Guideline for Clinical Application of Magnetoencephalography

Japanese Society of Clinical Neurophysiology
Working Group Members on Guidelines for The Clinical Application of MEG

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1. Introduction

1.1. Objective For Creating The Guideline

The present guideline is prepared in order to target the clinical applications of MEG. We try to cover all the necessary and extensive information with respect to the clinical applications of MEG in general when conducting an examination based on this guideline. However, our desire was to draft this guideline without establishing too much detail so that some decisions can be made at the discretion of each institution since we realize that the type of diseases dealt with and the purpose of the examination may vary at said institutions.

1.2. Definition and advantages of the clinical application of MEG

MEG is a record of the magnetic activity generated in response to the electrical activities of the brain utilizing a neuromagnetometer. In comparison with the extensively used electroencephalography (EEG), MEG essentially detects identical phenomena, but with a different approach. In short, a current is generated intra/extra-cellularly when a certain part of the apical dendrites of the cerebral cortex pyramidal cells are stimulated to be depolarized. EEG records such extra-cellular current. In contrast, MEG records the magnetic fields generated around the intra-cellular current. Both MEG and EEG are similar in that they both record the responses generated in the brain, but MEG recording does not require direct stimulation or stress and thus, MEG is quite safe. The essential risk of performing a MEG examination is virtually zero, and there are no reports or articles questioning the safety of MEG.

In comparison with EEG the biggest advantage of MEG is its high spatial resolution. As there are four layers-namely, the brain, cerebrospinal fluid, skull and skin-each having different conductivities from one another between the current source and sensors, the electric fields generated in the brain are highly affected by these layers. Consequently, accurate detection of the active areas of the brain based on the electroencephalographic electrodes placed on the scalp becomes a challenging task unless a special estimation method (for example, dipolar tracing method) is used. However, in case of MEG no magnetic field strains are generated as these four layers have almost the same magnetic permeability, and the active areas can be estimated quite accurately in terms of millimeters if the recording conditions are good. This is the biggest advantage of MEG. In contrast to PET and fMRI, the advantages of MEG include its complete non-invasiveness, direct recording of the electrical activity of

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the neurons instead of the local cerebral blood flow, and its high temporal resolution like EEG in order of milliseconds.

2. Examination Menu and Indications

2.1. Introduction

Both EEG and MEG measure the electrical activity of the brain; the former measures the potential and the latter measures the magnetic fields generated by the neuronal activity. MEG can be applied to cover all the EEG menus, such as the spontaneous brain activity, evoked-responses and event-related responses. However, MEG should be indicated clinically only when its advantages are expected, since MEG requires special instruments and techniques in comparison with EEG. The following examination menus have been established and can be applied clinically.

2.2. Spontaneous Brain Magnetic Fields

Neuromagnetic measurement of the spontaneous brain activity can be used to diagnose various types of neurological diseases. The advantages of MEG include-(i) abnormal waves that can not be detected with EEG, may be easily observed[2,32,42,61,98]; (ii) abnormal waves generated from multiple sites may be much easily separated than with EEG[43,97]; and (iii) abnormal waves can be localized with ease and accuracy in comparison with EEG[45,52]. The abnormal waves discussed here include idiopathic abnormal waves during the ictal and interictal states of epilepsy[32,39,42,43,60,62,77,80,90] and the abnormal slow waves generated from the vicinity of organic lesions[6,35].

The investigation of the spontaneous brain magnetic fields can be indicated for 1) patients with suspected epilepsy whose EEG is normal[42,61], 2) epilepsy patients whose classification is poorly diagnosed with EEG[29], 3) drug-resistant epilepsy patients with surgical intervention suggested[32,63,67,96], 4) patients with suspected dysfunction of the brain tissues adjacent to organic lesions[1,6,7,9,35], and 5) patients with local cerebral disorders due to functional disorders such as mental diseases and dementia[10,71,93].

2.3. Somatosensory Evoked Magnetic Fields

The somatosensory evoked magnetic fields, elicited by electrical or mechanical stimulation of the peripheral nerves, mucosa, skin of the upper and lower extremities, body trunk or head, have various advantages over the somatosensory potentials evoked in a similar manner. Unlike the somatosensory evoked potentials, somatosensory evoked magnetic fields can separate the cerebral cortical activities from the subcortical activities[33,40,87]. Especially, the initial component of the somatosensory fields can not only identify the central sulcus, but also localize the somatotopic organization of the primary somatosensory cortex precisely[34,49,51]. In addition, any abnormal function can be quantitatively evaluated by the latency delay with or without amplitude attenuation or magnification[31,88]. In contrast to the evoked potentials, measurement of the somatosensory evoked magnetic fields is especially useful for functional localization and evaluation of the gyri and sulci in the cerebral cortex since MEG measures the current tangential to the scalp while EEG measures both of the tangential and radial components. The somatosensory evoked magnetic fields can be indicated clinically to localize the central sulcus and the somatotopy or to evaluate the somatosensory function in the patients with i) either organic or functional brain diseases before surgical interventions such as craniotomy, endovascular or radiosurgical procedures[14,30,34,55,57] and/or ii) suspected abnormal conditions in a certain part of the somatosensory system from the peripheral to the central system[31].

2.4. Auditory Evoked Magnetic Fields

The magnetic fields evoked by monaural or binaural stimulation have various advantages in comparison with the auditory evoked potentials elicited in a similar manner. Unlike the auditory evoked potentials, the bilateral responses can be clearly and easily distinguishable from each other. Thus, any unilateral abnormality or inter-hemispherical difference between the bilateral auditory cortices can be accurately detected[37,38,53,81]. The source of the auditory field can be used as a useful

landmark for surgical intervention in temporal lobe diseases, since it originates from the posterior part of the temporal plane adjacent to the posterior language area. In addition, any abnormal auditory function can be quantitatively evaluated by the latency delay with or without amplitude attenuation[56,59].

The auditory magnetic fields can be indicated clinically to localize the auditory cortex and to evaluate the auditory function in patients with i) either organic or functional brain diseases before surgical interventions such as craniotomy, endovascular or radiosurgical procedures[36,44,56,57,64,69], and/or ii) suspected abnormal conditions in a certain part of the auditory system from the peripheral to the central system[11,47,68,86].

2.5. Visual Evoked Magnetic Fields

The magnetic fields evoked by monocular or binocular stimulation have various advantages in comparison with the visual evoked potentials elicited in a similar manner. Unlike the visual evoked potentials, the responses of the visual fields in the bilateral occipital lobes are clearly and easily distinguishable from each other using the visual stimulus for the full, the left-half or the right-half visual field[12,75]. Any unilateral abnormality in the visual cortex or inter-hemispherical difference between the bilateral cortices can be easily and accurately detected. Especially, the estimation accuracy of the signal source is higher for partial visual field stimulation of the right or left hemi-visual field. The initial component of the signal source is estimated to be near the calcarine sulcus in the occipital lobe[22,75,76], which is useful as a landmark for surgical intervention in occipital brain diseases. In addition, any abnormal visual function can be quantitatively evaluated by the latency delay with or without amplitude attenuation[54,55,57].

