetoencephalography center should be designed and equipped to meet the safety requirements of the state Department of Health for neurodiagnostic laboratories, while meeting all functional requirements necessary to obtain MEG–EEG recordings that meet at least minimum standards.

Magnetically Shielded Room

Magnetically shielded room that conforms to the current operational and safety standards should be used. The entire magnetically shielded room, including adjustable lighting system and audio–visual communication system, has to be inspected regularly to ensure proper operation.

Patient Bed and/or Chair

Patient bed and/or chair must be nonmagnetic and appropriate for use with the MEG system. Both must meet appropriate safety standards, including ensuring patient safety in the case of an epileptic seizure, drug reaction, or other potentially dangerous event. These may include a safety belt, protective rails, or other appropriate means.

Procedure Preparation Room

Procedure preparation room should be designed and equipped according to the regulations of the state Department of Health to optimize patient setup. Such a room is recommended for protecting patient's privacy, providing explanations and instructions, changing and storing patient clothing, placing and removing EEG electrodes, and the like. This room would particularly facilitate patient flow when several studies are performed daily.

Measurement System

A Food and Drug Administration–approved whole head system is necessary to record simultaneously from the entire cerebrum. All components of the MEG system, both hardware and software, must be Food and Drug Administration approved.

Simultaneous recording of MEG and EEG is most beneficial for a clinical epilepsy study. (refer General Recommendations for Analysis of Spontaneous MEG–EEG Recordings for more details). Thus, if an EEG module is not integrated within a whole head system, standard EEG equipment meeting existing Food and Drug Administration regulations and American Clinical Neurophysiology Society guidelines should be used. Technical standards recommended by the American Clinical Neurophysiology Society and the International Federation of Clinical Neurophysiology should form the basis for the selection of clinical EEG equipment.

Head Position and Digitization

Because exact information about the relative position of the head with respect to the sensor array is necessary for source localization, a reliable digitization system must be used to locate the head position. Most often, this is accomplished by determining the position of several "head position indicator" coils while the patient is in the array. Transient electrical signals within the head position indicator coils on the head create magnetic sources that can be localized by MEG, thus providing the position of the head in sensor space. Before recording, the positions of at least three external fiducial points (usually nasion, left preauricular point, and right preauricular point), head position indicator coils, and/or other anatomic landmarks for creating the Cartesian coordinate that allows coregistration of MEG data with MRI for source localization.

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**Task force for recording and analyses of spontaneous cerebral activity included A. I. Bagić, R. C. Knowlton, D. F. Rose, and J. S. Ebersole.

From the †University of Pittsburgh Comprehensive Epilepsy Center (UPCEC), Department of Neurology, University of Pittsburgh, Pittsburgh, Pennsylvania, U.S.A.; ‡UAB Epilepsy Center, Department of Neurology, University of Alabama at Birmingham School of Medicine, Birmingham, Alabama, U.S.A.; §Division of Neurology, Department of Pediatrics, Cincinnati Children's Hospital Medical Center, University of Cincinnati, Cincinnati, Ohio, U.S.A.; and ‖Department of Neurology, The University of Chicago, Chicago, Illinois, U.S.A.

Address correspondence and reprint requests to Anto I. Bagić, MD, University of Pittsburgh Comprehensive Epilepsy Center (UPCEC) Department of Neurology, University of Pittsburgh Suite 811, Kaufmann Medical Building 3471 Fifth Ave, Pittsburgh, PA 15213; e-mail: bagica@upmc.edu.

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Head position measurement is recommended before and after each recording segment (block), or continuously where available, to quantify any head movement and to determine the quality of the data recorded in the segment.

In preparation for an MEG–EEG study, a standardized digitization procedure commensurate with the MEG system must be followed to ensure accurate head localization in the sensor space, continuous head position tracking where available, and accurate coregistration of MEG data with subject's MRI for source localization.

Sampling Frequency

Sampling frequency of the MEG system must be set appropriately to ensure adequate acquisition of the signals of interest. The frequency of a low-pass filter of one half or less of the sampling frequency should be applied to the data before digital conversion to avoid aliasing. A high-pass filter is usually required to minimize effects of large low-frequency signals, but unlike EEG, spontaneous MEG recordings can be performed without a high-pass filter ("direct current coupled").

Real-Time Monitoring of Data Quality

The ongoing waveforms of a sampling of MEG and EEG channels should be displayed in real time to monitor the quality of the recording. Displays of electrooculogram, ECG, and electromyogram may also be useful.

Temporal Synchronization of Data

All recorded data must include the same synchronized time signal irrespective of the applied method of synchronization.

Quality Control Routines

Appropriate sensor tuning and overall quality control procedures must be performed regularly according to operational instructions of the particular MEG and EEG systems. Confirmation of accurate system performance using a phantom should be performed as often as feasible, preferably weekly.

Acquisition of Anatomic Image

A volumetric scan with recognized high neuroanatomic fidelity (such as T1-weighted gradient echo or multiecho flash with two different flip angles) is required. Voxel dimensions should be isotropic (1 mm is optimal) with scan and reconstruction matrix of at least 256 × 256 (higher resolution is not necessary) to allow good overlays. The field of view should be skin to skin, that is, include the face, ears, and entire scalp (sagittal orientation of slice acquisition is best) such that an accurate identification of superficial fiducial points is possible for MEG to MRI coregistration.

The MEG–MRI coregistration method will vary depending on the type of MEG system and software package used.

Safety Precautions and Subject Comfort Issues

All provisions for subject safety including laboratory access/egress, equipment safety checks, emergency plans, personnel qualifications and competencies, and access to emergency medical care have to be implemented and have passed the Department of Health inspection, as appropriate.

Attention must be paid to the patients' comfort because it will also significantly affect the quality of recording. Standard approaches used with other neurodiagnostic testing should be implemented.

Sedation, including *general anesthesia*, is considered appropriate when necessary to obtain an adequate clinical MEG–EEG recording. These procedures are always performed by an onsite specialized medical team that includes an anesthesiologist physician and/or other licensed provider qualified and credentialed in anesthesia/sedation. Sedation policies must conform with hospital rules on conscious sedation and/or general anesthesia depending on the procedure.

Quality Control of Localization Accuracy

The localization accuracy of source modeling software must be regularly verified using a phantom signal. Well-established physiologic landmarks, such as a short latency component of the somatosensory evoked fields (N20m), may be provide additional information for interpreting clinical studies relative to functional localization.

Data Storage and Management

Long-term storage and management of MEG–EEG data must comply with the current regulations regarding protected health information, medical records, studies, and tests.

Long-term storage should be of sufficient capacity to handle the projected annual volume of data with appropriate information security, backup, and data recovery. The capacity to store at least 60 minutes of spontaneous brain activity, acquired at the standard sampling frequency, must be available before beginning a clinical recording. A scheduled automatic backup of recorded data is recommended.

PREPARATION FOR MEG–EEG RECORDINGS

Technologists

Trained MEG–EEG technologists, under the supervision of a clinical magnetoencephalographer, should perform clinical MEG recordings.

Preparation

Accepted clinical procedures for neurodiagnostic studies must be followed in the preparation of an MEG–EEG study. In addition, the MEG–EEG technologist must be familiar with the procedures for preventing, identifying, and eliminating sources of MEG artifacts, including degaussing procedures. The need for advanced arrangements for turning off medical electronic devices, such as a vagus nerve stimulator, must be realized.

Subject and Data Monitoring

Spontaneous MEG–EEG signals change significantly according to the state of consciousness of the patient. Thus, a system for annotating the state of the patient, analogous to that used in EEG, should be implemented. This information aids accurate analysis, interpretation, and reporting by the clinical magnetoencephalographer.