The visual magnetic fields can be indicated clinically to localize the visual cortex and to evaluate the visual function in patients with i) either organic or functional brain diseases before surgical interventions such as craniotomy, endovascular or radiosurgical procedures[28,54,55,57,82], and/or ii) suspected abnormal condition in a certain part of the visual system[23,54,55].

2.6. Movement-related Brain Magnetic Fields

Various responses appear from the movement-related area preceding the voluntary movements. Among them, current components horizontal to the scalp are mainly generated from the contra-lateral movement, and thus, MEG is capable of recording much more clearly than EEG[8,15,18,21,25,50,58,85].

The movement-related magnetic fields can be indicated clinically to localize the central sulcus and the somatotopic organization of the primary motor cortex or to evaluate the motor function in patients with i) either organic or functional brain diseases before surgical interventions such as craniotomy, endovascular or radiosurgical procedures, and/or ii) suspected abnormal condition in a certain part of the motor system from the central to peripheral system.

2.7. Language-related Brain Magnetic Fields

When linguistic stimuli are presented acoustically or visually, the responses from the language areas may appear in addition to the primary auditory and visual responses. Since local information can be easily obtained by recording as evoked magnetic fields rather than evoked potentials, it can be applied to determine the language-dominant hemisphere[3,24,41,48,65,66,72,78,79].

The language-related brain magnetic fields can be indicated clinically i) to determine the language dominant hemisphere in patients with either organic or functional brain diseases before surgical interventions such as craniotomy, endovascular or radiosurgical procedures[65,79], and/or ii) when an objective functional evaluation of the language fields is required[4,84].

2.8. Other Neuromagnetic Studies

Brain magnetic fields other than those described above, spinal magnetic fields and peripheral nerve magnetic fields are rapidly under development. These procedures should be included in the present guideline after their clinical applications are established.

3. Recordings

3.1. Preparation Before Recordings

3.1.1. The clinical MEG examination should be performed under the supervision of physicians with adequate experience for conducting said procedure. When physician attendance is not possible at the time of the recording, a method for close communication between the technician and the physician needs to be established.

3.1.2. Informed consent should be obtained in advance after giving full explanation of the purpose and reasons for conducting the examination to each patient as well as his/her family prior to conducting the examination. This is especially true when a certain treatment such as administration of sedative drugs is necessary ; adequate explanation addressing the potential risk of the use of sedative drugs should be given, and informed consent needs to be obtained as well. When the purpose of the examination is research, a written explanation should be given to the subject and his/her family after first obtaining approval from the Research Ethics Committee at each institution to perform such research. More specifically, issues suggested to be discussed with the subjects include the purpose of the examination, pre-examination instructions, detailed overview of the examination, duration of examination, medications to be used (if any), type of medications (if any), date when the examination results become available, and name of the attending physician. In addition, the subject needs to be informed that he/she can request to terminate the examination if he/she feels any anxiety or pain.

3.1.3. A technician should obtain the clinical information necessary for conducting the examination from the physician in charge beforehand. In addition, it is important for the technician to check the condition of the subject on the day of examination by obtaining the relevant information such as the presence or absence of epilepsy immediately before the examination and the sleeping status on the evening before the examination. The technician needs to have minimum knowledge of emergency medical care procedures in case the condition of the subject suddenly changes. During the examination the conditions of the subject and the equipment need to be continuously monitored.

3.1.4. The technician needs to make sure that any magnetic materials worn on the body of the subject are removed as much as possible. It may be effective for the subject to wear laboratory robe and wash his/her hair and skin. Since a de-magnetizer may increase the magnetic noise in certain situations, extra caution is required for its use. If a de-magnetizer which has not been approved as a medical device is used, it is preferable to obtain an approval from the Ethics Committee.

3.1.5. Even when the sources of magnetic noise can not be completely eliminated or attenuated, useful data may be obtained by processing the signals if the target signal source and noise source are apart. The validity of the examination should be comprehensively determined after taking into consideration other conditions such as the property of the equipment used for the examination.

3.2. Examination Room

3.2.1. Safety aspects need to be taken into account for the entire layout of the examination room. In addition, the technician needs to communicate adequately with the subject so that he/she does not feel anxious.

3.2.2. It is preferable that a locker room or changing room is provided for the subject to change his/her clothes or store his/her personal belongings.

3.2.3. A magnetically shielded room is normally used for the clinical MEG. It is preferable that the magnetically shielded room is sound insulated and light blocking in addition to the blockings of magnetic noise and electrical noise. Ample space is required in the examination room for laboratory work, assisting the patient, and emergency treatment in case of

emergency.

3.2.4. It is necessary that the door of the magnetically shielded room be able to be opened from the inside as well as from the outside, and it should be designed so as to be manually operated in case of power outage.

3.2.5. In the magnetically shielded room, an emergency ventilation system is required should the helium gas vaporize suddenly. In addition, it is preferable to have a system to monitor the concentration of oxygen in the room. Air-conditioning is necessary to minimize the effect of sweating by the subject during the measurement of EEG in addition to provision of safety and conformability.

3.2.6. It is preferable that the illumination system in the magnetically shielded room is light-adjustable. When the light has to be dimmed for the examination, minimum lighting should be allowed to see the room to maintain safety.

3.2.7. The magnetically shielded room must be equipped with a system allowing the technician outside the room to communicate with the subject inside the room, and with a monitor to display the condition of the subject and room.

3.2.8. The bed of the subject should be designed so as to prevent the subject from falling off the bed. In addition, it is important to equip the bed with a safety belt or protective rail to insure the safety of the subject.

3.2.9. During the examination, unexpected events such as epileptic seizures, and drug-induced respiratory suppression may occur. In such cases the examiners should know how to get the subject out from the MEG gantry to ensure the safety of the patient. In addition, suction instrumentation and/or oxygen supply systems need to be prepared in case of emergency.

3.2.10. There are many advantages for having an assistant staying inside the examination room, in addition to the operator outside of the magnetically shielded room. This may prevent unforeseen accidents, reduce the subject's psychological anxiety, help in the careful watching of the subject, improve communication with the subject that can not be accomplished with microphone or monitor, and save time for setting up the measurement procedures. Not only hospital staff, but also a member of the subject's family may serve this function.

3.3. Measurement System

3.3.1. It is preferable that a magnetic sensor array covers an area more than 12 cm in diameter and has at least 30 measuring points. The detection coils should be placed as close as possible to the subject's head. The whole-head system may be positioned as close as possible to the region of interest, or neutrally to keep equal distance from the entire head surface. During the measurement, the relative positions of the sensor and the head and their angles need to be adjusted if necessary while confirming the magnetic distribution of the signals of interest. For long time measurements, extra attention should be given to the subject by allowing him/her to assume a relaxed position as much as possible so that the subject does not feel any pain. If necessary, the position of the subject may be adjusted or a small break may be given to the subject between the measurement sessions.

3.3.2. Source estimation of MEG requires measurement of the relative position between the detection coils and the head of the subject. Using a three-dimensional digitizer, the examiners can register several fiducial points and/or the shape of the head at multiple sites. It is also useful to repeat the measurement in a short time while registering the position to maintain the accuracy of the positional information.

3.3.3. It is necessary to investigate in advance whether the signal of an interest can be fully analyzed by confirming the maximum value of the sampling frequency of the system. It is recommended that the frequency of a low pass filter used as a pretreatment for digital con-

version is set to be less than one third of the sampling frequency to avoid aliasing. Similarly, a high pass filter should be set to a low frequency to minimize losing the original data, but this is subject to the limitation of the data quality such as noise and the system capacity.

3.3.4. It is necessary to use a recording medium with storage capacity longer than 30 min when recording the spontaneous brain activity.

3.3.5. It is recommended that the waveforms for all the MEG and EEG channels be able to be selected and displayed for real-time monitoring during the measurement.

3.3.6. The clock for the MEG, EEG and ECG should be strictly synchronized for recording. Calibration for all the signals should also be available.

3.4. Acquisition of Anatomical Image

3.4.1. For clinical usefulness, it is recommended to superimpose the MEG signal source onto anatomical images such as MRI.

3.4.2. The integration method of MEG and anatomical images may vary depending on the type of MEG system used. In any method, the localization accuracy should be verified using a phantom signal or well-established physiological landmarks such as a short latency component of the somatosensory evoked magnetic fields.

3.5. Recordings of the Spontaneous Activity

3.5.1. Spontaneous brain magnetic fields are generally used to detect abnormalities in the background brain rhythms and paroxysmal discharges and their localization in the functional brain diseases such as epilepsy, and organic diseases such as ischemia and tumors. The examination for spontaneous brain magnetic fields should be carried out in accordance with the standard clinical EEG guideline ; the present guideline covers the aspects unique to MEG.

3.5.2. Similar to EEG, MEG examination of spontaneous brain activity greatly changes waveforms depending on the internal and external factors of the subject. Therefore, it is important to accomplish the objective of the examination by monitoring the condition of the subject from various aspects while adjusting the internal and external factors according to the type of disease and the condition of the subject. Any changes in the subject that may occur during the measurement and any distinct noise contamination should be noted on the patient's record.

3.5.3. The data obtained from EEG and MEG are complementary to each other, and their combination is advantageous. It is preferable to record the EEG data using a common reference electrode so that montage reconfiguration and secondary processing can be easily carried out. Non-magnetic or less magnetic materials should be used for the EEG electrode and its lead wire. All the electrodes and connectors must be fixed to avoid noise generation due to the body motion.

3.5.4. Simultaneous ECG recording is useful to identify contaminated magnetocardiography waveforms and to monitor the subject's condition. If necessary, one may monitor the eye-movement, respiration, oxygen saturation and end-tidal carbon dioxide during various types of clinical studies.

3.5.5. In case of unexpected epileptic attacks during the MEG measurement, simultaneous video monitoring of the subject may be useful to compare the seizure symptoms with the MEG findings. If the subject is being videoed, it is preferable to take both an overview image as well as an enlarged head image of the subject and to synchronize the recording time with the MEG data.

3.5.6. The recording time of the spontaneous activities may vary depending on the purpose of the examination. For the epilepsy study, it is suggested to record at least 30 minutes including waking and sleeping states.

3.5.7. The recording in the resting and waking states is taken with eyes closed as a rule.

However, the basic waves of the subject can be easily determined by asking the subject to repeat opening and closing his/her eyes every 10 seconds since the amplitude of the occipital basic rhythm increases and decreases. Performing this procedure is recommended at the very beginning of the examination or immediately before completion of the examination.

3. 5. 8. Abnormal discharges tend to appear during sleep. Sleep study is highly recommended in the examination of epilepsy. Although natural sleep is preferable, sleeping pills-with special care towards patient safety-may be used to obtain a sleep state within the limited time for measurement. On the night prior to the MEG study sleep time is suggested to be around 3 hours, but it can be adjusted according to the condition of the subject.

3. 5. 9. Hyperventilation may be useful in activating the abnormal waves in organic diseases such as ischemia and tumors. During the hyperventilation, however, MEG usually has greater artifacts than EEG. Thus, the MEG data may be focused only for the post-hyperventilation period. Hyperventilation is not usually considered for epilepsy studies.

3. 5. 10. If necessary, the epilepsy discharges may be activated by several drugs under the guidance and responsibility of the attending physician. After providing adequate explanation to the subject and his/her family in advance, an informed consent should be obtained with documentation for the patient's clinical record.

3. 5. 11. Abnormal discharges may be evoked by various types of sensory stimuli. Among them, the visual stimuli are the most frequently used including flash stimuli, graphic stimuli and eye-closing movement. It should be noted that in general, the sensory stimuli elicit habituated or facilitated responses after repetition, and, therefore, of decreasing benefit, and consequent long-term repetitive stimulation should be avoided.

3. 5. 12. Sedative drugs may be used for the subjects who can not cooperate in the examination procedure, e.g., children, patients with consciousness disturbances, and mentally retarded patients. This will be further discussed in the section describing the examination of children. Under sedation the subject should be continuously monitored preferably by an assistant inside the magnetically shielded room, or by the MEG operator outside the magnetically shielded room using monitor images via the surveillance camera.

3. 6. General Instructions in Recording the Evoked Magnetic Fields

3. 6. 1. For functional mapping of the cerebral cortex with MEG there are methods to measure the response elicited by sensory stimuli and methods to measure the response associated with the task of motor or mental activities. In either method, a signal source is estimated and mapped on the anatomical image to identify the location of the function.

3. 6. 2. Most of the methods are similar to those utilized with EEG. The present guideline describes the methods unique to MEG.

3. 6. 3. The peripheral equipment, such as stimulator, can be a noise source in MEG. Thus, not all instruments used for EEG can be used for MEG without modification. Such modification may also vary depending on the type of MEG system at each institution.