Introduced Magnetic Noise and Its Prevention and Removal

The MEG–EEG technologist must make certain that all sources of magnetic noise are removed. This includes, but is not limited to, ferromagnetic materials on the subject including clothes and jewelry, hair sprays, make up, and the like. Having the patient routinely change into a hospital gown is the best approach. Sometimes a hair wash or skin cleaning may be necessary before an examination.

It may be an effective routine to degauss all subjects with known implants or other suspected sources of residual magnetization.

A commercially available handheld degausser should be used according to the manufacturer's instructions.

In cases where sources of unacceptable magnetic noise cannot be removed, such as with dental prostheses, cerebrospinal fluid shunts, or surgical implants and devices, the MEG recording may have to be aborted, if approved software for postacquisition artifact removal is not available. The clinical magnetoencephalographer and MEG–EEG technologist are responsible for making decisions regarding when to proceed, despite suboptimal recording situations.

Head Circumference Measurement

Because of a fixed head space in the MEG system helmet, it is worthwhile to measure the patient's head using a replica helmet before a study. Alternatively, this can be accomplished during an initial noise screening run, before electrodes are applied. It must be kept in mind that EEG electrodes, particularly when applied via EEG caps, may add to the head circumference significantly and lead to the inability to position the head appropriately in the helmet.

Screening Run

As a final preparation for a study, it may be useful to place the subject into the MEG system for a brief acquisition aimed at screening for sources of artifact.

EXAMINATION OF CHILDREN

Specifics of Recording Spontaneous Activity in Children

Generally, school age and older children may be sufficiently cooperative to be recorded without sedation. This is also true for infants who typically sleep after a feeding. However, toddlers, uncooperative, and/or developmentally delayed children often require sedation.

Recording spontaneous MEG–EEG during natural *sleep* is the preferred option, if attainable, because epileptiform activity is enhanced and untoward drug effects are avoided.

Utilization of *hypnotics* is not universally accepted as a means of sleep induction. If used, specific annotation of such should be made in the report. The presence of a parent or a staff member within shielded room may be necessary in this situation.

Sedation, including *general anesthesia*, may be necessary to obtain an adequate clinical MEG–EEG recording. These procedures are always performed by an onsite specialized medical team that includes an anesthesiologist physician and/or other licensed provider qualified in anesthesia/sedation, and MEG–EEG personnel should not be a part of this team.

Optimal Head Positioning

Particular attention must be paid to head positioning and fixation with children to obtain adequate recordings. Their small head size allows for significant movements within a conventional whole head MEG system helmet. Accordingly, these smaller heads should be carefully positioned and fixed using soft clothes, nonmagnetic padding, or nonmagnetic jelly-filled pads. For older children, it is often adequate simply to center the head in the helmet. Information regarding the head position must be appropriately recorded and documented at the time of the study and incorporated into the data analysis. Real-time head position tracking systems, which are available with some advanced systems, are expected to minimize this problem. Currently, corrections for head motion in the source solution may be required for an accurate signal source estimation.

RECORDING OF SPONTANEOUS CEREBRAL ACTIVITY

Indications

Currently, MEG–EEG recordings of spontaneous cerebral activity are indicated and accepted for detecting abnormalities in background rhythms and identifying *interictal epileptiform discharges* (IIEDs) for the purpose of epileptic focus localization.

If a seizure is recorded during an MEG study ("an ictal MEG"), localization of the seizure onset is also indicated and accepted. However, differences in the generation of single interictal versus repetitive and evolving ictal discharges must be taken into consideration during source modeling. Because seizures can quickly propagate, only ictal waveforms or "spikes" at the onset of the seizure will likely reflect the location of the seizure origin.