3. 6. 4. For evoked responses and event-related responses, measurements should be repeated at least twice under the same condition to confirm reproducibility. However, reproducibility of MEG may not be confirmed by waveforms, since the relative position of the detection coil and the head may change in each session. In such cases, the reproducibility may be confirmed using an estimated signal source.

3. 6. 5. During the signal averaging, the original waveforms may be stored for later off-line analysis in order to check the response changes over time, or to avoid selection of noise-contaminated data before averaging.

3.7. Recording of the Somatosensory Evoked Magnetic Fields

3.7.1. The initial components evoked by stimulation of the peripheral nerves, skin, and mucous membrane are known to be derived from the primary somatosensory field. It can be used to identify the central sulcus and to localize the somatotopic organization of the primary somatosensory functions. Most of the measuring methods are the same as those of the somatosensory evoked potentials, and the methods unique to the somatosensory evoked magnetic fields will be focused on in this section.

3.7.2. The sites of stimulation frequently used in clinical examination include the median nerve, tibial nerve, fingers, and lips. Electrical stimuli or occasionally mechanical stimuli are generally used. The frequency and intensity of the stimuli are similar to those of the somatosensory evoked potentials. However, a relatively high frequency stimulus at several times per second may be used to obtain a short latency component to identify the primary somatosensory area. In contrast, a relatively low frequency stimulus may be used to obtain a long latency component to evaluate the secondary and higher somatosensory areas. However, for the study of the short latency component in case of lip stimulation, a low frequency stimulus is useful to minimize the effects of the refractory period of the peripheral mechano-receptors.

3.7.3. In case of electrical stimuli, secure grounding of the body and electrical isolation from the stimulator are important to ensure the safety of the subject and to minimize the stimulation artifact. Other settings such as the duration or intensity of the stimulatory pulse may affect noise contamination. For safety reasons, the pulse duration should be less than 0.5 ms for electrical stimulation. Biphasic shorter pulses may help to reduce the stimulation artifact.

3.7.4. Sensor coils need to be placed to cover an estimated signal source. For the whole-head magnetometer, the head should be inserted as deep as possible. Somatosensory stimulation may be contaminated with low frequency noise synchronized with the body and head movements in response to the stimulation. The intensity of stimulation, fixation of the head and body parts may be adjusted as needed to minimize this problem.

3.7.5. The measurement time, sample frequency, filters and number of signal averaging are adjusted in a manner similar to those of the somatosensory evoked potentials.

3.8. Recordings of the Auditory Evoked Magnetic Fields

3.8.1. The medium to long latency (around 30-150 ms) components of the auditory evoked magnetic fields have higher signal to noise (S/N) ratio and spatial resolution than those of the auditory evoked potentials. Thus, the left and right hemispheric sources can be easily distinguished. Its signal source is considered to be near the Heschl's gyrus or planum temporale on the upper surface of the temporal lobe. The source of the auditory evoked magnetic fields can be used as a physiological landmark to localize the posterior language area. The auditory evoked magnetic fields are also suitable to assess functional abnormalities of the auditory cortex by taking advantage of the distinguishable resolution of each hemisphere.

3.8.2. Before the study of the auditory evoked magnetic fields, it is necessary to confirm that the subject had adequate sleep on the night before the examination as the state of the wakefulness is critical for the study. The occipital basic rhythm in simultaneous MEG may be used to monitor wakefulness during the measurement.

3.8.3. Stimulation sound is given monaurally or binaurally. In case of the former, the contralateral ear needs to be masked with white noise to eliminate the effects of cross hearing. The stimulus sounds include tone burst, click burst, and click. A tone burst at frequency of

1-2 kHz is generally used. An air tube is generally used to minimize the magnetic noise generated by the stimulator. At the exit of the stimulation tube, the actual value of the sound pressure needs to be measured as the attenuation rate with the sound conduction may vary depending on the frequency. The time delay of a stimulus needs to be considered according to the length of the air tube. The stimulus frequency to obtain long latency components is once every 1 second or longer. Pseudo-random interval of stimulus evokes larger responses than the constant interval stimulus.

3.8.4. Upon measurement, a sensor needs to be placed so that the detection coil covers the temporal region, an estimated signal source. For the whole-head magnetometer, the head should be inserted as deep as possible. When the positions of the sensor are limited or the size of the whole-head magnetometer is too large in comparison with the head size of the subject, the responses from the contra-lateral hemisphere with larger amplitude should be focused on in unilateral stimulation of the ear.

3.8.5. The measurement time, sample frequency, filters, and number of signal averaging are adjusted in a manner similar to those of the auditory evoked potentials.

3.9. Recordings of the Visual Evoked Magnetic Fields

3.9.1. In the visual evoked magnetic fields by pattern-reversal stimulation, the responses with latency shorter than 200 ms are considered to be derived from the primary visual cortex. In comparison with the visual evoked potentials, the visual evoked magnetic fields are superior in distinguishing the responses derived from the bilateral occipital lobes, and they are suitable for evaluation of the functional abnormality.

3.9.2. Before the study of the visual evoked magnetic fields, it is necessary to confirm that the subject had adequate sleep on the night before the examination as the state of wakefulness is critical for the study. The occipital basic rhythm in simultaneous MEG may be used to monitor wakefulness during the measurement.

3.9.3. The visual stimulator needs to be designed so that it will not generate magnetic noise. Such designs include the use of non-magnetic stimulator, the display of image from outside of the shielded room using a mirror, and the projection on an in-room screen from a projector placed outside of the room. It is preferable to measure the brightness of the stimulation in advance since it may affect the results.

3.9.4. The type and method of the visual stimulation are basically similar to those of the visual evoked potentials. Monocular or binocular stimulation can be introduced depending on its purpose. For a subject with myopia the visual acuity has to be corrected in advance with non-magnetic glasses. To distinguish and analyze the visual areas of the left and right hemispheres, partial visual stimulation such as the left or right half visual fields or the quadrant visual fields are suitable. In this case the subject has to fully understand the importance of eye fixation. When the subject can not strictly adhere to the eye fixation, stimulation of the entire visual area may be used. Even when EEG can not distinguish the activities of the left and right hemispheres, MEG may accomplish it.

3.9.5. For the whole-head magnetometer, the head should be inserted as deep as possible. When the positions of the sensor are limited, the measurement should be focused on the occipital region.

3.9.6. The measurement time, sample frequency, filters, and number of signal averaging are adjusted in a manner similar to those of the visual evoked potentials.

3.10. Recordings of the Movement-Related Brain Magnetic Fields

3.10.1. Among the brain magnetic fields associated with voluntary movements, the components preceding the motion trigger are known to be derived from the primary motor cortex, and it is useful to localize its

somatotopic organization.

3.10.2. Extension of the index finger is most commonly used for the study. Other parts of the four limbs or tongue movement may be used as well. When some parts of the four limbs are used, the subject is normally requested to quickly move one side at his/her own pace once every few seconds. Isometric long-lasting movement or repetitive movement may be used.

3.10.3. Magnetic motion artifact should be avoided strictly. Fixation of the body trunk and head is necessary so that they do not move in synchronization with the target movement. To prevent vibration of the support occurring when a certain part of the body returns to its original position at the end of the movement, it is useful to use a cushion as needed.

3.10.4. To prevent eye-movement synchronized with the target movement, asking the subject to watch a fixed point in front of him/her may be useful. It is preferable to avoid eye blinking during the measurement.

3.10.5. The onset of the target movement is generally used as the trigger time for signal averaging. The EMG signals or mechanical switch or accelerator may be used to detect movement onset. When the motion rise time is not consistent due to movement disorders, larger signals can be obtained by processing off-line analysis after visually determining the EMG onset time from the raw data.

3.10.6. The measurement time, sample frequency, filters, and number of signal averaging are adjusted in a manner similar to those of movement-related brain potentials.

3.10.7. Movement-related magnetic fields due to involuntary movements can also be measured. A longer time window is recommended for averaging of the involuntary movement in order to compare the averaged signals with the background brain activities.

3.11. Recordings of the Language-related Brain Magnetic Fields

3.11.1. Among the brain magnetic fields evoked by language stimulation, the long latency responses more than 200 ms contain the responses uniquely derived from the language area independent of the methods of stimulation such as auditory or visual stimulation. Normally such responses are intensified when a task requiring attention to the stimulation is given to the subject. The signal source is considered to be mainly derived from the posterior language area, and it is useful to identify the language dominant hemisphere.

3.11.2. Before the study of the language-related brain magnetic fields, it is necessary to confirm that the subject had adequate sleep on the night before the examination as the state of wakefulness is critical for the study. The occipital basic rhythm in simultaneous MEG may be used to monitor wakefulness during the measurement.

3.11.3. The system to display language stimulation may be similar to that of the auditory evoked magnetic fields and the visual evoked magnetic fields. Although the choice of the language stimulation can be designed at each institution, identification of the language dominant hemisphere can be easily accomplished by combining the language stimulation with non-language stimulation for comparison. To improve the attention of the subject, it is necessary to design a task requiring the subject to remember or judge the stimulation.

3.11.4. Upon measurement, the detection coils need to be placed around the temporal region expected to be a signal source. For the whole-head magnetometer, the head should be inserted as deep as possible. To assess the difference between the hemispheres, the sensor should be carefully placed so that the distance between the head and the sensor becomes symmetrical.

3.11.5. Measurement time should be designed to be much longer compared to that of the sensory stimulation evoked magnetic fields. In general, the frequency band of the brain activities associated with language is wide, and consequently the filters and sampling frequency, should be carefully selected to match the frequency targeted for analysis.

4. Examination of Children

4.1. Features of Pediatric Examination

4.1.1. For subjects who are children or adults whose cooperation in the examination can not be obtained due to mental retardation, a sedative procedure is necessary in preparing or performing the examination. In general MEG recording for a child 9 years or older can be examined in a similar fashion to an adult patient, but sedation is usually required if the subject is younger than 9 years.

4.1.2. Head fixation should be considered to obtain favorable recording for children, since the conventional whole head MEG system has been developed mostly for the adult subjects. The technician should be careful to fix the measuring position during the examination, since head movement may cause problems in the accuracy of signal source estimation due to their small head size. It is usually necessary for the children under 3 years of age to adjust the head position carefully.

4.2. Sedation

4.2.1. Various types of sedative drugs-similar to those for adults-can be administered to children, but physicians must be careful to determine the dose of drugs according to the age and weight of the subjects.

4.2.2. A sedative drug should be administered only when the sedative procedure is deemed to be indispensable for the performance and continuation of the study. Since the sedative drugs sometimes cause noise and attenuation of the signals, physicians need to consider the advantages and disadvantages of the application prior to administration[46,83].

4.2.3. Methods

Hypnotic drugs are administered to induce sedation, and minor tranquilizers can be used as well.

4.2.4. Points of Concern

4.2.4.1. Some sedative drugs may cause respiratory depression, epileptic attacks, and psychomotor simulation depending on the type of drug and its dose. The sedative drugs should be used by an experienced physician who understands the characteristics of each drug.

4.2.4.2. ECG and respiration need to be continuously monitored when sedative drugs are administered. If necessary, the oxygen saturation should be monitored.

4.2.4.3. It is preferred that an observer stays in a magnetically shielded room when sedative drugs are administered to the subjects. At the minimum a surveillance camera needs to be used to monitor the patient continuously, in case an observer can not be in the room.

4.2.4.4. Sometimes the sedative drugs persist in the body of the patients after the examination is completed. To avoid accidents caused by these drugs, it is recommended to determine the dosage with due deliberation, ensure adequate recovery after the examination or have someone in attendance when the subjects leaves the recording room.

4.2.5. Emergency Medical Equipment

4.2.5.1. When sedative drugs are used, the system to promptly cope with respiratory depression should be established. In addition it is preferable to have a stand-by ready-to-use aspirator and system to supply oxygen to the subjects.

4.2.6. Presence of Attendant in the Recording Room During the Examination

4.2.6.1. If necessary and to minimize the risk during the examination, the presence of an individual other than the subject in the recording room may be permitted.

4.2.6.2. An attendant in the recording room is permitted for the following reasons: to pre-

vent occurrence of accidents, to reduce any discomfort to the subject, to improve the communication with the subject when the subject complains of insufficiency of the communication using only a monitor or microphone, to assist the subject, and to monitor the subject's condition closely.

4.3. Head Positioning and Fixation

4.3.1. When there is a large space between the dewar and the head, stuffing (towel and/or sponges) to fill the space should be useful to fix the head of the subject.

4.3.2. When the head size of the subject is too small to collect the data at the center of the Dewar, the head can be aligned to one of the sides to improve the signal. At this time the head's position and direction need to be adjusted several times, if possible, so that the entire region of the head can be measured. The information regarding the head positioning needs to be documented at the time of recording, and this information needs to be incorporated into the data analysis.

4.3.3. To insure patient safety during the examination the bed used should be equipped with a protective band or a bed rail to prevent the subject from falling off.

4.4. Attention for Assessment

4.4.1. It is ideal to take measurement while the distance between each magnetic sensor and the head is constant, and extra attention is required in analyzing the data when the constancy is not possible.

5. Data Reading and Analysis

5.1. Data to Be Read and Analyzed

5.1.1. The main part of MEG analysis is the reading of the chronological data obtained at the end of the recording (spontaneous brain magnetic fields and evoked magnetic fields) and the generator source (see 5.4.1.1) analysis based on the reading.