Patient Monitoring

Spontaneous MEG–EEG signals change significantly according to the state of consciousness of the patient. Thus, an annotation system for patient state should be implemented to assist the clinical magnetoencephalographer in data analysis. If a digital annotation on the MEG recording is not available, a log sheet should be kept of the studies performed (spontaneous or evoked response) and any clinical events that occurred (seizure or excessive movement). It can also be helpful to note the beginning time of each study, the patient state during a given run (awake, drowsy, or asleep), whether epileptiform discharges occurred, and if so their general head location. A detailed and systematic annotation of artifacts that occur during the recording can provide invaluable assistance to the magnetoencephalographer during later interpretation of the record.

Simultaneous EEG Recording

It is highly recommended that EEG be recorded simultaneously with MEG. This should be considered a standard approach in epilepsy evaluations because these techniques provide complementary information and the highest yield when competently combined. It is recommended that EEG data be recorded using a common reference electrode, which will provide maximal reviewing and secondary processing flexibility. Magnetoencephalography compatible (i.e., nonmagnetic or minimally magnetic) EEG electrodes and lead wires should be used according to the well-established EEG practice.

The absence of simultaneous EEG recording for epilepsy recordings should be stated explicitly in the report, including its ramification for clinical interpretation.

EEG Identification of Artifacts

Simultaneous recording of electrooculogram, ECG, and, at times, electromyogram is also necessary to aid identification of eye movements, muscle activity, and magnetocardiographic contamination and also to monitor the patient's state. Well-established EEG practice should be followed.

Video Monitoring and Recording

Video monitoring that includes an overview image of the patient in the MEG system is necessary for patient safety and to detect head/body movement. Additional close-up images of the patient's head may be helpful. Although not routinely available, synchronized recording of the patient video that follows well-established EEG practice may be of invaluable help during data interpretation.

Recording Duration

Minimum duration of spontaneous MEG–EEG recording sessions should be 30 minutes, and preferably, this will include both wakefulness and sleep. A longer recording is recommended if IIEDs are insufficiently frequent to permit a reasonable clinical interpretation. A repeated study with longer recording times, additional sleep deprivation, antiepileptic drug manipulation coordinated with the patient's epileptologist, sedation, or other clinically acceptable means for increasing diagnostic yield may be necessary.

RECORDING STATES

Standards established in the clinical EEG field should be followed to the degree that they are compatible with quality MEG recording.

Sleep Recording

Recording during sleep should be a standard part of a spontaneous MEG–EEG study for epilepsy because of the activating effect of sleep on IIEDs. Although natural sleep is preferable, sedative pills can be used with care to help ensure that sleep is obtained during the limited time of a study. Utilization of partial sleep deprivation, for example, limiting sleep to 4 hours or less the night before the MEG recording, is recommended as a preferred way to enhance sleep likelihood.

Hyperventilation

Hyperventilation is a standard activating procedure for clinical EEG for epilepsy studies, and it may be implemented during MEG–EEG study. However, the MEG can be contaminated by large artifacts caused by associated head movements. Thus, if hyperventilation is used, the MEG data immediately after hyperventilation may be most useful.

Drug Activation

Activating IIEDs by pharmacologic means is not universally accepted. Thus, if pharmacologic activation is used, appropriate expertise, procedure, and documentation have to be implemented in these situations.

GENERAL RECOMMENDATIONS FOR ANALYSIS OF SPONTANEOUS MEG–EEG RECORDINGS

The standard elements of spontaneous MEG–EEG data analysis include examination of the time series data and source analysis computations using accepted methods.

Visual Inspection of Time Series (Spontaneous Activity)

Waveforms of MEG and EEG ("raw data," original data as collected) for the entire recording should be visually examined, following the principles established for clinical EEG. Visual inspection of time series is an obligatory initial step in the analysis of spontaneous MEG–EEG data that is aimed at the (1) identification of artifacts, (2) evaluation of overall data quality and integrity, and (3) identification of background rhythms, asymmetries and other background characteristics, and IIEDs, including morphologic and temporal characteristics, in both MEG and EEG. These findings should be evaluated and reported systematically for each study.

Filters

Use of filters is usually necessary to eliminate irrelevant biologic signals and the inherent noise of MEG system and environment.