5.1.2. Secondary processing may be performed on the chronological data to obtain more accurate generator source analysis.

5.2. Secondary Processing

5.2.1. Significance of Waveform Validation Prior to Secondary Processing

5.2.1.1. Filtering or averaging is often used as a secondary processing.

5.2.1.2. Prior to secondary processing, it is important to evaluate the chronological data of the MEG waveforms (continuously recorded data or averaged data). Observation of the waveforms of all channels makes it easy to detect artifact contamination and to validate the S/N ratio.

5.2.1.3. In the secondary processing the initial assessment of the waveforms becomes especially important for data analysis requiring alteration of the chronological information such as averaging and frequency analysis.

5.2.2. Use of Filters

5.2.2.1. Filters may be used in accordance with the waveform type and the purpose of the analysis since the recorded waveforms normally contain other biological signals irrelevant to the analysis purpose in addition to system and environmental noise.

5.2.2.2. Among the filters used for this analysis there are general frequency filters such as high pass filter, low pass filter, band pass filter, notch filter, and filters specific to a certain system.

5.2.2.3. Regardless of the type of a filter used judgment of the components to be eliminated such as noise need to be justified, and deliberate consideration is required for their application as well.

5.2.2.4. To facilitate waveform reading a low pass filter may be used. When the noise associated with 50 Hz or 60 Hz caused by the commercially available AC power source is not eliminated during the recording, a notch filter may be used for the data being recorded.

5.2.2.5. Sufficient data are required to meet the targeted frequency when a low cut filter is applied. During off-line averaging it is preferable to use a low cut filter prior to averaging.

5.2.2.6. It is preferable to modify the pass band,

stop band, and band characteristics of frequency filters according to the target waveforms and the purpose of the examination.

5. 2. 2. 7. Elimination of the direct current component is included in the filters (off-set filter) to be used, and it becomes especially important when the generator source is estimated based on the amplitude.

5. 2. 2. 8. To eliminate noise containing special characteristics such as ECG data, analytical noise elimination methods, such as the principal component analysis and independent component analysis, may be used. In such a case justification of the components to be removed needs to be deliberately discussed.

5. 2. 3. Averaging

5. 2. 3. 1. When the magnetic signals are small, the continuous recording data can be averaged off-line to improve the S/N ratio.

5. 2. 3. 2. For the off-line averaging in which initiation or termination of the external stimulation is used as a reference time point for averaging, it can be treated similarly to on-line averaging. However, it is important to average the reference signals (trigger signals) also and to confirm that their waveforms take the shape expected.

5. 2. 3. 3. The periods preceding and immediately following the averaging reference can be averaged after determining the new averaging reference using biological signals such as EEG, MEG, and EMG spikes or response signals.

5. 2. 3. 4. In the case described in the above section the time points can be selected as an averaging reference over the multiple time epochs subjected to the averaging, only when intracranial events are estimated to be identical. When a time point is selected based on the waveforms of EEG or MEG, it is recommended to use a peak or onset of the waveform of the interest. In case of EMG the onset is generally used. In addition averaging of the reference times can be selected only when their magnetic isofield maps resemble each other.

5. 2. 3. 5. The waveform obtained after averaging can be used for assessment of the waveform, creating a magnetic isofield map and analyzing the generator source similar to the original waveforms.

5. 3. Reading of the Spontaneous Brain Magnetic and Evoked Magnetic Fields

5. 3. 1. It is preferable to visually check the waveforms of the entire recording.

5. 3. 2. For spontaneous brain magnetic fields, similar to the reading for EEG waveforms, the presence or absence of abnormalities in the background activity of the brain magnetic fields including the dominant rhythm in the occipital region and paroxysmal activities such as magnetic spikes, sharp waves, and slow waves needs to be confirmed.

5. 3. 3. When any paroxysmal activities are observed, some information such as whether the appearance of the magnetic spikes is coincidental with the appearance of EEG spikes, shape of waveforms, and the latency needs to be evaluated.

5. 3. 4. The evoked magnetic fields can be read in a manner similar to the reading of the evoked potentials, and it is important to repeat the recording at least twice to confirm the reproducibility of the response.

5. 3. 5. When the reproducibility of the waveforms is observed at least in the two sets of the recordings, group averaged waveforms from multiple sets of the recordings can be used for the generator source analysis. At such time it is suggested to check that the relative positions of the detection coils and the head are within the acceptable range among the recording sets. In addition, when the S/N ratios of the waveforms in each set are favorable, the results of the generator source analysis can be used as a proof of reproducibility.

5. 3. 6. When the evoked potentials are recorded simultaneously with the evoked magnetic fields, it is necessary to check whether there is

any conflict between the distribution of the potentials and the distribution of the magnetic fields.

5.4. Generator Source Analysis

5.4.1. Data for the Generator Source Analysis

5.4.1.1. The generator source analysis is defined as a method to assume the electrophysiological activities of the brain based on the measured brain magnetic fields and evoked magnetic fields.

5.4.1.2. For assessment of the spontaneous brain magnetic fields and the evoked magnetic fields, the background brain magnetic fields and the baseline activity before the stimulation are introduced as a baseline, respectively, and an estimation is performed when drastic deviations from those baseline activities are observed.

5.4.2. Assessment of the Magnetic Isofield Map

5.4.2.1. Assessment of the magnetic isofield map at any point is useful in estimating the number of generator sources assumable and in understanding the overview of the geometric distribution (of the generator source)[17,94].

5.4.2.2. The advantage of the magnetic isofield map is that it is closer to the original data than the estimated generator source.

5.4.2.3. The magnetic isofield map is prepared based on the size of the signals over a target time, and the elimination of the direct current component and the frequency component not suitable for analysis is necessary in determining the amplitudes.

5.4.2.4. By eliminating the direct current component a certain time period can be designated either before or after the target signal, and an averaged value over the certain time period is considered to be a direct current component only if no effects caused by the target signal for analysis are guaranteed.

5.4.2.5. Like spontaneous brain magnetic fields, when adequately longer records are available in comparison with the duration of the signal for analysis, the entire recorded period can be used for inclusion or elimination of the direct current component calculation. For the averaged waveforms a part of the averaged time period is normally used to determine the time period for the direct current component as in the previous section (Section 5.4.2.4.) in many cases. When the designated averaged time period is in a stationary state as a total, the entire averaged time can be used as a time period for calculation of the direct current component.

5.4.2.6. When a frequency filter is used to eliminate the frequency component irrelevant to the analysis, the instructions for the use of the filters described in Section 5.2.2. should be considered.

5.4.2.7. In case of magnetometer or axial gradiometer the number and the position of the outflux and influx of the magnetic fields should be confirmed. In case of planar gradiometer the number of maxima and the direction of the magnetic field vector at the maxima should be confirmed.

5.4.2.8. When only a partial coverage for recording is accomplished because a non-whole-head type is used or the subject is a child even when a whole-head type is used, the magnetic isofield map should be prepared at the time of recording to obtain the best possible data by adjusting the positioning of the head of the subject and the dewar.

5.4.3. Single Equivalent Current Dipole Model Analysis

5.4.3.1. Indications for Single Equivalent Current Dipole Model

5.4.3.1.1. The equivalent current dipole indicates a state in which a pair of positive and negative equivalent charges virtually exists in the same spot, and their theoretical distribution on the magnetic isofield map when they exist in the brain is called a dipolar pattern[94].

5.4.3.1.2. When the magnetic isofield map at a certain point is determined to be similar to the dipolar pattern, a single dipole can be estimated as a generator source at this point using a single equivalent current dipole

model[5,19,70].

5. 4. 3. 1. 3. When multiple generator sources seem to exist, single dipole estimation can be performed by only selecting the channels highly associated with each generator source as long as they are separated from each other by a certain distance.

5. 4. 3. 1. 4. Since the signal amplitude is frequently used for the calculation or estimation at the time of target, attention must be paid to sections 5. 4. 2. 3. -5. 4. 2. 6 in terms of eliminating the direct current component and eliminating the frequency component not intended for the analysis.

5. 4. 3. 1. 5. Upon interpreting the results, it has to be kept in mind that a generator source has actually a limited area and that multiple generator sources too close to be resolved are possibly calculated as a single generator source even when the generator source can be approximated by the single equivalent current dipole model[20,45,60].

5. 4. 3. 1. 6. Even when the generator sources are separated by a distance greater than the resolution of a single dipole model, we should keep in mind that it may result in an incorrect estimation when the channel selection for estimation is inappropriate.

5. 4. 3. 2. Virtual Sphere Setting

5. 4. 3. 2. 1. To estimate a generator source using the single equivalent current dipole model, either a simple sphere model that treats the brain as a sphere or a realistic head model is used, but the assumption of the simple sphere model can be used for clinical examination[16,73,95].

5. 4. 3. 2. 2. The simple sphere model should be designed so that it contains a large portion of the area of interest of the cerebrum and has a minimum fitting error. The sphere should be designed based on the head shape obtained whichever way.

5. 4. 3. 3. Analytical Point of the Waveforms

5. 4. 3. 3. 1. As the size of the generator source and its distribution change over time, identification of the waveform calculated at what time point becomes important when analyzing the data.

5. 4. 3. 3. 2. In terms of the S/N ratio the time point with large amplitude is normally selected as an analytical point.

5. 4. 3. 3. 3. Not only at the peak of each component, multiple time points before and after the peak may be analyzed. In this case, if a single point is selected as an estimated generator source, it should be selected using the assessment index described in section 5. 4. 3. 4. 1.

5. 4. 3. 3. 4. The earliest possible component should be calculated to estimate the initial origin of abnormal waves, and the time point with a large amplitude should be selected to minimize the calculation error. Thus, the time point should be appropriately selected considering the above-mentioned two criteria. At this time, the assessment index described in Section 5. 4. 3. 4. 1. may be used.

5. 4. 3. 4. Reliability of the Single Equivalent Current Dipole Assumption

5. 4. 3. 4. 1. By assuming the single equivalent current dipole indexes indicating the approximation such as goodness of fit[19], total error, coefficient of correlation, and confidence volume[7] can be obtained. However, it should be noted that in the single equivalent current dipole estimation, any assessment index can be used to indicate the low reliability, but the numerical approximation does not guarantee the reliability of the model. The standard of these reliability indices should be determined at each institution.

5. 4. 3. 4. 2. The orientation and direction of the estimated generator source indicate the same anatomical orientation and direction of the apical dendrite of the pyramidal cells in the cerebral cortex and have diagnostic value[26].

5. 4. 3. 4. 3. For the orientation and direction of the generator source to have diagnostic value it is necessary that an analytical point needs always to be selected in accordance with a certain standard in the target component. In

the case of evoked magnetic fields the target component is identified by the analogy to the component in the evoked potentials or from the latencies, and their peak latencies can be used for assessment. In case of epileptiform discharges the initial peak latency is evaluated as a rule.

5.4.4. Multiple Dipole Estimation

5.4.4.1. When multiple dipolar patterns are recognized in a magnetic isofield map, multiple dipole estimation methods such as the 2-dipole method can be used to estimate the multiple generator sources[74].

5.4.4.2. When the number of estimated dipoles increases, the risk of fixing the estimated value to the local minimum increases. Therefore, it has to be determined deliberately in case of multiple dipole estimation and more carefully than in case of single dipole estimation.

5.4.4.3. In situations where areas are close to each other or the time periods are close to each other, it is generally difficult to apply the multiple dipole estimation, and extra caution is required as it may increase the estimation error.

5.4.5. Analytical Methods Other Than The Dipole Model

5.4.5.1. To estimate the generator source, the currently developing analytical methods other than the dipole model, such as spatial filter, L1 norm[89] or L2 norm[27], are available.

5.4.5.2. However, methods to estimate the generator source other than the dipole model have not yet been fully accepted, and their reliability has to be investigated at each institution.

5.4.5.3. When generator source estimation methods other than the dipole estimation method are used in conjunction with a clinical examination, they should be documented along with the analytical results by the conventional dipole model simultaneously.

5.4.6. Overlaying with Brain Images

5.4.6.1. Significant clinical information may be obtained by superimposing the estimated generator sources on various brain anatomical images.

5.4.6.2. MRI is the most commonly used brain anatomical image for superimposition, but other images may also provide significant information.

5.4.6.3. There are no limitations in terms of the method of superimposition with the brain anatomical images, and any method can be used if it results in precise superimposition.

5.5. Analysis of the Epileptiform Waves

5.5.1. Selection of a target for analysis

5.5.1.1. In the present guideline, it is recommended to select "the analytical point based on the assessment index such as correlation and goodness of fit after selecting and analyzing a certain period" or to select "the time point of the spike with the largest amplitude" when the individual epileptiform wave is estimated at a single point.

5.5.1.2. When an epileptogenic focus is investigated, the analysis of spikes is recommended.

5.5.1.3. When there is no choice but to target sharp waves or abnormal slow waves other than spikes in order to analyze the generator source of the epileptogenic focus, it must be mentioned in the report as a rule.

5.5.1.4. To investigate the chronological changes in the generator source of the epileptogenic focus with multiple analytical points, it is necessary to eliminate the inappropriate values after evaluating the reliability of the estimation at each time point although it can be analyzed regardless of the best value of the assessment index and the maximum amplitude.