The particular selection of a high-pass, low-pass, band-pass, and/or notch filters depends on the analysis to be performed and the characteristics of the MEG system used. This selection requires an appropriate conceptual understanding of the filtering method and practical experience in their use.

Most current analytical routines used for the analysis of spontaneous MEG–EEG data for localization of epileptic foci benefit from using high-pass filter of 1 to 4 Hz and low-pass filter of 40 to 70 Hz.

Artifact Removal

Some modern MEG systems are delivered with proprietary *software for noise elimination* based on a variety of methods. Understanding the method and consequences of its use is necessary regardless of the technique.

Generator Source Analysis

Introduction

Source analysis is used for estimating the location of the cortical generators of neuromagnetic activity of interest. For epilepsy studies, identified IIEDs are most often used for this purpose. However, source analysis of slow-wave activity or fast activity is currently under investigation and may become standard practice in the future, if proven useful. If a seizure is recorded during a study, the onset of the seizure may be localized using methods for spike analysis if the potential differences between interictal and ictal discharge generation are taken into consideration during source localization (refer Analysis of Seizures for more details).

Interictal Epileptiform Discharge Analysis

Source localization by the equivalent current dipole (ECD) modeling should be performed on all well-defined IIEDs; this includes spikes (20–70 milliseconds) and sharp waves (70–200 milliseconds). The clinical significance of both types of IIEDs in epileptic focus localization is equivalent.

The morphology, localization, and temporal characteristics of visually identified IIEDs should be reported in a standard fashion.

Although not routinely used by most clinical magnetoencephalographers, principal component analysis and independent component analysis can be useful to estimate the reasonable number of sources in the signal above background noise. If the background noise level has also been estimated, independent component analysis may be useful to identify and remove certain artifacts, such as ECG or eye movement artifact.

Analysis points in the interictal epileptiform discharge waveform. Several time points in the IIED waveform can be selected for source analysis. These include the spike peak or a point on the rising phase of the spike. Selecting the peak of

a large-amplitude spike will guarantee a high signal to noise ratio (SNR) that minimizes the calculation errors; however, the field at this latency may not represent the spike origin.

If an assessment of sequential field maps over a single spike phase shows no rotation, one can assume a stable source and model only at the spike peak for greatest SNR. If field rotation is evident, it is useful to model time points before the peak to seek an earlier source and throughout the spike time course to identify possible propagation. Note that modeling time points off the peak will mean lesser SNR and a larger confidence volume. This requires a more careful interpretation of the results. Cortical generators after the spike peak, such as the after coming wave, are typically complex and not well modeled by an ECD.

Head modeling for equivalent current dipole source analysis. The currently accepted clinical standard for the head model when analyzing MEG is a single sphere that best fits a three-dimensional reconstruction of the patient's head, derived usually from a volumetric MRI.

To minimize fitting errors, the sphere should include as much of the head in the area of interest as possible. It is legitimate and reasonable to use different spheres for the same subject to model separate sources in different parts of the brain.

Single equivalent current dipole model analysis. The ECD model is currently the most common and accepted method for modeling sources of IIEDs for the purpose of epileptic focus localization.

Assessment of magnetic isofield map. Evaluation of a magnetic isofield map at selected time points is necessary for estimating the number of generator sources and their spatial distributions. These maps will vary with the type of sensor coils in a particular MEG system.

When the magnetic isofield map at a selected time point contains a single, distinctive, dipolar pattern, a single ECD can be used to estimate the generator source. Multiple ECD analysis may have to be implemented if more complex fields are evident.

It is useful to view maps sequentially over the time course of the spike. If during a single phase of the spike, its magnetic field increases and decreases but does not rotate or change the shape, then one can assume a stable MEG source. If the field rotates during a single spike phase, the MEG source may be propagating.