5.5.2. Current Moment

5.5.2.1. For analysis of the epileptiform waves, the current moment of the estimated single equivalent current dipole can be used as a reasonable assessment[91,92].

5.5.2.2. When the current moment exceeding 500 nAm is estimated in the examination of the epileptiform waves, it must be either an extensive current source or an error. Thus, the

results have to be discarded, or a deliberate interpretation has to be made.

5.5.2.3. When the current moment smaller than 50 nAm is estimated in the examination of epileptiform waves, it may be a mistake in estimation. Accordingly, the results should be discarded as a rule.

5.5.3. Necessary Analysis Number

5.5.3.1. Since the reproducibility of the dipole estimation is low at the examination of the epileptiform waves, it is preferable to obtain highly reliable estimation for at least 10 spikes.

5.5.3.2. When the estimated locations of the estimated dipole are observed at multiple areas or distributed over a large area, the number of analytical points should be increased to insure reliability.

5.5.3.3. When only a few spikes are estimated for the generator source, additional examinations should be carried out if possible. If not, its reliability should be noted in the report.

5.5.4. Assessment of Cluster

5.5.4.1. When the distribution of the estimated generator source for the epileptiform waves is limited and concentrated, it can be determined as the presence of a cluster. Localization of a cluster can be declared when these estimated locations are limited within 1-2 gyri of the brain, but it may exceed this number depending on the abnormalities on the target brain.

5.5.4.2. A cluster indicates the generator source of epileptiform waves analyzed, and it should be noted that it is not necessary to indicate the location of the epileptogenic focus upon interpreting the results.

5.5.4.3. When the estimated generator source is distributed over a large area and no cluster is found, it should not be interpreted that the generator source is large, but rather that the generator source can not be specified.

5.5.4.4. When the estimated generator source is uni-directional, it may provide clinically significant information[13].

6. Maintenance of Records

6.1. General Instructions

6.1.1. The reports can be archived in either digital or paper format as long as its authenticity is maintained.

6.1.2. Upon reporting the examination results, the findings pertaining to the requested matter, if any, need to be clearly documented.

6.1.3. Considering that the reports may be accessed by non-specialist staff, it should be documented in plain language as much as possible.

6.1.4. The reports should be at least duplicated, and a copy of the report sent to the referring physician should be archived so that it can be retrieved at any time.

6.2. Style of the Documents

6.2.1. General instructions

6.2.1.1. The following items should be documented as needed on the top of the subject record. However, these items can be flexibly adjusted or eliminated according to individual situation at each institution.

6.2.1.2. When a simplified version of the report is used, the information regarding the subject's ID, date of examination, investigated items, and findings are mandatory.

6.2.2. Subject Attribution

6.2.2.1. Laboratory identification number or subject number, department name, type of admission (in-patient or out-patient)

6.2.2.2. Name, age, and sex of the subject

6.2.2.3. Recorded date and previous examination date

6.2.2.4. Serial number of MRI measurement used and the date of measurement

6.2.2.5. MEG recording number

6.2.3. Requested matter

6.2.3.1. Document a summary of special requests given by the attending physician at the time of MEG request.

6.2.4. Condition of the Subject at Examination

6.2.4.1. Meals and medications (injection) and their content

6.2.4.2. Notable neurological conditions (includ-

ing epileptic attack)
6.2.4.3. Behavior and psychological condition of the subject
6.2.5. Measurement condition
6.2.5.1. Clinical tests (spontaneous brain magnetic fields, concurrent EEG, and type of evoked magnetic fields)
6.2.5.2. Study condition (sampling frequency, on-line filter, type and method of stimuli, and averaging number in the evoked magnetic fields, etc.)
6.2.5.3. Head movements during the measurement
6.2.5.4. The person who is in charge of recording
6.2.6. Additional comments
6.2.6.1. Documentation of the measured area and the method to fix the patient's head when its size does not fit to the sensor
6.2.6.2. The type of the activating method, activator used for examination, dose of activator, when activation is performed
6.2.6.3. The total examination time spent from preparation to completion
6.2.7. Examination Findings
6.2.7.1. The examination findings are documented along with the name of personnel who analyzed the data.
6.2.7.2. The name/s of the personnel in charge of recordings and those of analysis need to be filled out separately even when the same persons perform these actions.

6.3. Documentation of the Examination Findings[1,3)]

6.3.1. General Instructions
6.3.1.1. It should be understood that MEG is complementary to EEG, not to assist EEG. Thus, upon documenting the examination findings, the technique needs to be described precisely similar to the other analytical methods conducted at each institution.
6.3.1.2. Lengthy description needs to be avoided ; rather concise and necessary information should be documented as objectively as possible. Therefore, the following instructions are not mandatory items to be documented, but are listed for reference.
6.3.2. Description regarding the waveforms
6.3.2.1. Dominant rhythm and background activity
6.3.2.2. Type, extent, and mode of appearance of major abnormal findings
6.3.2.3. Changes in response to activation
6.3.2.4. Relationship with the concurrent EEG data
6.3.2.5. Changes of the clinical symptoms observed during the examination and their relationship with the brain magnetic field profile
6.3.3. Signal source estimation
6.3.3.1. Analytical method and anatomical location of the estimated signal source
6.3.3.2. It is preferable to describe the analytical parameters such as off-line filter when documenting the analytical results.
6.3.3.3. It is preferable to display the location of signal source by superimposing them on the subject's head MRI data.
6.3.3.4. Analytical parameter values associated with estimated signal source (goodness of fit, errors, moments, z values, t-values, etc.)
6.3.4. Description of Advice Regarding the Diagnosis and Treatment
6.3.4.1. Additional description to clarify the confusing points in the values and images upon estimating the signal source. In addition questions and concerns brought up when the examination was requested should be answered as much as possible.

6.4. Archive Management of the Measured Data and Reports

6.4.1. As a rule it is preferable to electronically archive all the measured raw data for at least five years. In unavoidable circumstances at the minimum the significant parts that led to the abnormal findings and the parts used for signal source estimation should be archived.
6.4.2. It is preferable to archive the report and analytical results along with the original data and to create a database.
6.4.3. Upon archiving the data the data must be kept in the archive designated by the director

at each institution. The staffs who are in charge of analysis and reporting must maintain authenticity, legibility, and stability of the data while paying attention to the privacy of the subject.

6. 4. 4. To insure the safety of the archived data, it is recommended to archive the digital data in two ways.

Note :

The present guideline is prepared as a minimal agreement covering the individual current situations at each institution. This guideline should be revised or updated after a certain period of time as MEG technology is considered to be currently under development.

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