Current moment. In the analysis of the IIED, the current strength (dipole moment) of the estimated single ECD may be helpful in determining whether a field transient is a likely physiologic source and not an artifact. Equivalent current dipoles with an estimated current strength (dipole moment) between 50 and 500 nAm are physiologic and thus potentially clinically relevant. Dipole sources outside of this range are sometimes rejected as probably artifactual. Regardless, making this distinction requires an understanding of the character of real cerebral sources, both normal and pathologic. One cannot rely on any single dipole parameter.

Anatomic and physiologic plausibility. Equivalent current dipoles that meet the above requirements (Assessment of Magnetic Isofield Map and Current Moment) still have to meet the requirement of anatomic and physiologic plausibility to be believable and, more importantly, clinically interpreted.

Interpretation of equivalent current dipole results. When interpreting ECD results, one must realize that an ECD is a theoretical simplified representation of activity over a considerable cortical area. Additionally, multiple closely spaced sources may produce what appears to be a single field, and thus they cannot be individually resolved.

Selecting specific channel groups for the purpose of modeling a particular source or a part of complex source is a legitimate approach; however, one must also realize that an inappropriate channel selection can lead to an incorrect source estimation.

Reliability of the single equivalent current dipole assumption. Certain solution parameters available with source modeling software (goodness of fit, total error, coefficient of correlation, and confidence volume) provide additional measures of the appropriateness of applying the single ECD to model given MEG–EEG data. For example, goodness of fit more than 70% is one frequently used criterion. However, none of these parameters can guarantee the appropriateness of the model. An understanding of the strengths and weakness of MEG dipole models, an appreciation of the character of cortical spike sources, and an implementation of practice recommendations will increase the likelihood of a correct model and source solution.

Multiple equivalent current dipole analysis (multiple dipole estimation). When an isofield map suggests the presence of multiple dipolar sources, an ECD estimation should be performed by selecting subsets of channels associated with each dipolar field, as long as their locations are sufficiently separated from each other. In these cases, multiple-dipole estimation methods, such as a 2-dipole model, should be implemented. Multiple dipole methods and interpretation require considerable experience and an appreciation for the greater likelihood of misleading solutions.

Analysis methods other than the dipole model. While widely used in research settings, other methods for source localization, including dipole scan models, distributed dipole models, current source density distributions, beamformer models, and the like, are not widely accepted for clinical purposes. If used, they should be accompanied by a standard ECD analysis of the same data. Furthermore, the MEG–EEG report must state which method(s) was used in data analysis.

Spike Averaging

Averaging a number of similar spikes will improve the SNR, minimize variability because of the background brain activity, and reduce the confidence volume of a resultant dipole model. However, averaging will also blur differences in location or time course of spikes from separate, but apparently similar, sources. Only spikes that possess similar field maps and field map evolution should be averaged. Averaging may also be used to find the "center of activity" of a cluster of individual spike dipoles (see Spike Clusters). Some instruments include software that identify and align spikes that are similar based on a template specified for the particular patient before averaging. However, at this point, there is no uniform agreement regarding the use of averaged spikes in clinical routine.

Number of Spikes

Although the frequency of IIEDs may indicate the severity of epilepsy and may have a predictive value for surgical outcome in

certain patient groups, algorithms for using these quantitative data have not been standardized in clinical epilepsy.

Currently, clinical spontaneous MEG–EEG is used principally to locate the foci of epileptic spike activity. No minimum number of spikes has been established as being necessary for clinical interpretation. However, it is suggested that sources for at least 5 spikes should be identified from a given patient. Obviously, consistent spikes with similar source model location and character would allow for more confident interpretation, even if the number was relatively small, whereas more spikes would be necessary, if their dipole models were more variable.

If spike frequency is low, their absolute numbers should be reported, otherwise qualitative frequency is acceptable. If multiple spike types with distinct foci are present, some measure of relative predominance should be provided.

Spike Clusters

The degree to which spike dipoles cluster in near vicinity to one another may be a useful parameter for identifying distinct foci and the relative activity of each. The center of such a spike dipole cluster provides information as to focus location; however, the size of the cluster is related to SNR and confidence volume of the individual spikes and not to the area of cortex involved. Currently, there are no widely accepted standards for the definition of, minimal criteria for, or additive clinical interpretation of spike clustering.

Spike Orientation

Consistent orientation of spike dipole models, as well as location, suggests a single cortical source. Given that dipole orientation is orthogonal to the net orientation of the source cortex, this parameter can therefore be used to identify the most likely source cortex in the region of the dipole. If there is no cortex of appropriate orientation near a model dipole, the accuracy of the model should be questioned. Final interpretation of spike orientation must be considered in the context of the patient's individual anatomy.

Comparative Analysis with EEG

Simultaneously recorded EEG serves several purposes in MEG/EEG analysis. An EEG can be more quickly reviewed for IIEDs given the lesser number of channels. This can shorten the time necessary to find MEG spikes for modeling. However, because some MEG spikes do not have an EEG correlate, the MEG should be reviewed separately and completely. Conversely, some EEG spikes that have a radial field will not have an MEG correlate. An EEG review can also identify epileptiform "normal variants" that should not be considered pathologic. The relative timing of MEG versus EEG spikes can be useful in characterizing propagation. If an EEG spike or spike peak follows that of the MEG, propagation from a tangential source to a radial source is likely. If the MEG spike lags that of the EEG, propagation from a radial to a tangential source is likely. Finally, because most patients with epilepsy will have had extensive previous EEG studies, the simultaneous collection of EEG allows the magnetoencephalographer to relate the MEG localizations to the patient's previous EEG studies for the clinical interpretation in the context of the patient's prior studies.

Analysis of Slow-Wave Activity

Sometimes, MEG and EEG slow waves have a dipolar character, and thus, they can be modeled. Not only is focal slowing seen with lesions but also it can also be seen in focal epilepsies. Temporal intermittent rhythmic delta activity is an example. Source modeling of slow-wave activity, when it possesses a dipolar character, can provide more precise localization of the source than by simple visual inspection of the traces.

When nondipolar, MEG focal slowing may be commented on and taken into consideration in a final interpretation in much the same way as the focal EEG slowing is considered in traditional EEG interpretation.

Analysis of Seizures

Electrographic and/or electroclinical seizures may be recorded during an MEG–EEG study. Analysis of these ictal events can use methods similar to IIED analysis described above. However, ictal discharges may start as a lower amplitude fast activity rather than individual spikes. This lower amplitude activity may be difficult to localize with source modeling because of poor SNR. If attempted, inclusion of confidence volumes based on the SNR should be provided, or at least a notation of the low SNR should be given in the interpretation. If the ictal onset consists of repetitive spikes, sharp waves, or a higher amplitude ictal rhythm, consideration should be given to the fact that ictal activity can propagate rapidly into adjacent cortex. Accordingly, the earliest ictal potentials should be used for source modeling in seeking the location of seizure origin. In some cases, averaging repetitive ictal spikes or waveforms possessing the same field topography at seizure onset may enhance the SNR and reduce the confidence volume of the source solution.

Patients commonly move during a seizure, which can confound source localization and its coregistration with the brain MRI. If continuous head localization is not available, other indicators of patient movement should be used, such as muscle or movement artifact on the MEG or EEG, and every effort should be made to confine source solutions to the time before movement. As with video/EEG reports, a notation should be made in the body of the report and the interpretation regarding when the modeled ictal activity occurred relative to the electrographic and clinical seizure onset.

Coregistration of Magnetoencephalography Findings With Brain MRI

Referring physicians should receive MEG results in the form of EEG and MEG tracings of representative spikes or sharp waves used for source analysis in addition to magnetic source images that contain one dipole source localization and its moment per spike coregistered with the patient's brain MRI.

Methods of coregistration depend on MEG system and additional software used for source localization. Any approved, reliable, accurate, and established method of coregistration may be implemented.

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